Faculty of Bioscience Engineering

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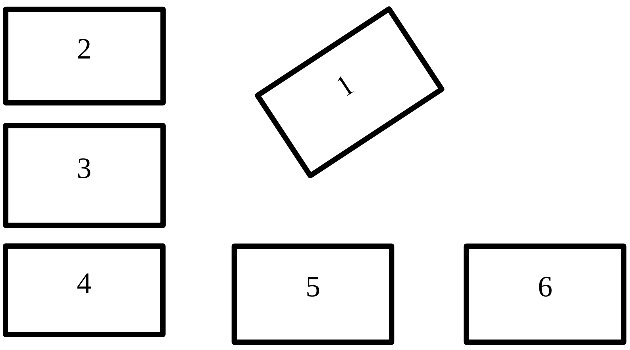
Stakeholders' Reactions toward Iodine Biofortified Foods: An Application of Protection Motivation Theory and Technology Acceptance Model

Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor (PhD) in Applied Biological Sciences

> "If you cannot judge a book by its cover, surely we should not judge an author by one book alone?"
> — E.A. Bucchianeri

Cover layout



Notes:-

@1: Study location: three East Africa countries: Kenya, Uganda, and Tanzania

@2: salt a key vehicle for micronutrient iodine

@3: Stakeholders on the supply-side (Producers-farmers) in a data collection session.

@ 4: A sample of biofortified vegetable legumes

@ 5: A child affected with both goitre and cretinism visible symptoms of iodine deficiency disorders

@6: Field survey with stakeholders on the demand-side, consumers (parents) in a data collection session

Dedicated to my mum: Purity Kanjiru Nkambi and Dina Kerubo Birundu, you are the two women I live to cherish. "Asante sana na Mungu

It's amazing how two words can

mean so much... Thank you.

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Did I go back to the first line? Yes. I feel indebted to you. I remember the first time you took us through your PhD thesis and you told a positive story about folate biofortification and how China and indeed the whole world could be saved. The idea struck me, during that Food policy class. You have completed another PhD in the course of helping me as my promoter. You visited Kenya, and you got food poisoning, after enjoying the African delicacy, Kenyan 'Ugali' with choma 'roast meat'. There were many ups and downs of trying to get me publishing - the part I will not miss post PhD, a part I will endure living with and, yes, I will improve each time and maybe I will even get to like it. There have been great times in the office and you have provided constant assistance. Hans De Steur, your name will stay with me and I will always acknowledge you at all times, not because of the many times I have wrongly spelt your name, but the hard time you had changing my scientific writing and thinking.

I could go on and on to acknowledge all those who worked with me, but your name written here won't express the great feeling I have for you, Prof. Xavier Gellynck, to you I say 'Asante sana.', which is often borrowed from Mama whenever great people interacted with us when I was growing up as a young boy in my village.

For love, patience and great support I give my sincere gratitude to my wife Irene Bonareri Manyibe, and to our little daughter Adryella Kanjiru Mogendi who cheered me up and showed me what life is all about "even in the midst of stress, there is room for one bright smile". To my parents, this is the culmination of the things you have instilled in me and I am very grateful. Finally and most importantly I gratefully acknowledge the support from BOF at Ghent University for financing this work, grant no: 01W02712) and all the staff at the international office for their support during the long process of application and PhD study.

Ir. Joseph Birundu Mogendi

To you all I say 'Thank you so much for being the one person I could talk to. Thank you for never leaving my side through the tough and ugly times. Thank you for being my rock. Thank you for being understanding. Thank you for being patient, kind, and friendly. Thank you for accepting me for who I was, and looking on the inside, not the outside.

But most of all…thank you for loving me- like no one else ever has, or ever will.

TABLE OF CONTENT

PREFACE

Foremost, the objective of this thesis is *to analyse stakeholders' reactions toward biofortified food*, with particular reference to iodine biofortification. This thesis consists of 6 studies falling in three categories: 1) testing of the framework applied and review of the current status of the art as a basis for this thesis; 2) Analysing the stakeholders on the demand-side (consumers) including households and schools feeding programs; and 3) analysis of stakeholders on the supply-side (farmers).

Each of the studies is presented as a distinct chapter which, together with two additional chapters on introduction and conclusion, constitute the 8 chapters of the doctoral dissertation. The conceptual framework adapted, adjusted and tested, from existing behavioural change models and economic valuation techniques, in chapter 2 forms the backbone for analysing stakeholders throughout the iodine biofortified food supply chain. In each of the studies conducted, innovative processes and procedures have been selected for data collection, analysis and presentation which are in tandem with the objectives of this thesis.

This doctoral research was supported under the BOF special research fund for developing countries through grant number: 01W02712, financed by Ghent University, Belgium. Whilst, literature review, development of data collection tools as well as data analysis and presentation were conducted at Ghent University, Division of Agri-Food Marketing and Chain Management at the Faculty of Bioscience Engineering; the actual studies were conducted in three iodine endemic locations in East African countries: Kenya, Uganda, and Tanzania.

SUMMARY

Constituting more than 7% of the global burden of disease, with a cost of US $180 billion per year (Robert E. Black et al., 2008), micronutrient malnutrition and its adverse health outcomes are very prevalent (Ahmed, Hossain, & Sanin, 2012; R. Black, 2003; Tulchinsky, 2010), especially in the developing world (Ahmed et al., 2012). Deficiencies of the "big four" micronutrients, i.e. Vitamin A, Iodine, Iron, and Zinc, still affect billions of people, albeit mostly in women and children (Ahmed et al., 2012). Iodine deficiency, for instance, is still a major public health problem worldwide and a well-known cause of preventable retardation of mental and neurological development.

However, despite considerable progress in eliminating these deficiencies through supplementation, dietary diversification, and fortification, and other food-based nutrition interventions which have been advocated for a long time, the goal is still far from being achieved (Bhutta et al.), particularly in rural landlocked areas of developing regions which are iodine endemic (M. B. Zimmermann & Andersson, 2012). This has led to consideration of new approaches to improve micronutrient intake levels. One such strategy is biofortification (Bouis, Hotz, McClafferty, Meenakshi, & Pfeiffer, 2011), which is a process of enhancing micronutrient concentrations in staple crops through conventional, such as use of enriched fertilizer, sprays and cross breeding or transgenic techniques, usually genetic modification (Graham, Welch, & Bouis, 2001; Hirschi, 2009; Mayer, Pfeiffer, & Beyer, 2008; Philip J. White & Broadley, 2005; Yuan et al., 2011; Zhu et al., 2007).

Therefore, biofortification of staple crops with iodine, commonly iodine biofortification (Hong, Weng, Qin, Yan, & Xie, 2008; Weng et al., 2008; Philip J White & Broadley, 2009; Zhu et al., 2007), is a potential strategy to address this gap, as demonstrated with other micronutrients (Bouis et al., 2011; Bouis & Welch, 2010), such as folate and vitamin A (Bouis et al., 2011; H. De Steur, Gellynck, Blancquaert, et al., 2012; Lyons, Stangoulis, & Graham, 2004; J. V. Meenakshi et al., 2010). This potential strategy could radically reverse iodine malnutrition if adopted and accepted by different populations (H De Steur et al., 2015; H De Steur et al., 2010). Increasing the iodine content of staple foods can be achieved through conventional plant breeding, provided there is genetic multiplicity, or by applying nutrient rich sprays or fertilizers to soils (Perez-Massot et al., 2013; Zhu et al., 2007). Otherwise, genetic engineering represents a viable alternative (Yuan et al., 2011).

Nonetheless, many studies have analysed the potential of health innovations and strategies in food supply chain to improve the health and wellbeing of consumers (Asenso-Okyere, Davis, & IFPRI, 2009; Smith & Martindale, 2010; Yakovleva, Flynn, Green, Foster, & Derwick, 2004), even in the case of pro-poor, pro-rural, health-oriented innovations (Asenso-Okyere et al., 2009; Renting, Marsden, & Banks, 2003). However, product and process-related innovations and technologies in

food, including biofortification, do not occur in a vacuum and their adoption, whether or not they are successful, is stakeholder driven (Feder & Umali, 1993; Smith & Martindale, 2010; Sunding & Zilberman, 2001; Yakovleva et al., 2004). In addition, there is little or no research on the role of stakeholders, including consumers, farmers, policy makers, and retailers, with respect to the uptake of novel food products and technologies, which is an important ingredient to address challenges in a food chain and subsequently the overall health and nutrition of consumers in resource-poor countries.

Consumers and producers alike make different decisions about the acceptance and adoption of biofortified foods once introduced to the market (Gilligan, 2012; Johnson, Guedenet, & Saltzman, 2015; Qaim, Stein, & Meenakshi, 2007; Stein, 2014). Such food choices are a function of many personal factors, such as the level of health consciousness, the ability to overcome healthy eating barriers, nutrition knowledge, previous experience with similar foods, attitudes towards novel foods (technologies), and their perceived (adverse) health effects, religious and cultural beliefs, as well as external factors, such as the way these products are produced and marketed (Mai & Hoffmann, 2012; Pounis et al., 2011; Verbeke, Scholderer, & Lahteenmaki, 2009). Therefore, a distinction is often made between stakeholders on the demand side, such as households and school feeding programmes, and those on the supply side, including smallholder farmers and retailers.

Therefore, the main objective of this doctoral dissertation is to investigate overall stakeholders' reactions toward iodine biofortified foods. Thorough insights are necessary to examine stakeholders from the demand-side (consumers) and the supply-side (farmers) within a biofortified food supply chain. Although many theories exist for analysing stakeholder reactions, alone they are often insufficient due to the diversity and specific characteristics of stakeholders in the chain (H. De Steur, Mogendi, Wesana, Makokha, & Gellynck, 2015; Feder, Just, & Zilberman, 1985; Feder & Umali, 1993; Munene, 2006; Siegrist, 2008; Sunding & Zilberman, 2001). A conceptual framework bringing together behavioural change models and technology acceptance modelling as well as economic valuation technique is adapted, adjusted and tested for use in analysing stakeholders.

Six distinct studies were conducted through desk review (UGent) and from locations drawn from three East African countries: Kenya; Uganda; and Tanzania, which have highest levels of iodine deficiency disorders (IDD) as well as retarded mental and neurological development coupled with poor school performance. These locations meet the criteria for iodine deficiency endemic areas with a large at risk population that seldom benefits from the existing intervention programs. Both primary and secondary data were collected and applied to support six research objectives developed in this doctoral research, the background and findings of which are presented as follows:

The **first objective** was to analyse the literature surrounding stakeholders' evaluation of food with nutritional benefits. This was motivated by the fact that consumers often view their kitchen cabinet more and more as a medicine cabinet which backs the increasing interest in, and development of various types of food with nutritional benefits, such as biofortified food. A systematic review was conducted to summarize evidence on the consumer evaluation of nutritious foods, which has a bearing on the reaction of stakeholders on the demand-side. Four groups of key determinants are highlighted including: nutrition knowledge and information; attitudes, beliefs, perceptions and consumer behaviour; price, process and product characteristics; and socio-demographics. The findings contribute to our understanding of nutritious food marketing and further support the development of appropriate strategies for improving health and wellbeing. Therefore they are incorporated in the conceptual framework used for further analysis of stakeholders in this thesis.

The focus of the **second objective** was to adapt, adjust, integrate and test a conceptual framework for analysing stakeholders, both consumers and producers within a healthy (biofortified) food supply chain. More often than not, novel strategies aimed at preventing micronutrient malnutrition, such as biofortification, often fail to consider the role and behavioural action of stakeholders in the chain, which often hampers their success. Existing literature on protection motivations (PMT), technology acceptance (TAM), economic valuations, as well as literature from the systematic review conducted (see objective 1 above) and other existing reviews were applied to develop an integrated model, referred in this research as PMTAM (Mogendi, De Steur, Makokha, & Gellynck, 2016) for analysing stakeholders' perceptions and behavioural actions. The resultant model has three parts: 1) PMT-based part for analysing stakeholders on the demand-side; 2) TAM-based model for analysing stakeholders on the supply-side; and 3) interlinking economic valuation technique for evaluating the overall behaviour exhibited by the stakeholders. The framework offers new insights into the appropriate protocol for analysing stakeholders on the demand-side (consumers) and supply-side (farmers), which are the basis for supporting the next objectives of this thesis.

The **third objective** of this thesis relates to the application of the resultant framework, developed and tested (in objective 2), to analyse the reaction of stakeholders on the demand-side (consumers: household and schools) towards iodine biofortified food. The part of the resultant framework that consists of the PMT constructs was applied to evaluate reaction in form of protection motivations (behavioural intention) towards iodine biofortified food in Uganda. A survey involving 360 parents of primary school children and 40 school heads was used for this analysis. PMT, and coping factors in particular, seem to be valuable for assessing intentions to adopt biofortified foods.

It was the **fourth objective** of this thesis to apply the conceptual framework developed to examining the willingness-to-pay a premium or a discount for iodine biofortified food and the concomitant determinants. In addressing this objective, an evaluation of adoption, purchase, and consumption of iodine biofortified vegetable legumes (IBVL) was conducted using the theory of protection motivations (PMT) integrated with an economic valuation technique. Data collected in objective together with data from land-locked in the other two East Africa countries: Kenya and Tanzania, giving of 1200 participants was used for this analysis. The survey elicited preferences for iodine biofortified foods when offered at a premium or discount. Determinants of protection motivations and preferences for iodine biofortified foods were assessed using path analysis modelling and two-limit Tobit regression, respectively.

Results demonstrated a positive willingness-to-pay a premium or acceptance of a lower discount for biofortification. Furthermore, preference towards iodine biofortified foods was a function of protection motivations, severity, vulnerability, fear, response efficacy, response cost, knowledge, iodine status, gender, age and household head. Results lend support for the prevention of iodine deficiency in at risk populations through biofortification; however ‘threat’ appraisal and socio-economic predictors are decisive in designing nutrition interventions and stimulating uptake of biofortification. In principle, the contribution is threefold: 1) Successful application of the integrated model to guide policy formulation; 2) Offer guidance to stakeholders to identify and tap into niche markets; 3) stimulation of rural economic growth around school feeding programmes.

The **fifth objective** was to conduct experimental auctions to determine the willingness-to-pay values for iodine biofortified food, exhibited by consumers under different prevailing marketing conditions and using the most effective and accurate procedures. Preference for micronutrient rich food is increasingly used as a means of ascertaining the value consumers attach to foods that improve their health. To support this objective a study was conducted to evaluate the preference for iodine biofortified food using the Becker-Degroot-Marschak (BDM) method. An attempt is also made to validate a short messaging service (SMS) in BDM auctions. The study occasioned a longitudinal auction, with a sample of 180 participants from open-air markets in 3 different locations in East Africa. Data on willingness-to-pay was collected using standard BDM and SMS-based BDM in five treatment scenarios. The results provide insights into the impact of different treatments on willingness-to-pay and communicating a person’s iodine status has a more significant effect than the method using production and product characteristics. SMS-based bidding was found to yield high validity values and could consistently be used to obtain accurate results in the most convenient, attractive, quick, cheap, and reliable way, which is in line with novel ways of purchasing food. Evidence points to the potential of technologically sound systems in conducting experimental auctions and highlights the importance of communicating iodine status, health benefits, and methods of improvement when launching nutrition intervention programmes that utilise biofortified food.

The **sixth objective** was to apply the resultant framework (J. Mogendi et al., 2016) to investigating farmers’ (producers’) willingness, ability and the frequency for adopting iodine biofortification at the farm level. To address this objective, the portion of the conceptual framework that contains technology acceptance modelling constructs was employed analyse farmers’ perceptions and willingness-to-pay to adopt iodine biofortification. Our findings suggest significant and consistent heterogeneity of individual, TAM and mediating factors influencing willingness- to-pay to adopt (WTPA), intention to adopt, attitude, and frequency of adoption at the farm level. This is crucial for designing policies and programs that efficiently and sustainably promote the adoption of biofortification as a strategy to improve the micronutrient intake among vulnerable groups where existing strategies are ineffective.

In **conclusion**, the contribution of this thesis is threefold. *First of all,* scientific contribution, the findings from each study conducted present both a methodological and empirical contribution which improves the performance of consumer research. For instance, the systematic review is a crucial element that not only streamlines how the impact of different studies can be summarised, for ease of applicability, but also the overall conduct of primary studies based on the quality appraisal criteria presented. Furthermore, the conceptual framework developed and tested will guide research and provide an avenue for understanding stakeholders throughout food supply chain, particularly when launching new healthy products. In addition, integration and validation of the short messaging service (SMS) is a unique way of conducting experimental auctions in a faster, safer, technologically sound and more accurate and attractive way. This is important in pricing and decision making in relation to the marketing of healthy food or, for that matter, any new product. On the scientific front, the overall data generated about the adoption of new strategies is important, for example in designing new products, as well as in identifying the most appropriate conditions for acceptability and uptake in this case.

Next, at the policy level, this thesis provides insights for both health and agricultural interventions. Whereas, in terms of health interventions, the findings provide crucial information not only for building a policy framework to guide the overall prevention of iodine deficiency among vulnerable groups in the affected region, but also to improve micronutrient intake and overall mental and neurological development, which are considered a major public health challenge. At the agriculture or farm intervention level these findings provide an opportunity not only to guide the policy framework for the production of biofortified foods but also to guide the smallholder farmers to tap into the niche-demand-driven market for biofortified foods. In principle, this improves their livelihoods as well protecting their households from health problems, such as those associated with the iodine deficiency.

*Subsequently, a*t the society level, the findings from this thesis have the potential to improve the overall health of vulnerable groups with regard to iodine deficiency disorders, improve mental and neurological development and subsequently improve school performance, which is often a prerequisite for socio-economic development. In addition, the demand market created, improves the livelihoods and overall socioeconomic status of rural smallholder farmers. In essence, these are pillars of development not only in the target location, but also in the entire region as components of sustainable development goals (SDG).

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

BDM	Becker-Degroot-Marschak Method
CV	Contingent Valuation
EA	East Africa
EBSCO	Elton B. Stephen Company Database
EUFIC	European Food Information Council
FAO	Food and Agriculture Organisation
FSN	Food Neophobia Scale
GEE	Generalised Equation Modelling
GM	Genetically Modified
GCDF	Group and Community Driving Factors
HBM	Health Belief Model
HH	Household
ICCIDD	International Council for the Control of Iodine Deficiency Disorders
IFPRI	International Food and Policy Research Institute
IFIC	International Food Information Council
A1	International Peer-Reviewed Journals and Papers
IBVL	Iodine Biofortified Vegetable Legumes
IDD	Iodine Deficiency Disorders
KES	Kenya Shilling
KDE	Kernel Density Estimate
MDG	Millennium Development Goals
NALDR	National Agricultural Library Digital Repository
LR-	Negative Likelihood Ratio
NPV	Negative Predictive Value
LR+	Positive Likelihood Ratio
PPV	Positive Predictive Value
PMTAM	Protection Motivation and Technology Acceptance Model*
PMT	Protection Motivations Theory
SMS	Short Messaging Service
SHF	Smallholder Farmers
SCT	Social Cognitive Theory
SD	Standard Deviation
SEM	Structural Equation Modelling
SDG	Sustainable Development Goals
TZS	Tanzania Shilling
TACT	Target, Action, Context, and Time
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TTM/SCM	Transtheoretical (or Social Change) Model
UGX	Uganda Shilling
ESRC	UK Economic and Social Research Council
USD ($)	United States Dollar
WTA	Willingness to Accept
WTP	Willingness-to-pay
WHO	World Health Organisation
SSRS	Standard Simple Random Sampling

"The food you eat can be either the safest and most powerful form of medicine or the slowest form of poison." — Ann Wigmore

PART I GENERAL INTRODUCTION

This part was established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition*. Volume 55, Issue 2 pp. 182-208.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X (2016). Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis. *International Journal of Food Sciences and Nutrition.* Volume 67, Issue 4 pp. 355-371.

Chapter 1 General Introduction: Contextual Information, Conceptual Framework and Thesis Structure

This chapter is established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition*. Volume 55, Issue 2 pp. 182-208.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X (2016). Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis. *International Journal of Food Sciences and Nutrition.* Volume 67, Issue 4 pp. 355-371.

1.1 Background

Despite the progress made through existing strategies to prevent micronutrient malnutrition (Harrison, 2010), including fortification and supplementation, there is still a large unprotected population. This has increased the need for novel strategies, such as biofortification, as alternatives to agriculturally based interventions for vulnerable groups (Graham et al., 2001; Maberly, Trowbridge, Yip, Sullivan, & West, 1994; Mayer et al., 2008). The 'big five' : Vitamin A, Iron, Iodine, Zinc, and lately Folate are of greatest importance in endemic areas (Ramakrishnan, 2002). Deficiencies of these micronutrients often affects the population over a long period of time without being noticed, unlike other forms of malnutrition, and can occur even in the presence of a staple diet (Cafiero & Gennari, 2011; WHES, 2015).

Thereby, the term ' hidden hunger' has been coined to describe the insidious nature of micronutrient malnutrition (Tulchinsky, 2010; von Grebmer et al., 2014). Although 'hidden hunger' is largely contained by existing nutrition interventions (Harrison, 2010), some micronutrients, e.g. iodine, are still a major public health challenge (De Benoist, Andersson, Egli, Takkouche, & Allen, 2004). Iodine is readily available within the earth's crust and is of great importance to human nutrition throughout the lifecycle (Melse-Boonstra & Jaiswal, 2010), Its particular impact on mental and neurological development (Francois Delange, 2000; Kapil, 2007) is a motivation for new strategies, such as iodine biofortification (D. D. Miller & Welch, 2013; Philip J. White & Broadley, 2005). This is particularly so for iodine deficient areas where other existing strategies (Maria Andersson, de Benoist, & Rogers, 2010) are largely ineffective (Kapil, 2011).

Therefore it is important to understand the reactions of key stakeholders in the biofortified food supply chain, as this has a bearing on the launch of iodine biofortification. In principle, two stakeholders are identified: stakeholders on the demand side (consumers) and stakeholders on the supply side (producers).

1.2 Rationale and relevance of the case

1.2.1 Rationale

The food supply chain traditionally includes all stages from agricultural production to consumption and is continuously susceptible to a wide variety of product and process innovations which are a function of resources, competition, actors and regulations (Smith & Martindale, 2010; Yakovleva et al., 2004). Despite these growth opportunities, the rural poor who depend on agriculture face health, technical and socio-economic challenges which affect their production, consumption and wellbeing (Marsden, Banks, & Bristow, 2002). Therefore, innovations should also lead to food chains that are targeted at the poor in order to remain sustainable and competitive, while protecting the environment and, above all, improving the health and wellbeing of consumers, in a dynamic world (Asenso-Okyere et al., 2009).

A distinction is therefore needed for health-based agricultural innovations, referring to innovations that are aimed at improving health e.g. biofortified foods and biofortification across the food supply chain for the optimal health of consumers. However, these product- and process-related innovations and technologies in the food supply chain do not occur in a vacuum and their adoption, whether or not they are successful, is stakeholder driven (Feder & Umali, 1993; Smith & Martindale, 2010; Sunding & Zilberman, 2001; Yakovleva et al., 2004). Therefore, a distinction is also made between stakeholders on the demand-side, (consumers) and those on the supply-side, including farmers, processors, and retailers.

In addition, there is a surfeit of literature on the potential for healthy innovations in food supply chains to improve the health and wellbeing of consumers (Asenso-Okyere et al., 2009; Smith & Martindale, 2010; Yakovleva et al., 2004), even in the case of pro-poor, pro-rural, health-oriented innovations (Renting et al., 2003). This is because, more often than not, innovations in the food supply chain are largely proactive, while health innovations are reactive and hence the stakeholders are predicted to follow a particular protective behaviour. However, there is a lack of research on the framework for analysing the reactions (such as consumption evaluations, protection motivations and behavioural actions) of stakeholders, including consumers, farmers, processors, policymakers, and retailers, with regard to novel health strategies, products, innovations, and/or technologies. This is an important ingredient to address challenges in the biofortified food supply chain and subsequently the overall health of consumers, particularly in resource-poor countries. Therefore, many theories have been put forward for analysing these stakeholder reactions. These are often inadequate due to the diversity and specific characteristics of stakeholders within the chain (H. De Steur et al., 2015; Feder et al., 1985; Feder & Umali, 1993; Munene, 2006; Siegrist, 2008; Sunding & Zilberman, 2001), and are often not targeted at healthy innovations in agriculture, such as biofortification. Therefore, the focus of this thesis is to investigate stakeholders’ reactions towards iodine biofortified foods as a healthy food strategy and innovation for the prevention of iodine malnutrition.

Existing research presents behavioural models as candidates for explaining behaviour towards biofortified food, albeit more for stakeholders on the demand-side (consumers), than those on the supply-side (producers) (H. De Steur et al., 2015; Urala & Lähteenmäki, 2003, 2007; Vecchione, Feldman, & Wunderlich, 2015; Verbeke, 2006; Verbeke et al., 2009; West, Gendron, Larue, & Lambert, 2002; Williams, 2005). Nevertheless, numerous, adjustments, adaptations, modifications, combinations, and integrations of these models have been successfully applied to explain intentions and resultant behavioural actions (Sutton, 2001, 2011), particularly in the health field (Baban & Craciun, 2007). For many decades these models have been used to explain human behaviour towards changes in health and environments, e.g. by adopting novel strategies, innovations and technologies. Therefore, these elements have motivated the exploration employed throughout this doctoral research.

Firstly, with regard to stakeholders on the demand-side (consumers), research demonstrates that there are significant differences between individuals' behaviour depending on their level of influence on their health and environment - for instance, health-promoting practices, food substances and innovations call for different psychological models, or a combination of models (Baranowski, Cullen, & Baranowski, 1999; D. N. Cox, Koster, & Russell, 2004; Fishbein & Ajzen, 1975; Floyd, Prentice-Dunn, & Rogers, 2000; Prochaska & DiClemente, 1994; Rutter & Quine, 2002). Moreover, the explanatory power of the models that are mostly applied within food consumer research is often low. For instance, in their review Baranowski et al. (1999) found that the Theory of Reasoned Action (TRA) (Ajzen, 1985); Theory of Planned Behaviour (TPB) (Fishbein & Ajzen, 1975); Transtheoretical (or Social Change) Model (Prochaska & DiClemente, 1994); Social Cognitive Theory (SCT) (Bandura, 1999); and Health Belief Model (HBM), only explain a small proportion of the variance (~30%) in the intention to consume certain healthy foods, such as fruit and vegetables.

Nonetheless, the protection motivations theory (Ronald W. Rogers, 1975) has successfully been applied to many health promoting and lifestyle enhancing behaviours, with a very high degree of explained variance compared to previous models (David N. Cox & Bastiaans, 2007; D. N. Cox, Evans, & Lease, 2008; D. N. Cox et al., 2004; Floyd et al., 2000). For example, the meta-analysis by Floyd et al. (Floyd et al., 2000) identified six major applications, namely cancer prevention (17%), healthy lifestyle (17%), smoking, HIV prevention (9%), alcohol consumption (9%) and adherence to medical-treatment regimens (6%) (Floyd et al., 2000). This model is a health behaviour model which proposes that when a person, or stakeholder, is confronted with a health threat, e.g. micronutrient deficiency, protection motivation (intention) and protection behaviour, are a function of "threat" appraisal and "coping" appraisal (see Figure 5). Each construct is defined using these elements: threat (perceived severity, perceived fear, and perceived vulnerability) and coping appraisal (response efficacy, response cost and self-efficacy). This model was originally developed by Rogers (1975) to understand fear appeals and how people cope with them. Later on, it was expanded into a more general theory of persuasive communication by incorporating cognitive processes of behaviour change (Maddux & Rogers, 1983), which have been used in personal health contexts to examine the behaviours of specific target groups. However, to our knowledge only a few studies have applied this model to explore protection behaviour by dietary means (D. N. Cox et al., 2004). Moreover, none of them have specifically examined biofortified food consumption as a (protection) behaviour to address micronutrient malnutrition.

Secondly, regarding the stakeholders on the supply side (producers), the behavioural intentions and behavioural action towards adopting healthy innovations and strategies, i.e. biofortification, in the production of healthy foods are considered. Although, acceptance of new technologies and innovations has been analysed extensively in different domains, to our knowledge, acceptance, uptake and adoption of healthy innovations by producers, i.e. smallholder farmers, in a food supply chain is not well documented. Building upon the technology acceptance literature, it is clear that many behavioural models have been applied to explain the acceptance of new innovations and technologies (Chen, Li, & Li, 2011), not only from the information and service industry viewpoint (Li, 2010), but also in the health sector (Holden & Karsh, 2010) and agriculture (Rezaei-Moghaddam & Salehi, 2010). However, these models, as well as modifications and extensions of them, have been found to present numerous inconsistencies in the technology acceptance sphere (Chen et al., 2011). Nevertheless, the TAM model has been applied successfully with consistent results, and in different areas and disciplines (King & He, 2006; Surendran, 2012) . This therefore points to its potential in exploring stakeholders' uptake, adoption or acceptance of health-related innovations and technologies across the biofortified food supply chain.

TAM is an information systems theory that explains how people accept or adopt a particular technology or innovation. It states that attitudes towards a novel product or technology, and the subsequent behaviour in using the technology, are determined by Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). TAM can be also considered as an extension of the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975). Initially developed by Fred Davis (1989), other researchers have expanded the model into the TAM 2 model (Venkatesh & Davis, 2000) and the Unified Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003). The original model proposes that when people are presented with a novel technology, their decision about how and when to use the technology is influenced by a number of factors, notably: how much the person believes using the technology would enhance their output (perceived usefulness) and how much effort they believe would be needed to use the technology (Perceived Ease Of Use). However, further advances in technology have led to a further expanded model, known as TAM 3, which incorporates elements of trust and risk in terms of technology use. This model has been widely applied to analyse the adoption of various novel technologies and innovations in many areas, including healthcare (Chen et al., 2011; Feder & Umali, 1993; King & He, 2006; Mahajan, Muller, & Bass, 1991; Surendran, 2012) and agriculture (Feder & Umali, 1993; Holden & Karsh, 2010; Surendran, 2012).

In this doctoral research, there is a need to explore the potential of TAM constructs in analysing the adoption of biofortification as an agriculture-based technology by stakeholders, in this case farmers in a biofortified food supply chain. Therefore, it is important to evaluate model constructs, including perceived ease of use and perceived usefulness, that are crucial in ascertaining the degree to which they reflect the adoption and use of these technologies, at the production level (Chen et al., 2011; Feder et al., 1985; Feder & Umali, 1993; Holden & Karsh, 2010; King & He, 2006; Surendran, 2012). Nevertheless, to our knowledge, no studies have used it, either alone or integrated into another model, within the field of biofortification, or other interventions to tackle micronutrient malnutrition, or to analyse stakeholders' reactions toward biofortified food.

However, both Protection motivation theory and the technology acceptance model present behavioural action as a unique feature which is generic to each model. Therefore, it is important to understand the overall economic value stakeholders attach to the product or process of the healthy foods system. As the focus is on stakeholders' behaviour regarding healthy food, we also refer to an Economic Valuation technique to measure an outcome indicator (e.g. willingness-to-pay, WTP), in addition to statements on intention or resultant behaviour. Therefore, both stated preference (Carlsson & Martinsson, 2003; Louviere & Street, 2000) and revealed methods (Elbakidze & Nayga, 2015; Jayson L Lusk & Shogren, 2007) of ascertaining the economic value stakeholders, consumers and producers alike, attach to the final product or process, depict their resultant behaviour.

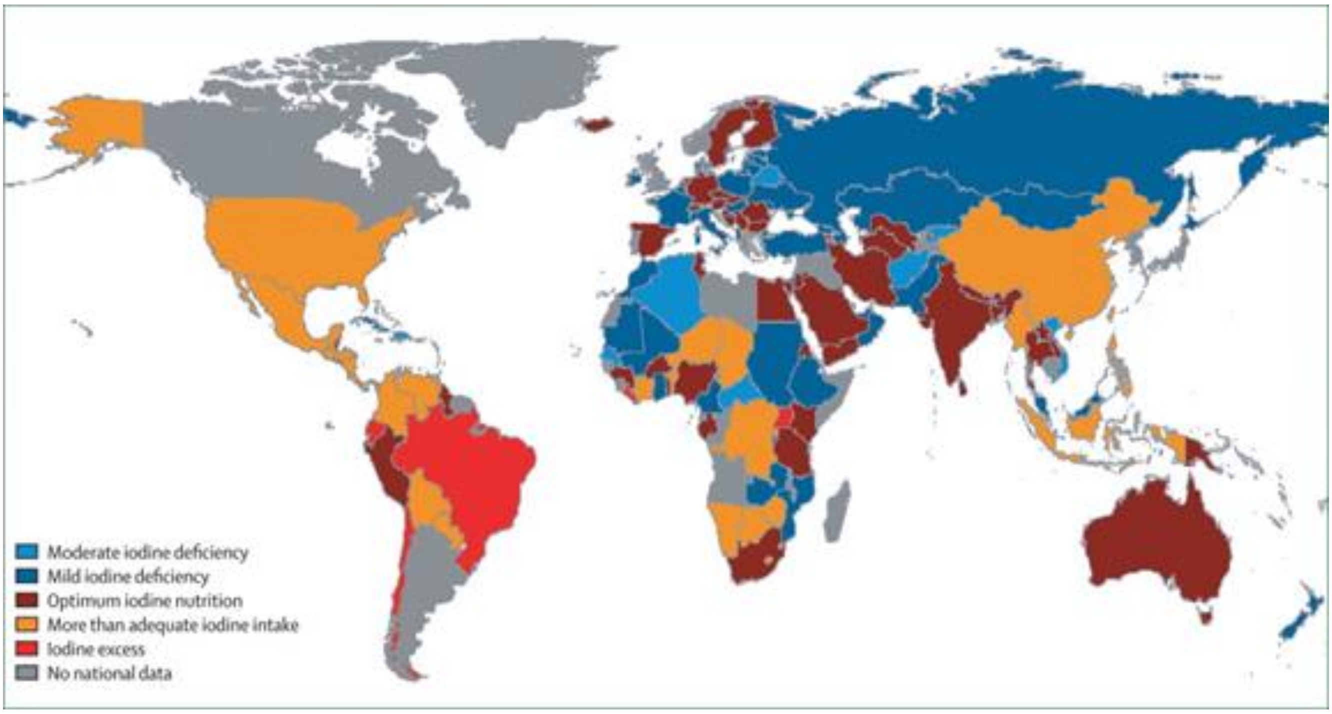
Economic valuation research aims to determine the maximum value a specific actor attaches to a good or service, also referred to as willingness-to-pay (WTP) (Reutterer & Breidert, 2007). With respect to behavioural change studies, there is evidence for the integration of economic valuation techniques, such as stated preference methods (Barro, Manfredo, Brown, & Peterson, 1996; Luzar & Cosse, 1998; Whitehead, 2005a, 2005b) and their applications in health systems (Bridges, 2003; Carlsson & Martinsson, 2003). Stated preference, involves direct questioning of an individual about how much they are willing to pay (WTP), or the amount of compensation they are willing to accept (WTA) for a given good or service (Breidert, Hahsler, & Reutterer, 2006). Different methods have been developed and tested, such as open-ended or dichotomous choice and payment card contingent valuation, which have been carefully selected for this research (Breidert et al., 2006; Voelckner, 2006; Wertenbroch & Skiera, 2002). In addition, there are others such as revealed preference, which could be used in cases where the actual products are presented to the consumer (Breidert et al., 2006; Elbakidze & Nayga, 2015; Jayson L Lusk & Shogren, 2007; Reutterer & Breidert, 2007), even in health fields (de Bekker-

Grob, Ryan, & Gerard, 2012). This was not the case with the current study as hypothetical products were used.

Despite the existence of these procedures, there are limited studies that have tried to apply the combination of behaviour models and economic valuation techniques to evaluate the intention to behave, or resultant behaviour, as a WTP towards biofortified food. In principle, there are no studies that have utilised the linkage between behavioural change models and economic valuation to determine the stakeholders' (consumers and producers) reactions to biofortified food in a biofortified food supply chain.

Therefore, since elements and stakeholders in any food supply chain do not occur in isolation, an integration of the three, PMT, TAM and Economic valuation, is crucial to providing a snapshot of stakeholders' behavioural action before launching innovations, products, and/ or technologies and, in particular, iodine biofortification technology and biofortified foods.

This thesis therefore presents the resultant evaluation of the consumer (household and schools) and producer (smallholder farmers) reactions towards biofortified food and iodine biofortification, respectively. The analysis employs an adjusted, integrated and tested conceptual framework drawn from behavioural models and economic valuation techniques. An understanding of stakeholder reactions is crucial in designing iodine intervention programs using biofortification, particularly in areas where existing interventions are ineffective. It is also an important element in policy formulation affecting both the production and distribution of biofortified food, as well as micronutrient malnutrition in the most vulnerable regions of the world, such as East Africa and sub-Saharan Africa.



1.2.2 Relevance of the case

This thesis analyses the reactions exhibited by stakeholders toward biofortified foods using the case of iodine biofortified food, (a nutrition-based health product) and biofortification (a process, innovation, strategy, or technology for increasing the micronutrient content) of staple food. These products are often targeted towards reducing micronutrient malnutrition among the most vulnerable groups. Micronutrient malnutrition and its adverse health outcomes are still prevalent (Ahmed et al., 2012; R. Black, 2003), especially in the developing world (Ahmed et al., 2012), constituting 7% of the global burden of disease with a cost of over US $180 billion per year (Robert E. Black et al.). Deficiencies of the “big four” micronutrients, i.e. Vitamin A, Iodine, Iron, and Zinc, are still prevalent and affect billions of people, particularly women and children (Tulchinsky, 2010).

Iodine deficiency alone affects over 2 billion people, particularly in developing countries (Ahad & Ganie, 2010; De Benoist et al., 2004; M. B. Zimmermann & Andersson, 2012). Iodine is an essential trace element found in seafood, iodized salt, and certain vegetables and is an important component of thyroid hormones, which generally determine human metabolic rate and promote growth and development throughout the body, including the brain, bones, skin, nerves, nails, and teeth (Fisher & Delange, 1998). Iodine deficiency mainly results in overgrowth of the thyroid gland, known as goitre, and in the long-term leads to a spectrum of diseases commonly referred to as Iodine Deficiency Disorders (IDD). Iodine directly impacts on the cognitive development of infants, pre-school, and school–aged children (Francois Delange, 2000). Iodine deficiency could prevent children at different levels from attaining their full intellectual potential and subsequently affects their overall school performance (Bougma, Aboud, Harding, & Marquis, 2013), which is a key motivation for the current research.

Nevertheless, there is a pool of evidence that these disorders can be corrected by adequate dietary supply of iodine (Bhutta et al., 2008; Francois Delange, 2000; Tornatzky & Klein, 1982). Notwithstanding its uneven distribution on the earth’s crust, accelerated deforestation, soil erosion, and leaching processes, result in low amounts of iodine in food, making iodine deficiency a major public health problem affecting both developing and developed countries (Rasmussen, 1998). Given the critical role of iodine in human nutrition (F Delange, 1994), various strategies have been implemented, including: supplementation, dietary diversification, and fortification. Fortification is by far the most widely applied strategy through iodization of widely consumed foods, such as salt, oil, flour, water, and milk. This strategy has been implemented over time to improve dietary iodine intake (Pearce, Andersson, & Zimmermann, 2013). However, despite considerable progress in eliminating iodine deficiencies through these strategies, which have been advocated for a long time (Harrison, 2010), the goal is still far from being achieved (Bhutta et al.).

Therefore there is a need to explore new approaches to improve iodine intake levels, such as iodine biofortification (Nestel, Bouis, Meenakshi, & Pfeiffer, 2006). Biofortification is a strategy to enhance micronutrient concentrations in staple crops through conventional or transgenic breeding techniques (Bouis et al., 2011; Nestel et al., 2006; Tucker, 2003). This potential strategy could radically reverse iodine malnutrition if adopted and accepted by different populations (H De Steur et al., 2015; H De Steur et al., 2010; Johns & Eyzaguirre, 2007; Mayer et al., 2008; Qaim et al., 2007). In the case of iodine, this strategy is particularly important for people living in remote, landlocked and mountainous areas, and groups consuming traditional vegetables and vegetation high in salt (Kapil, 2011), and in regions far from water masses with a diet low in iodine (Ahmed et al., 2012; Pearce et al., 2013).

In remote areas of the developing world, iodine distribution is often restricted, and therefore salt reaching these areas takes longer and the iodine content is often lost due to its volatile nature (Dunn, 1996; Kapil, 2011). Mountainous areas are heavily depleted of iodine due to erosion. Crops and other products grown in these areas are low in iodine and the local people consuming them therefore have a low intake of iodine (Dunn, 1996; Gaitan & Dunn, 1992; Kapil, 2011; Peterson, 2000; M. B. Zimmermann & Andersson, 2012). Landlocked areas are also far from large water bodies and therefore have limited access to seafood and other products which are key sources of iodine (Carlé, Krejbjerg, & Laurberg, 2014; Gaitan & Dunn, 1992; The, 2008). Therefore iodine biofortification, increasing the iodine content of staple foods, in this areas can be achieved through conventional plant breeding, provided there is genetic multiplicity, or by applying nutrient rich sprays or fertilizers to soils (Perez-Massot et al., 2013; Zhu et al., 2007). Otherwise genetic engineering is a viable alternative (Yuan et al., 2011).

Based on these risk factors, Eastern Africa fits this description, leading to its purposive selection for the current research. Identified as one of the least developed regions of Sub-Saharan Africa, the region is remote, mountainous and landlocked with limited access to seafood and iodized salt, which are key physiognomies for endemic iodine deficiency and consequently IDD (Peterson, 2000). Iodine deficiency is estimated to be 2.4% in Kenya, 4.2% in Uganda, and 41.5% in Tanzania (ICCIDD, 2014), with a large at risk population, based on the existing methods of intervention (ICCIDD, 2014; P. Jooste, Andersson, & Assey, 2014; Pearce et al., 2013).

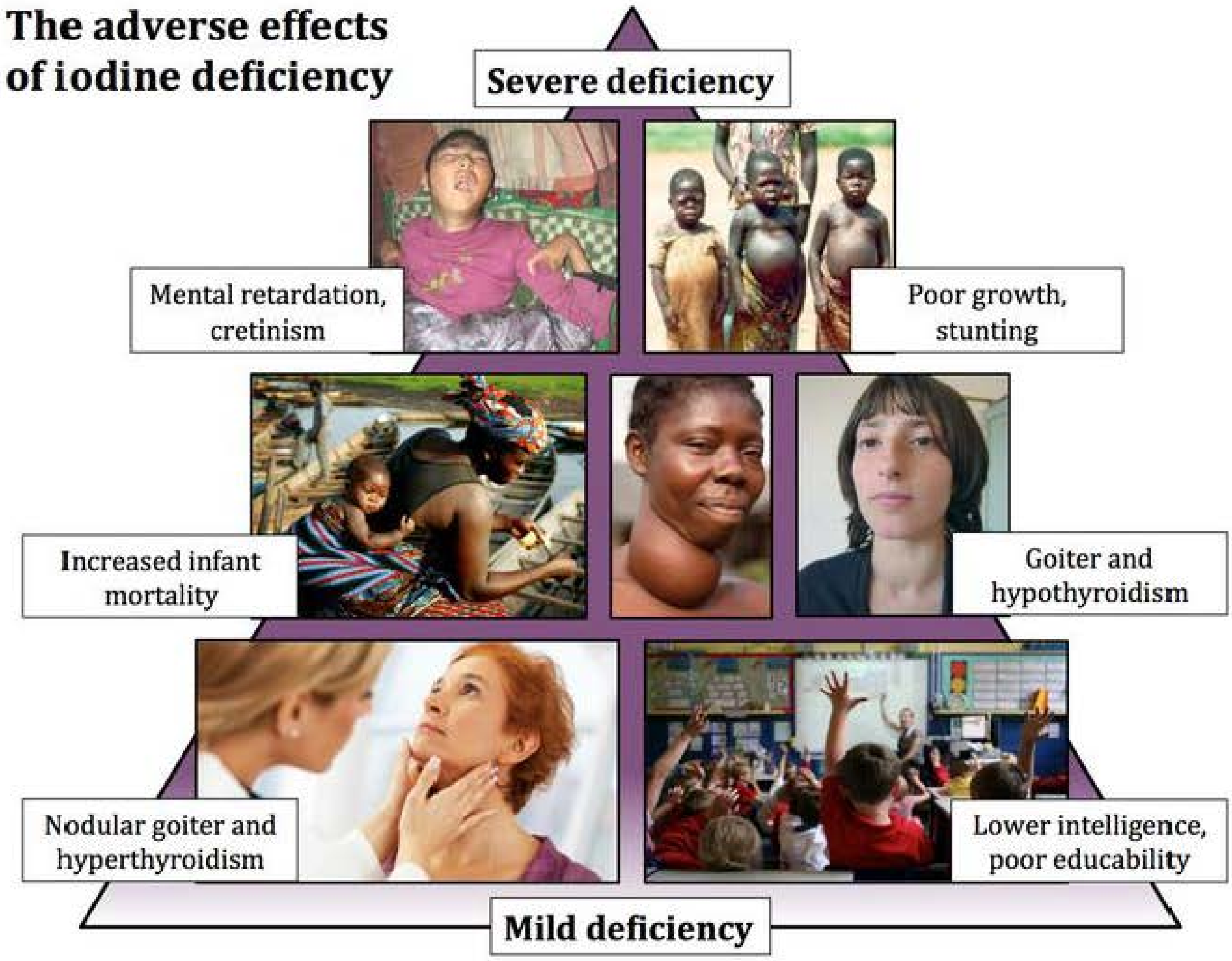
Although, other potential agricultural-food-based nutrition interventions have been successfully implemented (Morón, 2006), including the development of community gardens with nutritious foods, hydroponic gardens, the promotion of traditional crops rich in nutrients, as well as small-agro industries, the intrinsic characteristics of these areas (poor, remote, landlocked and mountainous), point to the favourability of biofortification as a potential strategy, since it provides elevated levels of the target micronutrient (Blasco et al., 2008; Caffagni et al., 2011; Hong et al., 2008; Weng et al., 2008). Iodine is a very sensitive and rare micronutrient which can only be tackled with a single directed intervention, to ensure the final product has elevated levels of the micronutrient, particularly in the staple food consumed in the community (Blasco et al., 2008; Caffagni et al., 2011). Furthermore, this procedure has been found to produce products with high levels of micronutrients (Bouis et al., 2011; Nestel et al., 2006; Philip J White & Broadley, 2009), even in the case of iodine (Blasco et al., 2008; Caffagni et al., 2011) and could therefore be a potential strategy for such areas. This is also the case with other minerals closely related to iodine, such as selenium (Thavarajah, Ruszkowski, & Vandenberg, 2008).

In addition, biofortification of crops has proved to be a cost effective approach to preventing micronutrient malnutrition (J. V. Meenakshi et al., 2010), albeit more in the case of multi-biofortified crops (H. De Steur, Gellynck, Blancquaert, et al., 2012). This could be a departure from the salt iodization which often presents additional costs for these specific areas.

Therefore, biofortification is a potential strategy for addressing the problem of iodine deficiency disorders, particularly for populations unprotected by salt iodization programs in sub Saharan Africa, and particularly the target locations in east Africa. The procedure is potentially effective in the presence of other food-based nutrition interventions owing to the specific nature and cost effectiveness of the procedure used with other crops and micronutrients, such as vitamin A and iron.

However, uptake of these novel strategies is more often than not, stakeholder driven (Feder et al., 1985; Yakovleva et al., 2004). Both consumption and producers are vital players in ensuring the new strategy succeeds and that the most vulnerable groups access food with a high iodine content, to protect them from IDD. In areas where iodine deficiency is endemic, the most notable stakeholders on the demand-side are the consumers themselves, at the household level or, in the case of school feeding programs, the schools themselves. While at the production level, smallholder farmers are the key drivers. Yet, there is little evidence on the role of these stakeholders, and, to our knowledge, this is the first attempt to investigate the reactions of stakeholders across the biofortified food supply chain towards iodine biofortified food and iodine biofortification as a technology.

Furthermore, there is a need to develop and test a conceptual framework that can readily analyse these stakeholders using a standard procedure, not only for iodine biofortified food, but also for biofortification as an agricultural based health strategy, innovation and/or technology. More often than not, the benefits of biofortification have largely been investigated in relation to consumer benefits. However, the increased market demand created by the added health benefits, is a key resource for producers, including smallholder farmers, to tap into the niche market and sell their produce. Therefore, this is a key source of income and improved socio-economic status for the communities living in resource-poor locations.



The adverse effects of iodine deficiency
Severe deficiency
Mental retardation, cretinism
Poor growth, stunting
Increased infant mortality
Goiter and hypothyroidism
Nodular goiter and hyperthyroidism
Lower intelligence, poor educability
Mild deficiency

1.3 Conceptual framework

Stakeholders' reactions and the resultant behavioural actions exhibited are considered essential ingredients for the successful introduction of health innovations and strategies in the food supply chain, particularly those targeted at improving the health and wellbeing of consumers (Feder & Umali, 1993; Yakovleva et al., 2004). Therefore, consumer research is required to characterise stakeholders across the health food supply chain before launching new healthy agriculture-related products, strategies, innovations, and /or technologies (Feder & Umali, 1993; Mahajan et al., 1991; Masset, Haddad, Cornelius, & Isaza-Castro, 2011; Munro, Lewin, Swart, & Volmink, 2007).

The objective of this thesis is to analyse stakeholders' reactions towards biofortified food and biofortification, with particular reference to iodine biofortification. The objective stems from the fact that existing health interventions and strategies to prevent iodine deficiency are largely ineffective in areas where iodine deficiency is endemic. Despite the existence of these different strategies to combat iodine-related deficiencies, millions of people remain at risk and continue to suffer from IDD, as described in the previous section covering the relevance of the case. Consequently, there is a need to explore stakeholders' roles and overall reactions, following the presentation and partial implementation of biofortification, particularly with the leading micronutrients: vitamin A, selenium, folate iron, iodine and zinc as a potential strategy for fighting micronutrient malnutrition. This therefore support the successful launch and implementation of iodine biofortification as an alternative measure to prevent iodine deficiency disorders. To our knowledge, this doctoral research is the first attempt to comprehensively explore key stakeholders' reactions towards iodine biofortification across the food supply chain.

To achieve this, a conceptual framework for this doctoral dissertation, as depicted in figure 1, has been adapted and tested, as shown in chapter 3 (J. Mogendi et al., 2016). In principle, two behavioural models: the Protection Motivation Theory (PMT) model (Ronald W. Rogers, 1975) and the Technology Acceptance Model (TAM) (Davis, 1989) are integrated with an economic valuation technique (Reutterer & Breidert, 2007; Wertenbroch & Skiera, 2002), either stated or revealed preference (Voelckner, 2006). This is a novel attempt that seeks to combine the behavioural dimension of stakeholders with uptake, willingness-to-pay or adoption of novel strategies, such as biofortification, across biofortified food supply chains, notwithstanding previous attempts to combine WTP and behavioural models in consumer research. The conceptual framework allows for the analysis of stakeholders on the demand-side and supply-side, in a iodine biofortified food supply chain, by building upon the two key behavioural models, i.e. Protection Motivation Theory (Ronald W. Rogers, 1975) and the Technology Acceptance Model (Davis, 1989). The former is clearly oriented toward analysing consumers' reactions toward iodine biofortified food and their evaluation of behavioural action to cope with the potential threat, such as biofortified food as a coping strategy.

However, the latter focuses on analysis of the reaction exhibited by stakeholders on the supply side towards iodine biofortification technology or innovation, in the production of iodine biofortified food. As such, applying a model that integrates both models allows a snapshot engagement of the key stakeholders, consumers and producers and the analysis of their overall reactions within a biofortified food supply chain.

Furthermore, as successful implementation of a food-based health strategy requires acceptance and adoption by different members of the food chain, these types of multi-stakeholder analyses can be considered a first step towards prevention of market failures for iodine biofortification (H. De Steur et al., 2015; Di Pasquale, Adinolfi, & Capitanio, 2011; Feder et al., 1985; Lynn Frewer, Scholderer, & Lambert, 2003; Mahajan et al., 1991; Smith & Martindale, 2010; Yakovleva et al., 2004). Therefore, an economic valuation technique is also integrated to quantify the overall value the stakeholders, from both the demand-side and supply-side, attach to the biofortified product and biofortification process respectively, often in the form of willingness-to-pay (Reutterer & Breidert, 2007). There are various methods of ascertaining the economic value at the level of the food supply chain, including both stated and revealed. The contingent valuation technique (Barro et al., 1996; Luzar & Cosse, 1998; Whitehead, 2005a, 2005b) as well as the experimental auction (Breidert et al., 2006), are two crucial valuation techniques that have been integrated within the conceptual framework as indices of overall behavioural action of the stakeholders in the study. Therefore, to investigate stakeholders' reactions towards iodine biofortified food, emphasis is placed on the three parts of this conceptual framework.

1.3.1 Protection motivation theory (PMT) model

From its advent as a fear-arousing theory (Ronald W. Rogers, 1975), PMT evolved into a more comprehensive persuasion model explaining how the cognitive process of threat appraisal interacts with coping appraisal to generate an intention towards a health-related behavioural change (Maddux & Rogers, 1983) . Protection motivation involves a decision-making process by which an individual evaluates the gravity of, and exposure to, an imminent risk and chooses a suitable alternative to deal with the threat (K. A. Cameron, 2009; K.A. Cameron & DeJoy, 2006). The PMT incorporates maladaptive and adaptive behaviours, which, respectively, constitute threat and coping appraisal. A threat follows arousal of fear for one to perceive danger (severity) and consider the extent of the risk involved (vulnerability) (Neuwirth, Dunwoody, & Griffin, 2000).

The interaction between these three components decreases the probability that a maladaptive behaviour will occur (threat appraisal). Similarly, one's confidence about the effectiveness of the proposed health behaviour to cope with the threat (response efficacy) and one's belief about the ability to successfully undertake this health preventive action (self-efficacy) both increase the likelihood that an adaptive behaviour will occur (coping appraisal), while the evaluation of the costs involved in the execution of the health behaviour (response cost) negatively affects the occurrence of the latter (S. Henson, Masakure, & Cranfield, 2008; R. W. Rogers & Prentice-Dunn, 1997).

This model has a superior capacity to determine and describe health preventive behaviour, because it covers more components that have been underpinned by a wide array of empirical and theoretical research, especially in the field of health behaviour theory (Hodgkins & Orbell, 1998; Maddux & Rogers, 1983; R. W. Rogers & Prentice-Dunn, 1997). Therefore, the conceptualization of this model entails individuals' motivation to start or maintain, and select a specific action to protect themselves or others from a threat (Ch'ng & Glendon, 2013). Although health preventive intentions are associated with actual health behaviour (Milne, Sheeran, & Orbell, 2000), the latter also depends on the stability of intentions over time, which is, in turn, affected by a number of individual factors, such as feelings of remorse for not performing an adaptive behaviour (Cooke & Sheeran, 2004). Therefore, in exploring the reactions of stakeholders on the demand-side towards iodine biofortified food, the part of the conceptual framework that consists of constructs from PMT was employed. However, although the PMT model has been found to be successful in previous applications, a review was necessary to determine other exogenous variables that significantly influence stakeholders' uptake of biofortification across the food supply chain (chapter 2). This review, together with a EUFIC review (EUFIC, 2005) on the determinants of foods with nutritional benefits, supported the extension of the consumption-oriented part of the conceptual framework (J. Mogendi et al., 2016). See Figure 1.

1.3.2 Technology acceptance model (TAM)

This portion of the framework is targeted towards the stakeholders on the supply-side, and applies the TAM constructs to explore the adoption of, and WTP for iodine biofortification as a novel strategy for preventing IDD at the farm level. The TAM model, a well-known model related to technology acceptance and its use, was originally developed by Fred Davis (1987). This model has been demonstrated to be a theoretical model that helps explain user behaviour towards a new technology, not only in the information technology sphere (King & He, 2006) but also in the agricultural sector (Adrian, Norwood, & Mask, 2005; Rezaei-Moghaddam & Salehi, 2010).

This model is a significant extension of the Theory of Reasoned Action (TRA) by Ajzen and Fishbein (1980) and demonstrates that actual use of a technology or innovation is influenced directly or indirectly by the users' behavioural intentions, attitudes, perceived usefulness (PU) and perceived ease of use (PEOU) towards the innovation or technology i.e. iodine biofortification. Nevertheless numerous extensions demonstrate that external factors also play an important mediating effect on the intention as well as attitudes, directly or indirectly, through perceived usefulness or perceived ease of use (Chen et al., 2011). Thereby, this explains the applicability of the model for analysing the adoption of iodine biofortification among smallholder farmers (SHF). Figure 6 depicts the original TAM according to Fred Davis (1987).

1.3.3 Economic valuation

Both the PMT and TAM models have behavioural action as their resultant measure, alongside intention and attitude, as well as other driving factors that come in-between. However, there is a need to quantify the behavioural action exhibited by the stakeholders. Therefore, an economic valuation technique has been integrated into the framework to quantify the economic value, in terms of willingness-to-pay (WTP) for the iodine biofortified food, or willingness to adopt the healthy innovation or technology i.e. iodine biofortification.

Although numerous economic valuation techniques exist (Rusche, Wilker, Blaen, & Benning, 2013), the current doctoral research incorporated both stated and revealed economic valuation techniques (Voelckner, 2006; Wertenbroch & Skiera, 2002) as an indicator of the resultant stakeholder reaction. Regarding stated preference, the contingent valuation technique (Bishop & Heberlein, 1990) was applied as a hypothetical indicator of behavioural action exhibited by the stakeholders on the demand-side, notwithstanding the challenges and controversies that surround its application (Carson, Flores, & Meade, 2001). However, to improve its validity, a premium card method was used in place of a dichotomous procedure (Breidert et al., 2006). In addition, other non-hypothetical techniques were used, such as an experimental auction based on the Becker-Degroot-Marschak (BDM) auction, to ascertain the resultant willingness-to-pay values exhibited by stakeholders when the iodine biofortified food was presented to them (Breidert et al., 2006; Elbakidze & Nayga, 2015; Reutterer & Breidert, 2007). These economic valuation techniques were used in addition to the other indices of resultant behaviour towards adoption of biofortification in endemic areas.

Despite the existence of these procedures, there are very few studies that have integrated them with health behaviour models to evaluate either the intention to behave or resultant behaviour as a WTP toward biofortified food. In principle, there are no studies that have utilised the linkage between behavioural change models and economic valuation to determine the resultant behaviour of consumers and producers within a biofortified food supply chain. Therefore, the resultant conceptual framework involved integration and validation of the protection motivations theory model, targeted at stakeholders on the demand side, technology acceptance modelling, targeted at stakeholders from the supply side, and an economic valuation system, to predict the resultant behavioural action of the stakeholders. This is a crucial combination that provides a snapshot exploration of stakeholders across the biofortified food supply chain, before launching products, processes, innovations or strategies geared towards improving health and wellbeing.

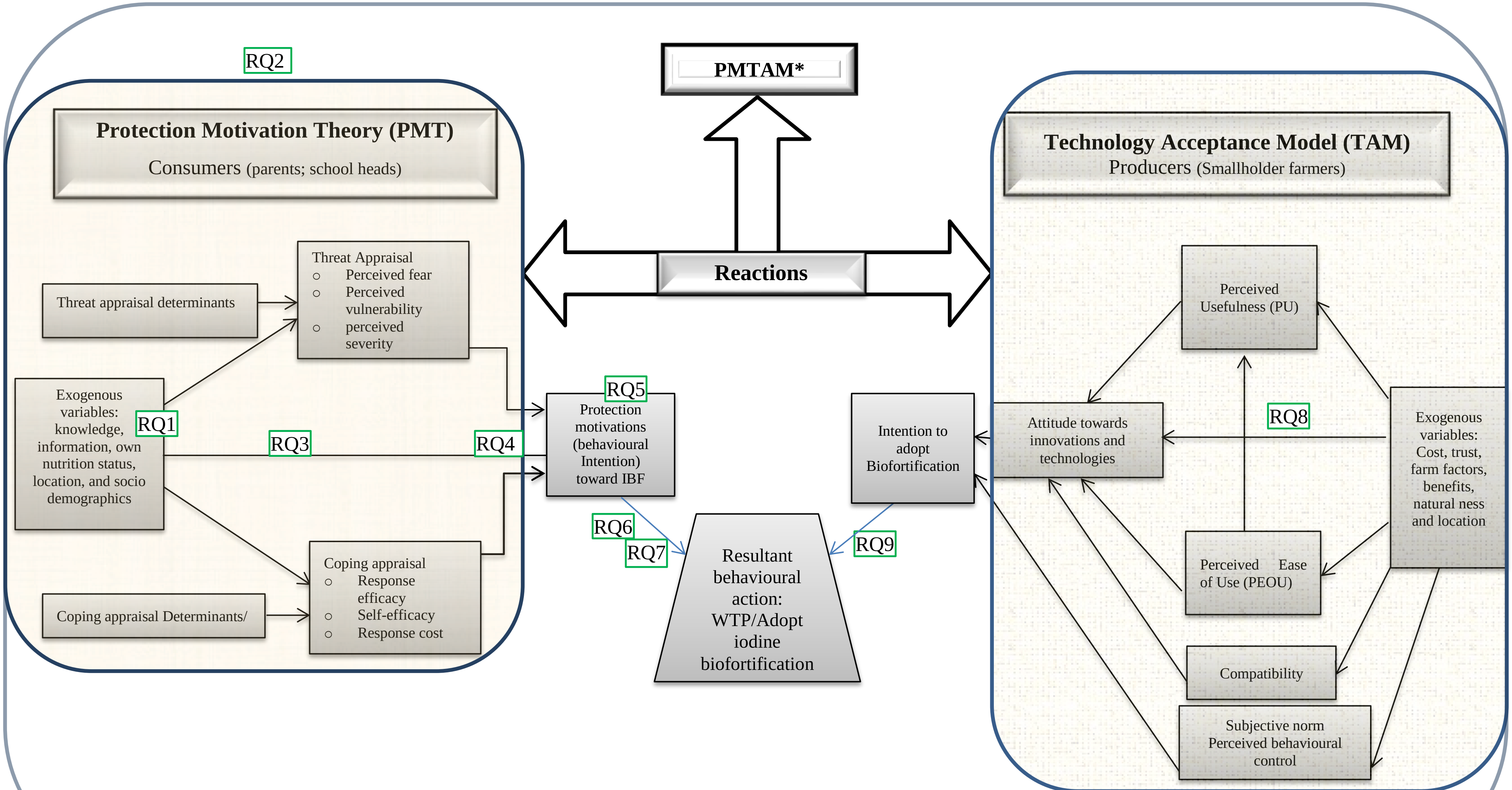


Figure 1: Conceptual framework (PMTAM Model), integrating PMT, TAM model and Economic valuation

Notes:-IBF: Iodine Biofortified Food; PMT: Protection Motivation Theory; TAM: Technology Acceptance Model; Developed and validation of this conceptual framework was established from own compilation based on Mogendi et al. ***(2015b)***.

1.4 Research objectives and questions

1.4.1 Main objective

The major objective of this thesis is '*to explore the stakeholders' reactions toward biofortified food'*. In this regard, the case of iodine biofortification is used to examine two categories of stakeholders, including stakeholders from the demand-side (consumers) and those from the supply-side (producers). Therefore, stakeholders living in select locations of East Africa, where iodine deficiency is endemic, are analysed to understand *what are the overall stakeholders' reactions towards biofortified food, in particular iodine biofortified food*.

To address this objective, two groups of specific objectives are differentiated: 1) 'conceptual' specific objectives; and 2) 'methodological and empirical' specific objectives. According to our definition, 'conceptual' specific objectives are those aimed at building the model for analysing and presenting the empirical objectives. They mainly require the application of existing literature and secondary data to address them. However, 'Methodological and empirical' specific objectives require the application of primary data and a standardized research design to address them. Based on the literature and a comprehensive review, two process-specific objectives and three empirical objectives have been identified, leading to a total of 9 research questions and consequently the chapters (2-6) presented in this thesis to address the main objective.

1.4.2 'Conceptual' objectives

To analyse the literature surrounding stakeholders' evaluations of nutritious food [Ch. 2]

Over recent decades, there has been a growing consumer interest in, and demand for, biofortified foods, with particular attention being paid to nutritional composition (Menrad, 2003). Given the plethora of evidence that promotion and maintenance of good health is a function of diet and nutrition (Mollet & Rowland, 2002; WHO, 2003), the modern consumer considers nutritious foods more and more as an important part of health behaviour. Not surprisingly, as well as traditional product attributes (e.g. taste, price and availability), nutritional benefits are becoming more important for purchase decisions (Barreiro-Hurle, Gracia, & De-Magistris, 2010; Harrington, 1994), with consumers often willing to compromise on many of these aspects for health (Bogue, Coleman, & Sorenson, 2005; Hossain & Onyango, 2004; Verbeke, 2005, 2006).

This growing interest in foods with nutritional benefits means that consumers now view their "kitchen cabinet as the medicine cabinet" (Hardy, 2000). It is this phenomenon of "self-care" that forms the rationale behind the growth in the nutritious food market (Hasler, 2002; Joana Gil-Chávez et al., 2013; Siro, Kapolna, Kapolna, & Lugasi, 2008; Urala & Lähteenmäki, 2003). In consumer science, acceptance of foods with nutritional benefits measures whether a consumer is favourable towards them and is considered a key explanatory factor in demand and consumption (Verbeke, 2005). This therefore begs the question, *what influences consumers' evaluation of food with nutritional benefits **(RQ1)**, **f**or example iodine biofortified food.*

To build and test a conceptual framework for analysing stakeholders, both on the demand-side and supply-side, in a biofortified food supply chain. [Ch. 3]

Traditionally, the food supply chain, including its generic stages from agricultural production to consumption, is continuously faced with a wide variety of product and process innovations which are a function of resources, competition, actors and regulations (Smith & Martindale, 2010; Yakovleva et al., 2004). Despite these growth opportunities, the rural poor, who depend on agriculture, face health, technical and socio-economic challenges which affect their production, consumption and wellbeing (Marsden et al., 2002). Therefore, innovations should also lead to food chains that are targeted at the poor in order to remain sustainable and competitive, while protecting the environment and improving consumer health and wellbeing in a dynamic world (Asenso-Okyere et al., 2009).

However, product and process-related innovations and technologies in food do not occur in a vacuum and their adoption, whether or not they are successful, is stakeholder driven (Feder & Umali, 1993; Smith & Martindale, 2010; Sunding & Zilberman, 2001; Yakovleva et al., 2004). In addition, a distinction is often made between stakeholders on the demand side, such as households and school feeding programmes, and the supply side, including smallholder farmers and retailers. Although there is a surfeit of literature on behavioural models, such as protection motivation theory, which has been shown to explain reactions towards a particular inherent condition, the technology acceptance model has been shown to explain the uptake of a technology or innovation as well as the economic valuation techniques, that quantify the economic value people attach to the resultant good or service. Until now, there has been only a limited attempt to build a framework that brings together these elements to analyse stakeholders across biofortified food supply chains. Therefore, to support this objective there is a need to explore and answer the question: *Is a conceptual framework that integrates protection motivations and technology acceptance modelling, as well as economic valuation techniques, valid to explain stakeholders' reactions toward biofortified food?**(RQ2).***

This integration should provide three dimensions: 1) a dimension that examines the behaviour of stakeholders on the demand-side (consumers: households and schools) towards biofortified food i.e. Iodine biofortified food; 2) a dimension that quantifies the economic value they attach to either the product (biofortified food) or the technology/innovation/strategy (biofortification); and 3) a dimension that investigates the behaviour of stakeholders on the supply-side (producer: farmers) towards adoption of an agricultural technology or innovation i.e. iodine biofortification

To support the above dimensions from the model, three 'empirical' specific objectives are identified.

1.4.3 'Methodological and empirical' objectives

To apply the conceptual framework in analysing stakeholders' reactions toward iodine biofortified food. [Ch. 4]

Iodine deficiency, a well-known cause of preventable mental retardation, is still a major public health problem worldwide, e.g. 240.9 million school-aged children are affected, of which 24% originate from Sub-Saharan Africa (M. Andersson, Karumbunathan, & Zimmermann, 2012). Given the profound effect of iodine deficiency on school performance (Pineda-Lucatero, Avila-Jimenez, Ramos-Hernandez, Magos, & Martinez, 2008; Qian et al., 2005) and the lack of iodine-rich foods in East-African School Feeding Programs (Murphy, Gewa, Grillenberger, Bwibo, & Neumann, 2007), there is a need for novel strategies to improve iodine intake levels. Although Universal Salt Iodization and supplementation has successfully reduced Iodine Deficiency Disorders (IDDs) in many countries, albeit more in developed than developing countries, a third of the world population is still at risk, particularly in rural landlocked areas of developing regions where IDDs are still endemic (M. B. Zimmermann & Andersson, 2012). Therefore, biofortification of staple crops with iodine is a potential strategy to address this gap, as is the case with other micronutrients, such as folate and vitamin A (Bouis et al., 2011; H. De Steur, Gellynck, Blancquaert, et al., 2012; Lyons et al., 2004; J. V. Meenakshi et al., 2010).

Nonetheless, consumers are likely to make different decisions about the acceptance and adoption of iodine biofortified foods, once introduced to the market. Such food choices are a function of many factors which are the focus of our systematic review on conceptual objectives (1.3.2 above) as well as the EUFIC review on determinants of food with nutritional benefits (EUFIC, 2005).This highlights the influence of both personal factors, such as the level of health consciousness, the ability to overcome healthy eating barriers, nutrition knowledge, previous experience with similar foods, attitudes towards novel foods (technologies), and their perceived (adverse) health effects, religious and cultural beliefs, as well as external factors, such as the way in which these products are marketed (Mai & Hoffmann, 2012; Pounis et al., 2011; Verbeke et al., 2009).

The introduction of iodine biofortification as a novel strategy to prevent IDDs will most likely involve a cognitive process leading to a motivated decision made by consumers. Therefore, Health Behaviour Models such as the Health Belief Model (HBM), the Theory of Planned Behaviour (TPB), the Social Cognitive Theory (SCT) and the Trans-theoretical Model of Change (TTM) are often used to explain people's motivational factors to perform, or not perform, health-oriented behaviours (Baban & Craciun, 2007). However, since these models mainly focus on threats, and often only partially incorporate efficacy factors, the conceptual framework developed ('process' objective 1.3.2 above), which is based on Protection Motivation Theory (PMT) (Ronald W. Rogers, 1975) is a potential candidate and appropriate tool to answer the question *what are the stakeholders' reactions towards iodine biofortified food* ***(RQ3).***

Furthermore, it also investigates coping factors as crucial persuasive communication elements for maintaining or initiating health behaviours (Milne et al., 2000), as well as helping to increase the generally low explained variance. Nevertheless, a few studies have employed PMT, specifically to analyse consumer motivations to dietary change, i.e. functional foods (David N. Cox & Bastiaans, 2007; S. Henson et al., 2008), even though none have been applied to biofortified foods, or in the context of a resource-poor, developing country such as the target regions.

To apply the model in examining the willingness-to-pay a premium or discount, for iodine biofortified food and the concomitant determinants [Ch. 5]

There is a strong link between protection motivations (intention) and resultant protection behaviour (preference as defined by willingness-to-pay) with regard to health interventions, i.e. iodine biofortification (Park, Hoover, Dodd, Huffman, & Feng, 2011; Prentice-Dunn & Rogers, 1986; R. W. Rogers, 1983). Therefore, it is crucial to understand elements that should form part of health and nutritional promotion programmes for prevention of micronutrient deficiencies e.g. iodine deficiency and its subsequent impact on school performance. Although the previous objective sought an understanding of the overall reactions of consumers, there is a need to highlight not only the general consumer reactions, but also to explore *what elements predict protection behaviour (intention) and resultant protection behaviour regarding the purchase and consumption of iodine biofortified food in endemic areas?**(RQ4)*** when offered in the market.

However, this often revolves around evaluating the effect of endogenous and exogenous variables to the PMT model that influence protection behaviour or preference for adopting biofortified foods. When products are offered in the market, consumers often react by being willing to pay a premium or a discount to obtain the product. It is therefore crucial to understand *what factors influence consumers' willingness to pay a premium or discount for iodine biofortified food* ***(RQ5).*** This is important, particularly in the design of iodine intervention programs using real market products.

To conduct experimental auctions to determine willingness-to-pay for iodine biofortified food, under different conditions prevailing in the market and using the most effective and accurate procedures.[Ch. 6]

Preference, in the form of WTP, for micronutrient rich food is increasingly used, in many parts of the world, as a means of ascertaining the value consumers attach to foods that improve their health and wellbeing, such as biofortified food. Nevertheless, accurate determination of willingness-to-pay (WTP) is crucial in understanding demand for new food products and services, as well as for designing food policies and interventions, often because the demand estimates for computing cost benefits, pricing and profits are not readily available (Maria Lus Loureiro & McCluskey, 2000; Mørkbak, Christensen, & Gyrd-Hansen, 2011; Voelckner, 2006).

Therefore, different procedures have been developed and applied that specifically elicit acceptance (De Groote et al., 2014) and WTP for food - both stated (e.g. contingent valuation methods) and revealed WTP (e.g. hedonic pricing) (Breidert et al., 2006; De Groote & Kimenju, 2008; Marette, Messéan, & Millet, 2012; K. M. Miller, Hofstetter, Krohmer, & Zhang, 2011; Xu, Zeng, Fong, Lone, & Liu, 2012; Zhang, Bai, & Wahl, 2012). Experimental auctions are increasingly considered as an appropriate tool for eliciting consumers' WTP for food and services (De Groote & Kimenju, 2008; Hellyer, Fraser, & Haddock-Fraser, 2012; Marette et al., 2012; Poole, Martı´nez, & Giménez, 2007). The Becker-Degroot-Marschak (BDM) auction (Becker, DeGroot, & Marschak, 1964), is a specific type of auction, as it is the only one measuring WTP on an individual basis (Breidert et al., 2006). Since its inception, it has been widely used in experimental economics to measure WTP (Breidert et al., 2006; K. M. Miller et al., 2011; Noussair, Robin, & Ruffieux, 2004), especially in a developing context (De Groote, Kimenju, & Morawetz, 2011), notwithstanding several improvements and variations (Berry, Fischer, & Guiteras, 2011; Keller, Segal, & Wang, 1993).

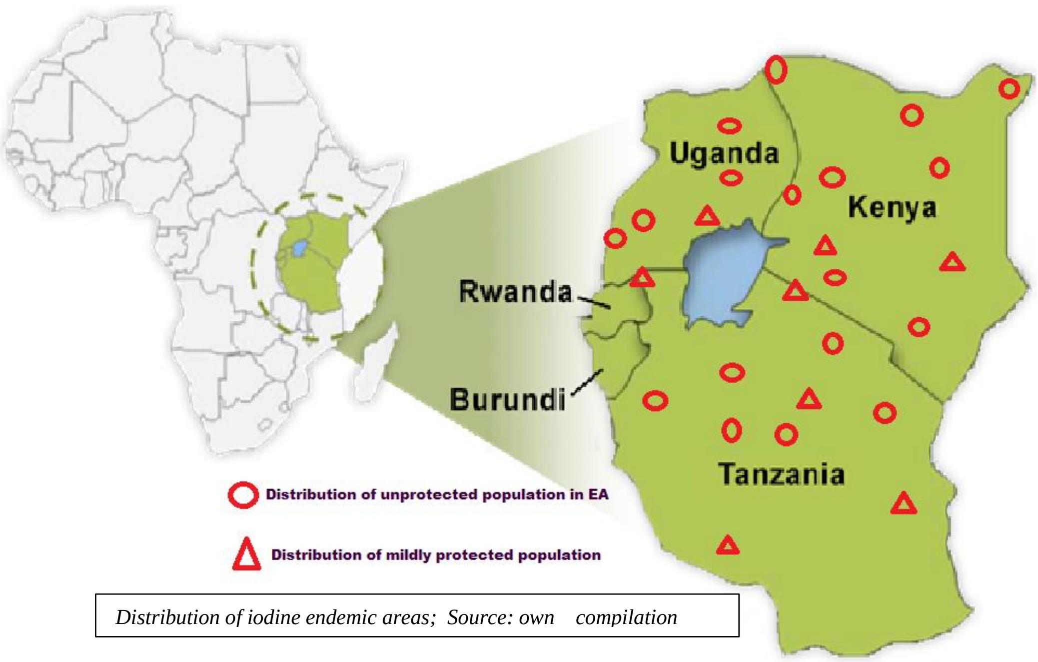
This procedure is an example of an incentive-compatible method, whereby participants submit a bid for an auctioned item and then a market price is randomly determined by drawing from a uniform distribution of prices (Jayson L Lusk, Feldkamp, & Schroeder, 2004). The participants are obliged to purchase the item if their bid is equal to, or above, that market price, although they are only required to pay the market price for the item (Berry et al., 2011; Kaas & Ruprecht, 2006).

Despite the validity of the BDM procedure, this procedure requires the physical presence of the interviewer, as well as contact with the participants, during the whole auction, which could reduce the sample size and involve time constraints (Berry et al., 2011; Keller et al., 1993; Noussair et al., 2004). Therefore, it is important to determine '*what is the validity of using the short messaging service (SMS) as a bidding procedure for eliciting WTP through BDM auction?'* ***(RQ6).*** SMS, commonly referred to as 'text messaging', is a protocol developed for sending short messages via the Web, Phone or Mobile network (Gayomali, 2012; Trosby, Holley, Harris, & Hillebrand, 2010). The SMS is one of the innovative approaches that has been absorbed into behavioural research (Lin & Rivera-Sánchez, 2012; Reimers & Stewart, 2009) and its use has increased in various fields, especially in economic and consumer research (Cheung, 2008; Kew, 2010; Lin & Rivera-Sánchez, 2012; Reimers & Stewart, 2009). When different conditions prevail in the market, consumer uptake of products and services varies from one product to another and is based on a number of other market forces. Equally, when consumers are confronted with the health product (biofortified food), the health threat (IDD), a product improvement protocol (GM and conventional) and information about their nutrient intake (iodine intake), their preference (WTP) is volatile. Therefore, when these conditions prevail, it is important to examine *what is the resultant preference (WTP) for iodine biofortified food* (***RQ7),*** particularly among the most vulnerable groups.

To apply the adjusted framework to investigate the farmers' (producers') willingness, ability and frequency of adopting iodine biofortification at the farm level [Ch.7]

Although the adoption of innovation and technologies in the food supply chain is stakeholder-driven (H. De Steur et al., 2015; Doss, 2006; Feder & Umali, 1993), research on the adoption of biofortification and biofortified products has largely, if not always, been conducted on the consumers, even in the case of iodine biofortification (H. De Steur et al., 2015). Therefore, there is a need to understand: *what is the reaction and overall trend in the adoption of iodine biofortification by smallholder farmers* ***(RQ8)***, with regard to the adoption of biofortification, even though the benefits accrued from biofortification are largely perceived to be inclined towards consumers. This misconception underlies the potential of biofortification as an avenue for creating new niche markets to benefit, not only the consumers, but also smallholder farmers and their households, by expanding the market for their produce based on willingness-to-pay and the ability to adopt biofortified food.

In the current study, we employed a uniquely adjusted conceptual framework for analysing stakeholders' uptake of biofortified food (J. Mogendi et al., 2016), to explore the adoption of iodine biofortification, among smallholder farmers in areas drawn from three East African countries where iodine deficiency is endemic. The framework integrates the technology acceptance modelling and economic valuation technique to determine *what would be the willingness and frequency of adopting iodine biofortification among smallholder farmers in endemic areas* ***(RQ9)***. An attempt is also made to explore decisive determinants of farmers' adoption of iodine biofortification.



Distribution of iodine endemic areas; Source: own compilation

1.5 Research design and data sources

To investigate the research questions raised, this thesis employed both primary and secondary sources of data, as well as exploratory and conclusive statistical techniques, on the analysis front, as the backbone to the doctoral research design. As demonstrated in the next section (see thesis outline, Figure 3) this thesis brings together different research papers and chapters, which stem from different designs, data collection and analytical procedures. Therefore, a 'mixed-method research design' is appropriate to describe the combination of both qualitative and quantitative approaches employed throughout the individual studies which constitute this thesis study. This dimension is appropriate, considering the main objective of this thesis.

In figure 2, an overview is presented of the different components of the research design applied in this thesis. The figure outlines the interconnectivity between primary and secondary data, as well as collection methods, for the exploratory and conclusive procedures for analysis. Nevertheless, more details about specific research designs are presented in each of the chapters, or in addressing each of the research questions and subsequent results. Consequently, we also highlight the key methods applied in this thesis, as discussed in each distinct study.

However, a distinction is made between the methodological design and the empirical design. First, we employ a methodological design, where secondary data from key studies is used to investigate the consumer acceptance of foods with nutritional benefits. In this case, we aim not only to conceptualize the acceptance of biofortified foods but also, to examine the key determinants of consumer acceptance of nutritious food. To achieve this, a protocol for systematic reviews (Higgins & Green, 2005) was used to comprehensively review the existing literature from primary studies focusing on the acceptance of food based on its nutritional benefits. A total of 38 studies were systematically selected and narrative syntheses built around the determinants of acceptance and their most probable conceptual application (chapter 2).

Second, both the methodological and empirical designs were employed to develop and test a conceptual framework for analysing stakeholders with consumption and production orientation. In this regard, two behavioural models, integrated with an economic technique, were applied to secondary data sources, while primary data was used to test the resultant model through empirical data analysis. A total of n=1080 stakeholders, parents and school heads, were recruited and responses collected using a semi-structured interview. Structural equation modelling was employed as a conclusive procedure to examine the appropriateness of the resultant conceptual framework (chapter 3).

Third, Part of the data (n=360) collected in the second stage above, was then applied to analyse the overall stakeholders' reactions towards iodine biofortified food (chapter4). This chapter applies the primary data collected, together with exploratory and conclusive statistics to analyse the stakeholders.

Fourth, the willingness-to-pay a premium or a discount was investigated among the consumers (parents and school heads) for school-aged children who are more susceptible to IDD. The study used the complete dataset (n=1080) from the previous section (section 2). The factors that influence the willingness-to-pay a premium or a discount were modelled to determine the most appropriate control elements for iodine biofortification programs (chapter 5).

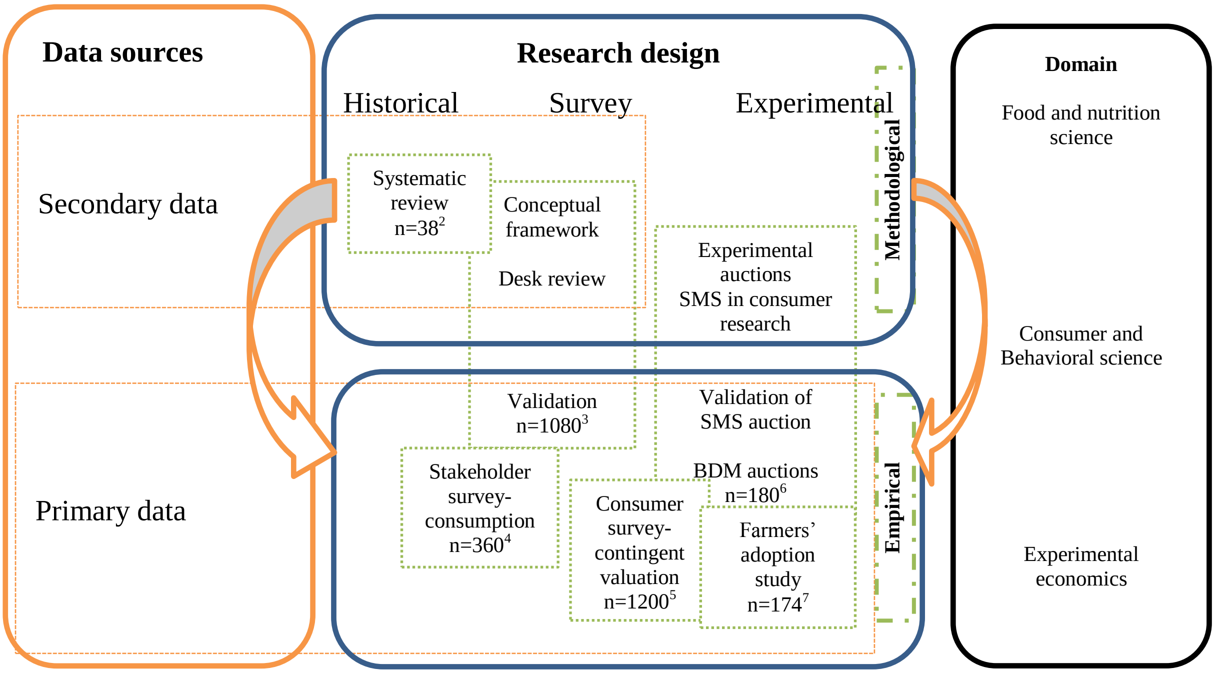


Figure 2: Research design and sources of data

Five, an experimental auction study was conducted, using a longitudinal approach, based on the BDM system. A sample of 180 participants from open-air markets, in 3 different locations in East Africa, was carefully recruited to participate in this study. Both original BDM bidding and integrated SMS-Based BDM bidding was employed to collect data on willingness-to-pay for different levels of treatment, as well as factors such as socio-demographics, trust, attitude, and the market characteristics of the iodine biofortified vegetable legumes. An attempt was also made to validate the use of the short service messaging (SMS) in auction studies.

Evidence from this study revealed that SMS-Based BDM has a high validity and could be consistently used, integrated with other auction studies or separately, to yield accurate results in the most convenient, attractive, quick, cheap and reliable way, which is in line with novel ways of purchasing food. The results also provide insights into the impact of different treatments on willingness-to-pay for iodine biofortified food. Sixth, this section applied the empirical design. By employing the second portion of the conceptual framework (chapter 3), which contains constructs for analysing producers, a cross-sectional survey was conducted. The survey involved face-to-face interviews with 174 smallholder farmers (SHF) recruited from areas in East Africa where iodine deficiency is endemic, representing 58 SHF from each country. Data was collected using a semi-structured interview and analysed through both exploratory and conclusive statistical procedures.

The key data sources included in the study are presented in the figure as superscript numbers next to the sample size. These represent the chapter in which the data source was used. In this case, data sources include: chapter 2, primary studies in consumer evaluations of food; chapter 3, case study to test the model with parents data; chapter 4, consumers household and school; chapter 5, contingent valuation with consumers, households and school heads; chapter 6 experimental auction with consumers in open air markets in EA; and chapter 7, adoption study with smallholder farmers in select location of EA

1.6 Outline of thesis

The chapters of this doctoral thesis explain very distinct aspects of the PhD research and are presented in a unique structure (Figure 1, ch.1) based on papers that have been published (chapter 2,4), accepted (chapter 5) or submitted (chapter 3, 6, 7) as contributions to international peer-reviewed journals (A1). The overall research covers various scientific disciplines including agriculture, behavioural modelling, consumer behaviour, food marketing, food and nutrition sciences, and public health.

This thesis is divided into 8 chapters (chapter1-8), constituting 5 parts in total (Part I-V), as depicted in figure 3. The first and last chapters (chapter 1 and chapter 8), cover the general introduction and conclusions of this thesis. However, the other 6 chapters are based on empirical research and reviews. First, chapter 2 gives a systematic review of consumer acceptance of food with additional nutritional benefits. This is necessary to build an appropriate conceptual framework for analysing stakeholders' reactions. The review highlights four groups of determinants: (1) nutrition knowledge and information; (2) attitudes, beliefs, perceptions and consumer behaviour; (3) price, process and product characteristics; and (4) socio-demographics, which have a significant impact on consumers' acceptance of biofortified food. Meanwhile, the chapter also tries to conceptualize "consumer acceptance" through insights into its operationalization.

Second, chapter 3 focuses on combining behavioural change models and economic valuation techniques to build a conceptual framework for analysing stakeholders in the biofortified food supply chain. Two behavioural models: the protection motivation theory model and the technology acceptance model are integrated with an economic valuation technique, such as contingent valuation (CV) and an experimental auction procedure, resulting in a conceptual framework for use in analysing the uptake of novel strategies across a biofortified food supply chain. The literature from the systematic review, as well as the literature on the two models and economic valuation, has been instrumental in shaping this chapter.

Third, Chapters 4, 5 and 6 apply the framework developed (chapter 2); to analyse the consumers from three locations in East Africa where iodine deficiency is endemic. Chapter 4 analyses the overall stakeholders' reactions and underlying factors in relation to the consumption of iodine biofortified food; while chapter 5 applies the framework to analyse the determinants of willingness-to-pay a premium or discount, for iodine biofortified food using the stated preference method. However, chapter six applies the model to examine the overall willingness-to-pay for these products through an experimental auction. In chapter six, an attempt is also made to improve the conduct of experimental auctions by validating the use of a technology-based system (Short Messaging Service) for elicitation of WTP.

Fourth, chapter 7 applies the model to the producers in the same region. The chapter analyses farmers' willingness to adopt iodine biofortification as an agricultural innovation to increase the nutritional value of the crop, with regard to iodine. Although this is often considered a consumer benefit, an understanding of consumers' willingness-to-pay a premium creates an avenue for farmers to tap into a new demand market.

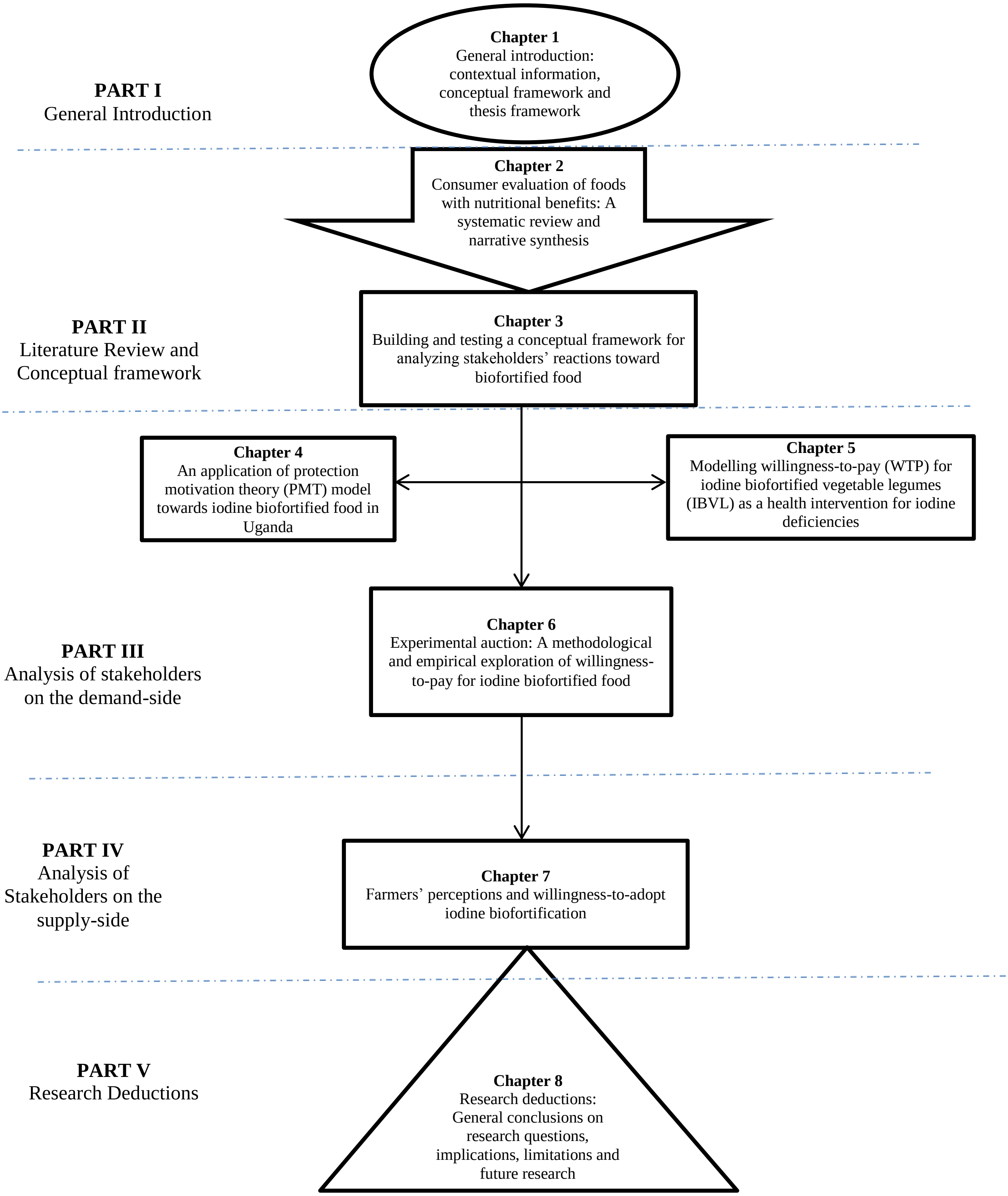


Figure 3 Thesis outline

PART II LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

This chapter part established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition*. Volume 55, Issue 2 pp. 182-208.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis. *International Journal of Food Sciences and Nutrition.* Volume 67, Issue 4 pp. 355-371.

Chapter 2 Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis

This chapter is established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis. *International Journal of Food Sciences and Nutrition*. Volume 67, Issue 4 pp. 355-371.

Abstract

As a consequence of the growing interest in, and development of, various types of food with nutritional benefits, the modern consumer views their kitchen cabinet more and more as a medicine cabinet. Given that consumer evaluation of food is considered key to the successful production, marketing and finally consumption of food, a procedure commonly used in medical fields was employed to systematically review and summarize evidence of consumer evaluation studies on nutritious foods. The focus is primarily on consumer understanding of nutritious food and the underlying determinants of consumer evaluation.

Our results highlight four groups of key determinants: (1) nutrition knowledge and information; (2) attitudes, beliefs, perceptions and behavioural determinants; (3) price, process and product characteristics; and (4) socio-demographics. The findings also point to the importance of understanding consumer acceptance as one of many concepts in the consumer evaluation process, and provide support for developing appropriate strategies for improving health and wellbeing of consumers.

2.1 Introduction

Over recent decades, there has been a growing consumer interest in, and demand for, healthy foods, with a particular focus on nutritional composition (Magkos, Arvaniti, & Zampelas, 2003; Menrad, 2003). Given the plethora of evidence that promotion and maintenance of good health is a function of diet and nutrition (Mollet & Rowland, 2002; WHO, 2003), the modern consumer considers nutritious foods more and more as an important part of health behaviour. Not surprisingly, alongside traditional product attributes (e.g. taste, price and availability), nutritional benefits are becoming more important for purchase decisions (Harrington, 1994), with consumers often willing to compromise many of these aspects for health (Bogue et al., 2005; Bourn & Prescott, 2002; Hossain & Onyango, 2004; Verbeke, 2005, 2006).

This growing interest in foods with nutritional benefits means that consumers now view their "kitchen cabinet as the medicine cabinet" (Hardy, 2000). It is this phenomenon of "self-care" that forms the rationale behind the growth of the nutritious food market (Hasler, 2002; Joana Gil-Chávez et al., 2013; Siro et al., 2008; Urala & Lähteenmäki, 2003).

Consumer evaluation of food entails a heterogeneous group of concepts, including willingness to pay, purchase intention, sensory liking, attitude, perceptions or acceptance. Even though these concepts contribute to the overall determination of consumer evaluation of products and services, they are often diverse in many fronts, chiefly their definitions and measurement. For instance, acceptance measures whether a consumer is favourable towards a product, while willingness-to-pay reflects the economic value a consumer attaches to a product.

This paper conducts a systematic review of empirical studies on consumer evaluation of different categories of nutritious foods. Thereby, specific attention is given to the determinants of different consumer evaluation studies. Although there have been attempts to review evidence on specific subcategories of nutritious foods (Cowburn & Stockley, 2005; Hasler, 2002; Siro et al., 2008), this is the first review that provides a systematic review at this level.

Broadly, foods with nutritional benefits are presented in a variety of categories and terminologies, such as functional, fortified, nutrient rich/enriched, biofortified, genetically modified (GM) biofortified or second generation GM foods, or nutraceuticals (Hasler, 2002). This may cause confusion among researchers when not clearly explained and communicated. Because nutritional benefits are not always clearly distinguished from other health benefits (Urala & Lähteenmäki, 2003), we aim to provide insights in the typology of the examined nutritious foods.

Furthermore, the use, conceptualization and operationalization of specific consumer evaluation studies (e.g. acceptance studies) are often lacking uniformity, which also may lead to confusion. As different consumer evaluation, like willingness-to-pay and acceptance, are sometimes used interchangeably, even though they clearly measure a different aspect of consumer evaluation, this review also aims to provide insights in this diversity of consumer evaluation studies, thereby making reference to the actual concepts that were measured in the studies.

As such, our focus on looking at the broad umbrella of consumer evaluation and its subcategories is in line with other types of categorization, like the study of Frewer et al. 2013 on consumer research on GM food. The following sections of this review outline the methodology applied to select and review the primary studies, followed by a clear presentation of the results through a narrative synthesis. The final section summarizes the results and provides a discussion together with key limitations and future research directions.

2.2 Methodology

2.2.1 Search strategy and selection of primary studies

A systematic review of published evidence on consumer evaluation studies of foods with nutritional benefits was undertaken based on guidelines for systematic reviews by Higgins and Green (2005) and Popay et al (2006). A protocol statement was developed and validated with peers and experts in systematic reviews. To ensure that the review builds upon a sound methodology and appropriate syntax, two external nutrition and consumer research experts were consulted to provide more insights on the protocol development, search terms and search syntax to apply.

A generic search strategy, comprising agreed search terms, was then used to comprehensively search electronic and manual databases for target consumer studies. Key terms that describe consumer evaluation as well as other elements under consideration were clearly identified and used to build a search syntax which was then agreed upon by the researchers and adopted for retrieving the primary studies.

For instance, the combination of the syntax adapted to search studies from web of science data base, which was also applied in other data bases, had, but not limited to, the following combination of search terms: *("willingness to pay" or "willingness to accept" or "consumer valuation" or "perception" or "sensory evaluation" or "consumer behaviour" or "consumer preference" or "consumer attitude" or "acceptance" or "purchase intention" or "consumer trade-offs" or "consumer evaluation") and TITLE-ABSTR-KEY ("food" or "Nutritious food" or "nutritional food" "nutraceutical" or "GM food" or "genetically modified food" or "gmo" or "non-gm food" or "conventional food") AND LIMIT-TO(content type, "1,2","Journal") AND LIMIT-TO (topics, "functional food, food acceptance, genetically modified, food, consumer acceptance, consumer attitude, food product, novel food, consumer, organic food, new food, purchase intention").*

The primary consumer studies were obtained by adjusting the search syntax for each of the following databases: EBSCO, EconLit, Agricola, AgEcon, Greenfile, compendex, and Web of Science. The search was extended to the Google scholar platform and the National Agricultural Library Digital Repository (NALDR). Studies in languages other than English, French or Spanish, studies focusing on other benefits, and other non-food products, as well as those focusing on farmers' benefits, were excluded.

2.2.2 Screening of primary studies

All retrieved studies were managed using Endnote X5, pooled into one database and evaluated against the inclusion and exclusion criteria by two independent researchers. Studies for which there was no consensus were discussed by the two researchers working together which is equivalent to a third independent researcher. Figure 4 outlines the five screening steps included in this review:

First, screening to weed out any double records as identified; Second, screening on the topic to exclude all the records not related to the focus area; Third, screening of title and abstract to retain only articles focusing on consumer evaluation of food for full article screening; Fourth, searching and full-text article screening to exclude all articles not measuring consumer evaluation, in its totality, as defined by different concepts. Explanation and agreement between researchers for eliminating full articles not meeting the criteria was mandatory. Finally, screening to remove low quality and biased studies was carried out using the quality assessment instrument developed for this review (Table 1). All articles that meet the screening and quality criteria in the preceding stages were retained and used in the current review.

The final database obtained represents record of primary studies of substantial quality that focused on the consumer evaluation of food with nutritional benefits and acceptance in particular. Relevant data and components responding to the objective of the current review were then extracted and tabulated. Because the concept of consumer evaluation of food is considered heterogeneous, measured through a variety of methods, reflecting different outcomes, a meta-analysis was not feasible for the current review and we used a narrative synthesis procedure provided for and supported in the Cochrane and ESRC guidelines (Higgins & Green, 2005; Popay et al., 2006)

2.2.3 Quality appraisal and data extraction

Unlike most systematic reviews undertaken in consumer research on food products (Dannenberg, 2009; de Beer, 2012; J. L. Lusk, Jamal, Kurlander, Roucan, & Taulman, 2005), quality appraisal was incorporated to evaluate the selected studies, in line with the common procedure for systematic reviews in the medical and epidemiological research domains. Following the Cochrane and ESRC guidelines, as well as existing instruments for quality appraisal (Higgins & Green, 2005; Popay et al., 2006; Sverige, 2006), a quality and bias assessment tool was developed that addresses the internal, external and statistical validity of the data based on 6 parameters (Table 1). All parameters are measured on a scale from 1 (low quality) to 4 (high quality) and the average score was computed for each of the articles, except the impact factor ranking.

Internal validity is defined by the quality of the research design; external validity refers to the outcome measures, while statistical validity focuses on sampling criteria and statistical analyses/estimates. Another quality parameter is added, namely the Thompson Reuters impact factor of the journal. Although it is important to consider this quality indicator of the journal of primary studies when conducting systematic reviews, no papers were excluded on the basis of impact factor. This is because its measurement is based on number of citations and, therefore, is not always a reliable indicator of the quality of the article. After screening the quality of selected studies, a final database was constructed. For each selected study, key data was extracted and tabulated in line with the objective of this review.

Table 1 Quality appraisal tool

Quality Parameter	Description of principle question
Sampling characteristics	Is the population well defined and is the sample representative?
Data collection procedure	Is the data collection procedure well conducted? Are the key variables well operationalized?
Measurement method	What are the measurement methods used and are they well rooted in consumer studies
Sensitivity analyses and validity tests	Is the use of the statistical techniques valid and what is the statistical uncertainty of the estimated values reported in terms of confidence intervals and standard deviations or p-values? Are the results (correctly) put into perspective?
Risk of biases	Does the study address any potential sources of bias (blinding, randomization, intention to treat)?
Journal impact Factor	Is the journal in which the primary study has been published well established? What is the impact factor of the journal?

Source: Own compilation, adapted from the Cochrane handbook (2005) (Higgins & Green, 2005), and Sverige, N (2006)(Sverige, 2006)

2.3 Results and narrative synthesis

2.3.1 Description of included studies

Figure 4 presents the flow diagram of the selection process (literature search, screening and quality appraisal). The initial literature search resulted in 13,948 potential studies from different databases, which included Web of Science/PubMed (8,157), Econlit (3, 892), Greenfile (153), Eric (81), Agricola (42), and other databases (Google Scholar, Business Source database and NADLR) (815). Conference articles derived from these databases were inserted separately (808). After the removal of duplicates, 12,097 articles were retained. Both title and abstract were then analysed, resulting in the selection of 758 articles. Full article screening identified 106 articles that met the inclusion criteria outlined in the protocol. Out of these, 62 articles did not meet the next level of inclusion criteria, leaving 44 articles for quality assessment.

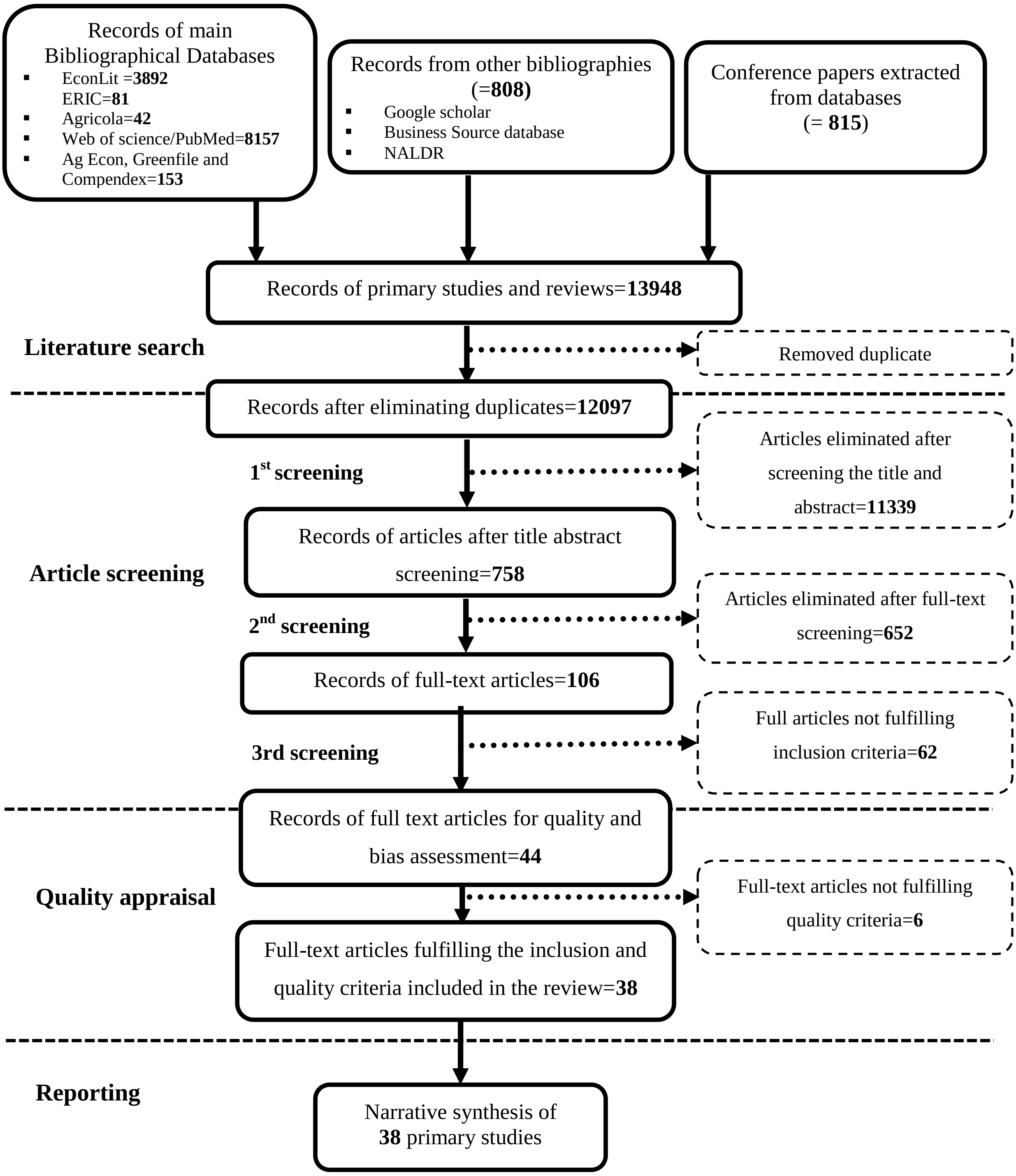
Applications of the quality assessment tool to the 44 articles resulted in 38 articles that were considered to have sufficient levels of internal, external and statistical validity and, thus, were appropriate for analysis. An average based on the six parameters (except for the impact factor of the journal) was computed and only articles with a score below 2 (14%) were excluded. These articles were characterized by low quality, high risk of biases, and/or methodological flaws. This means that 86% of all articles subjected to quality appraisal obtained an adequate quality score, of which 43% had a score of 4 and the other 43 had a score above 2.

In the first instance, we provide an overview of the key characteristics and components of the included studies. The majority used a standardized survey as the main data collection method: 11 studies administered their surveys face to face, 20 studies were based on self-administered questionnaires and 15 studies used telephone or computer-aided questionnaires. Fifteen studies integrated a survey into their main data collection method, such as economic evaluation methods (experimental auctions, conjoint analysis and choice experiments), sensory evaluation, or repertory grid methods. The variety of methods used to analyse consumer evaluation of foods with nutritional benefits underlines the heterogeneity of the (measurement of this) concept. When looking at the research locations, most studies were conducted in Europe (15) and North America (9), including a joint study between both continents (1). Except for Africa (5), the other continents, i.e. South America (3) Asia (3), Australia (2), are less represented in the sample. The majority of these studies still focus on populations in developed countries, calling for increased research efforts in developing regions, where the need for nutritious foods is highest. All studies are targeted at adults in general, or at specific subpopulations, such as women of childbearing age, students, rural populations or urban consumers.

2.3.2 Conceptualization of consumer evaluation

As mentioned before, consumer evaluation is generally defined and described using different concepts. We provide an overview of the different concepts and methods that are applied to describe and measure consumer evaluation, respectively (Table 2). While several authors focus on ‘acceptance’ (9 studies), others use other indicators to describe consumer evaluation, such as ‘attitudes’ (12 studies), ‘beliefs’ (2 studies) and ‘perceptions’ (14 studies), or refer to ‘preferences’ (13 studies), ‘purchase intentions’ (5 studies) and ‘consumption behaviour’ (6 studies). It is important to mention that the term acceptance has not only been used in studies that measure acceptance as such, but also in studies targeting other concepts related to consumer evaluation. This leads to confusion, e.g. WTP studies simultaneously referring to terms acceptance and willingness-to-pay to discuss the latter(Gonzalez, Johnson, & Qaim, 2009). Rather than to further reinforce the misleading use of acceptance as an umbrella concept, researchers should consider consumer evaluation (and not acceptance) as the more general umbrella encompassing concepts such as WTP, purchase intention, attitude, perceptions and acceptance. In other words, one should treat acceptance as one of many concepts measuring consumer evaluation, rather than to use it to describe one of the other concepts.

The differences in the conceptualization of consumer evaluation also lead to variations in their operationalization, ranging from survey questions (in-person, self-administered, telephone and/or computer aided questionnaires) to economic valuations (open or closed-ended questions or bids), or sensory analysis. This variation in defining and operationalizing consumer evaluation, but also its underlying concepts, like willingness-to-pay (economic valuation), could affect the outcomes (N. M. Childs, 1997; Menrad, 2003; Urala & Lähteenmäki, 2003), and may lead to method bias. This makes it difficult to interpret and compare the results of consumer evaluation studies as a whole, but also of studies targeting specific concepts, like acceptance. In other words, at least for our topic of consumer studies on foods with nutritional benefits, there is a need for clarification and consistent use of consumer evaluation concepts, and acceptance in particular.



Notes:-NALDR: National Agricultural Library Digital Repository; ERIC: Education resources information centre

Figure 4 Review flow diagram

An appropriate use of the right typology and terminology would improve understanding in line with previous research on acceptance of traditional foods in the supply chain (Kühne, Vanhonacker, Gellynck, & Verbeke, 2010; Vanhonacker et al., 2013) and avoid confusion for the readers. This is especially important as producers have difficulties to understand acceptance towards novel nutritious foods, given the equivocal distinction between different reactions exhibited by consumers in the market (N. M. Childs, 1997; Siro et al., 2008; Williams, 2005).

Table 2 Description of primary studies included in the review

Study characteristics				Consumer evaluation types		Results: Targeted product, nutrition benefits and outcome parameters		
Study	**Quality Appraisal**	**Location**	**Sample (target Group)**	**Conceptualization**	**Measurement method**	**Food product category**	**Nutrition benefit Macro/micro and Supplementary**	**Outcome determinants**
Szakaly(Szakaly, Szente, Kover, Polereczki, & Szigeti, 2012)	4	Europe-Hungary	N=1000	Acceptance, behavioural segmentation , and consumption pattern	Nationwide questionnaire-based survey	Functional food: Enriched with nutrients	Macro: – Low sugar – Low fat Micro: – Vitamin; – Minerals; Supplementary: – Dietary fibre; – Probiotics	– Lifestyle – Consumption behaviour quality
Lawless(Lawless et al., 2012)	3	North America-Arkansas (US)	N=47 (men)	Acceptance and preference	Survey: Non-hypothetical experimental auction sessions	Nutraceutical: Juice blend	Supplementary: – Anthocyanin	– Sensory: taste – Information
Hellyer(Hellyer et al., 2012)	4	Europe Kent-UK	N=138 (staff and students)	Acceptance and preference for nutrient rich bread	Survey and experimental auction sessions	Functional: Bread.	Macro: – Proteins Micro: – Vitamin and minerals, Supplementary: -Fibre	– Nutrition information
De Steur (H. De Steur, Gellynck, Feng, Rutsaert, & Verbeke, 2012)	4	Asia-China Shanxi Province	N=252 women (student and non-students)	Acceptance and preference of folate biofortified	Survey and experimental Auction sessions	Biofortified: Rice	Micro: – Folate	– Objective knowledge – Socio demographics – Price
Pounis(Pounis et al., 2011)	4	Europe-Greece (South and Central)	N=500	Consumer perception and consumption trend	survey	Fortified: iron fortified	Micro: – Iron	– Knowledge – Sensory – Socio-demographics
Markovina(		Europe-	N=1035	Perception and	Survey: Self-	Functional:	Micro	– Sensory :taste

Markovina, Cacic, Kljusuric, & Kovacic, 2011)	4	Croatia		attitudes	administered questionnaires	Dairy, fruit and vegetables, cereals, tea, olive oil	– Vitamins – minerals	– Price/quality ratio
Degroote(De Groote et al., 2011)	3	Africa-Kenya	250	Attitudes and preference	Experimental auctions and consumer survey	Biofortified: Maize	Micro: – Pro-vitamin A	– Knowledge – Attitudes – Socio-demographics
Colson(Colson, Huffman, & Rousu, 2011)	4	North America-US: two separate cities	N=190	Acceptance	Survey with experimental auction procedure	GM biofortified: Broccoli, tomato and potato	Micro: – Vitamin C Supplementary: – Antioxidant	– Information
Chowdhury (Chowdhury, Meenakshi, Tomlins, & Owori, 2011)	4	Africa-Uganda	N=236	Preference and choice procedure	Survey combined choice experiment	Biofortified: Sweet potato	Micro: – Pro-vitamin A	– Nutrition information – Sensory – Socio demographics
Hayat(Hayat et al., 2010)	4	Asia-Pakistan	N=262	Perception	survey	Functional: Designer eggs	Supplementary: – Omega-3 fatty acids – Lower saturated fats.	– Knowledge – Attention – Sensory – Socio-demographics
De Steur(H. De Steur et al., 2010)	4	Asia- Shanxi (China)	N=944	Acceptance and perception	Survey	Biofortified: Rice	Micro – Folate	– Objective knowledge – Benefits and risk perception
Annunziata(Annunziata & Vecchio, 2010)	4	Europe-Italy	N=340 (Adult population)	Intentions, perceptions and opinions to functional foods	Survey:	Functional	Macro/Micro/Supplementary:	– Knowledge – Attitude – Dietary habits and lifestyle
Sabbe(Sabbe, Verbeke, Deliza, Matta, & Van Damme, 2009)	3	Europe-Belgium	N=86 (Staff and students)	Attitudes, perception and purchase intentions	Survey:- Standard questionnaire and sensory evaluation	Functional:	Supplementary: – Antioxidant	– Attitudes – Socio demographics – Knowledge – Nutrition claim
Hoefkens(Hoefkens, Verbeke, Aertsens, Mondelaers, & Van Camp, 2009)	4	Europe-Belgium-Flemish	N=529	perceptions of nutritional and toxicological quality	Survey: self-administered questionnaire	Organic and conventional: Vegetables	Micro: – Vitamin and minerals Supplementary:	– Knowledge

Hartl(Hartl & Herrmann, 2009)	3	Europe-Germany	N=1556	Acceptance	Survey: online survey	Functional: rapeseed oil	Supplementary: – Long chain Omega-3 FA, – Phytosterol	– Product characteristic
Hailu(Hailu, Boecker, Henson, & Cranfield, 2009)	4	North America-Canada (Ontario)	N=267 (shoppers)	Preference, perception and choice	Survey: Conjoint and choice experiment	Functional and nutraceutical	Supplementary: Probiotics	– Nutrition claim
Gonzale(Gonzalez et al., 2009)	4	South America-Brazil	414 (Household members)	Attitudes	Survey: face-to-face interviews	GM biofortified: Cassava	Micro: – Pro-vitamin A	– Knowledge – Attitudes – Price – Socio-demographics
Gellynck(Gellynck, Kuhne, Van Bockstaele, Van de Walle, & Dewettinck, 2009)	3	Europe-Belgium	N=251 (shoppers)	Perception and attitudes	Survey with Segmentation of consumers	Functional/nutraceutical: Bread	Macro, micro and Supplementary: – Nutrients in bread	– Nutrition attributes – Quality – Sensory
Canavari(Canavari & Nayga, 2009)	3	Europe-Italy	N=433	Purchase intention	Survey: telephone survey	GM:-nutritional benefits	Macro, Micro and Supplementary	– Trust – Knowledge – Price
Stevens(Stevens & Winter-Nelson, 2008)	4	Africa-Mozambique	N=201 (adults)	Acceptance and preference	Framed field experiment	Biofortified : Maize	Micro: – Pro-vitamin A	– Socio demographics – Quality – Sensory: taste, colour and texture
Muzhingi(Muzhingi, Langyintuo, Malaba, & Banziger, 2008)	3	Africa-Zimbabwe	N=360 (Rural households)	Attitudes towards nutrition rich product	Survey :Structured questionnaire	Biofortified: Yellow Maize	Macro: – Oils – Fructose Micro: – Pro-vitamin A-carotenoids	– Nutrition attributes – Knowledge – Sensory-taste
Degroote(De Groote & Kimenju, 2008)	3	Africa-Kenya	600 (Urban consumers)	Preference	Survey: two-stage approach with stratified sample	Biofortified: Maize	Micro: – Provitamin A	– Sensory parameters – Knowledge – Socio-demographics
Cox(D. N. Cox et al., 2008)	3	Australia	N=220	Intentions, consumers	Survey: computer-administered	Functional: Fish containing	Supplementary: – Long chain omega	– Knowledge – Information

				likelihood to purchase	questionnaires		3 fatty acid	– Self-efficacy
Cox(D. N. Cox et al., 2008)	3	Australia	N=220	Preferences	Survey	Functional: conventional and novel food	Supplementary: – Long chain omega 3 fatty acid	– Attitudes
Barrios(Barrios, Bayarri, Carbonell, Izquierdo, & Costell, 2008)	2	Europe-Spain	N=59	Attitudes, opinions and beliefs	Survey: Computer administered questionnaires and focus group interviews	Functional: Yoghurt	Macro, Micro, Supplementary:	– Knowledge – Information – Attitude – Sensorial – Price
Ares(Ares, Gimenez, & Gambaro, 2008)	4	South America-Uruguay	N=200 (consumers of functional foods)	Perceptions and attitudes	Survey: self-administered –open ended questionnaire	Functional: yoghurt	Micro: – Vitamins – Calcium – Iron Supplementary: – Soluble fibre – Antioxidants	– Nutrition claims
Behrens(Behrens, Villanueva, & da Silva, 2007)	2	South America-Brazil	N=56	Sensory liking	Acceptance and sensory evaluation test: Sensory laboratory test	Functional: yoghurt-like fermented soya milk	Macro, Micro, Supplementary:	– Knowledge – Nutrition Information and claim – Sensory characteristic
Verbeke (Verbeke, 2006)	3	Europe-Belgium	N=460 (1st sample N=255 and 2nd sample 205)	Consumption behaviour, attitudes and willingness to Accept	Survey: Self-administered questionnaires	Functional: General	Macro, Micro, Supplementary:	– Attitudinal – Sensory-taste – Nutrition claim
Peng(Peng, West, & Wang, 2006)	3	North America-Canada-(Alberta and BC)	N=803	Acceptance and attitudes	Survey: Telephone survey	Functional: Dairy products	Supplementary: – CLA	– Attitudes – Sensory-taste – Socio-demographics – Knowledge – Nutrition claims
O'Connor(O' Connor, Cowan, Williams, O'Connell, & Boland, 2006)	3	Europe-Ireland	N=300	Acceptance and preference	Survey: Standard consumer/food choice questionnaire,	GM biofortified: Yoghurt	Macro, Micro and Supplementary:	– Knowledge – Attitudes

Verbeke[Verbeke, 2005]	3	Europe-Belgium	N=215	Acceptance	Survey: self-administered	Functional	Macro, Micro: – and Supplementary:	– Attitude and Beliefs – Socio-demographics – Knowledge
Bogue[Bogue et al., 2005]	3	Europe-Ireland	N=300	Attitudes and perception	Survey: Self-administered questionnaires and multi stage clustering	Functional	– Macro, Micro: – and Supplementary:	– Knowledge – Attitudes, Perceptions and behaviour – Socio-demographics
Asselin[Asselin, 2005]	4	North America-Canada	N=128 (egg consumers)	Preference	Survey: Self-administered questionnaire	Functional: Egg	– Micro: – Vitamin – Supplementary: – Long chain omega-3 FA	– Knowledge-Education of masses – Attitudes and health behaviour – Price
Onyango[Onyango & Nayga, 2004]	4	North America-US	N=1203 (Adult consumer)	Acceptance and preference	Survey: telephone survey	GM: nutrient enhanced	– Macro, Micro and Other:	– Acceptance and preference – Determinants: – Awareness and opinions
Hossain[Hossain & Onyango, 2004]	3	North America-US	N=1203 Non-institutional US adults and civilian population	Perception and preference (WTP)	Survey: telephone survey questionnaire	GM: nutrient enhanced	– Macro, Micro and Supplementary:	– Attitudes – Perceptions – Socio-demographics
Bech[Bech-Larsen & Grunert, 2003]	4	North America/Europe (USA, Denmark and Finland)	N=1500 (500 household consumers)	Perception	Survey with conjoint task	Functional: juice, yoghurt and spread	– Supplementary: – Omega-3 FA – Oligosaccharides	– Product type and production method – Nutrition claim
West[West et al., 2002]	4	North America-Canada	N=1008 (household food shoppers)	Attitudes and preference	Survey: telephone survey with stated choice experiment	Functional: GM, organic and conventional	– Micro: – Vitamin – Minerals	– Price – Knowledge and Information – Belief and trust
Saba[Saba & Rosati, 2002]	3	Europe- Italy	N=135 (study1 120 Study2 15)	Perception	Survey: Standard questionnaire ,conjoint and RGM-Repertory Grid Method	Functional: Yoghurt	– Micro: – Vitamin C & E – Calcium – Supplementary: – Probiotics	– Certification and Production method – Nutrition claims

Notes: - GM: Genetically modified; QA, quality appraisal; CLA: conjugated linoleic acid; FA: fatty acid; N: sample size; WTP: willingness-to-pay; [a] Functional foods listed here refer to foods with various improved attributes, including nutritional benefits.

2.3.3 *Conceptualization of foods with nutritional benefits*

There are differences according to the type of nutritionally beneficial food targeted. Twenty studies perceive them as 'functional' food (Annunziata & Vecchio, 2010; Ares et al., 2008; Asselin, 2005; Barrios et al., 2008; Bech-Larsen & Grunert, 2003; Behrens et al., 2007; Bogue et al., 2005; D. N. Cox et al., 2008; Hartl & Herrmann, 2009; Hayat et al., 2010; Hellyer et al., 2012; Markovina et al., 2011; Peng et al., 2006; Saba & Rosati, 2002; Sabbe et al., 2009; Szakaly et al., 2012; Verbeke, 2005, 2006; West et al., 2002), 13 studies focus on 'biofortified' food (Canavari & Nayga, 2009; Chowdhury et al., 2011; Colson et al., 2011; De Groote et al., 2014; De Groote & Kimenju, 2008; De Groote et al., 2011; H. De Steur, Gellynck, Feng, et al., 2012; H. De Steur et al., 2010; Gonzalez et al., 2009; Hossain & Onyango, 2004; Muzhingi et al., 2008; O'Connor et al., 2006; Onyango & Nayga, 2004; Stevens & Winter-Nelson, 2008) whereas others refer to 'nutraceutical' (Lawless et al., 2012), industrial fortified food (Pounis et al., 2011) enhanced food (Hoefkens et al., 2009) or a combination of terms, e.g. 'functional and nutraceutical' (Gellynck et al., 2009; Hailu et al., 2009).

Surprisingly, more than half of the foods examined are referred to as functional food, while nutritional benefits are only one of many functional food attributes (Bigliardi & Galati, 2013). Functional foods are defined as those whole, fortified, enhanced or enriched foods that confer some health benefit for consumers (Hardy, 2000; Hasler, 2002). Since its introduction in Japan in 1980, where it was coined as "Food of Specified Health Uses" (Hardy, 2000), different terminologies for functional foods have been developed and used interchangeably (Hardy, 2000; Hasler, 2002; Siro et al., 2008). When it comes to consumer research on foods with nutritional benefits, referring to a broader product category, such as functional foods, may lead to confusion among the participants, affecting the results, and misinterpretation among the readers. Due to the discrepancy in defining foods with nutritional benefits, consumers are often confused when making purchase decisions (N. M. Childs, 1997; Urala & Lähteenmäki, 2003; Washington:, 1999; Williams, 2005).

Given the positive impact of nutritional information, as shown in the next section, researchers, as well as producers of foods with nutritional benefits, should clearly take into account potential differences in consumer evaluations due to the terminology used. As such, more efforts should be made in consumer evaluation research towards consistent and targeted (use of the) conceptualization of foods with nutritional benefits, in order to better market nutritional foods like functional foods (Hasler, 2002; Menrad, 2003; Siro et al., 2008).

When looking at targeted nutrients, only two studies focus on macronutrients, whereas 18 studies examine foods with high micronutrient levels (vitamins and minerals) and 13 studies are (also) oriented towards another source ('other'). Another twelve studies targeted different nutritional benefits together.

2.3.4 Determinants of consumer evaluation of food with nutritional benefits

The key determinants of consumer evaluation of nutritious foods are categorized into four groups: (1) nutritional knowledge and information (claims); (2) attitude, perceptions and consumer behaviour (as underlying concepts of consumer evaluation); (3) price and product characteristics; and (4) socio-demographics (age, gender, income, education). From the tabulation, we also relate these determinants to the study locations. As foods with nutritional benefits can be considered as health interventions, it is important to distinguish between target regions, i.e. less developed or developing regions and developed regions.

a) Nutritional knowledge, information and claims

There is strong evidence that nutritional knowledge, but also information or claims about the nutritional/health benefits of foods, influence consumers' acceptance, purchase intentions and resultant consumption. Nineteen studies have reported a significant effect of nutritional knowledge (Annunziata & Vecchio, 2010; Asselin, 2005; Barrios et al., 2008; Bogue et al., 2005; Canavari & Nayga, 2009; D. N. Cox et al., 2008; De Groote & Kimenju, 2008; De Groote et al., 2011; H. De Steur, Gellynck, Feng, et al., 2012; H. De Steur et al., 2010; Gonzalez et al., 2009; Hayat et al., 2010; Hoefkens et al., 2009; Muzhingi et al., 2008; O'Connor et al., 2006; Peng et al., 2006; Pounis et al., 2011; Sabbe et al., 2009; Verbeke, 2005). This increases the likelihood that consumers believe the foods actually have a positive benefit to their diet and overall health (Markovina et al., 2011; Pounis et al., 2011; Verbeke, 2005, 2006).

Regarding the type of knowledge, both overall and nutrient-specific knowledge significantly affects the outcomes of consumer evaluation studies (De Groote et al., 2011; H. De Steur, Gellynck, Feng, et al., 2012; Peng et al., 2006; Pounis et al., 2011), even in the case of sensitive products such as GMOs (Vecchione et al., 2015). Ordinarily the nutritional knowledge is a function of socio-demographic elements and often determines the risk and benefit perception as well as attitudes and preference toward nutritious foods (H. De Steur et al., 2010; Verbeke, 2005). This is particularly the case for fortified foods (D. N. Cox et al., 2008; Pounis et al., 2011).

Evidence shows that higher nutrition knowledge results in a positive reaction towards foods with nutritional benefits. Similarly, education about the nutritional benefits of food is found to increase interest in health behaviour (Verbeke, 2005). However, increased awareness of the link between dietary behaviour and health, as well as a high level of interest in nutritional and health aspects, may not always result in adaptive health behaviour and may even lead to confusion among highly knowledgeable consumers, which in turn may affect consumer decisions (Annunziata & Vecchio, 2010; Verbeke, 2005, 2006). Understanding the influence of knowledge and its interaction with other factors is therefore crucial to enhance consumers' awareness and assist them in making informed choices, as well as to improve and refine the marketing of such foods (Ares et al., 2008; Verbeke, 2005).

Sixteen studies underlined the importance of information and claims about the nutritional benefits of the targeted food as an important determinant of consumer evaluation, regardless of how it is measured (e.g. purchase behaviour and consumption behaviour)(Ares et al., 2008; Barrios et al., 2008; Bech-Larsen & Grunert, 2003; Behrens et al., 2007; Chowdhury et al., 2011; Colson et al., 2011; Hailu et al., 2009; Hellyer et al., 2012; Lawless et al., 2012; Markovina et al., 2011; Onyango & Nayga, 2004; Peng et al., 2006; Saba & Rosati, 2002; Sabbe et al., 2009; Verbeke, 2006; West et al., 2002). The study by Chowdhury et al. (Chowdhury et al., 2011) on acceptance of biofortified orange-fleshed versus white sweet potatoes, for example, reported a significant impact of information provision on purchase intentions. This is also the case when consumers are given nutritional information through a combination of nutritional and health claims (e.g. on the physiological effects or the nutrient level).

However, some consumers may perceive these claims as marketing tricks and believe they have more control over their health (Verbeke, 2006). One study even postulates that, although it is important, nutrition information may not be effective in influencing acceptance (Sabbe et al., 2009). Nutrition information is often secondary to other determinants, such as nutrition knowledge, but also sensory evaluation, attitudes and socio-demographics (Colson et al., 2011; Pounis et al., 2011; Sabbe et al., 2009; Verbeke, 2006). Some studies strongly conclude that acceptance is mainly a consequence of consumers' trade-off between nutritional benefits and sensory attributes (Sabbe et al., 2009), by which they are not willing to compromise taste for health (Verbeke, 2006).

b) Cognitive (attitudes, beliefs and perceptions) and behavioural determinants (lifestyle and eating behaviour)

Seventeen studies highlight attitudes, beliefs and trust as a significant influence of the consumer evaluation of foods with nutritional benefits (Annunziata & Vecchio, 2010; Ares et al., 2008; Asselin, 2005; Barrios et al., 2008; Bogue et al., 2005; Canavari & Nayga, 2009; D. N. Cox et al., 2008; De Groote et al., 2011; Gonzalez et al., 2009; Hossain & Onyango, 2004; Muzhingi et al., 2008; O'Connor et al., 2006; Peng et al., 2006; Sabbe et al., 2009; Verbeke, 2005, 2006; West et al., 2002). Similarly, beliefs regarding nutritional benefits positively affect consumer acceptance (Verbeke, 2005, 2006; West et al., 2002), but also purchase intentions and willingness-to-pay. Acceptance is determined by positive attitudes and beliefs (Hayat et al., 2010; Verbeke, 2005, 2006; West et al., 2002). Even if controversial technologies are implemented, such as GM technology, consumer attitudes towards enhanced nutritional benefits are generally positive (Gonzalez et al., 2009; O'Connor et al., 2006) and are associated with increased probability of acceptance and purchase intentions (West et al., 2002). Moreover, attitudes themselves also differ according to food type and are influenced by other determinants, particularly socio-demographic factors such as age, gender, education, and socio-economic status (Bogue et al., 2005).

Furthermore, there is a likelihood of increased acceptance towards food with nutritional benefits as a consequence of consumer beliefs regarding health and susceptibility to disease upon consuming these foods. Additionally, two studies found that trust has, relatively, the largest impact on consumer acceptance (Hossain & Onyango, 2004; West et al., 2002). Credible stakeholders (nutritionists, doctors, but also food producers) and individuals with a positive opinion are likely to increase consumer acceptance, purchase intentions and consumption behaviour for foods with nutritional benefits. Three studies have examined the influence of consumer perceptions regarding risks, benefits and safety (Ares et al., 2008; H. De Steur et al., 2010; Hossain & Onyango, 2004). In particular, potential benefits and safety issues significantly influence acceptance, purchase intentions and willingness-to-pay.

Regarding GM foods, it is the risk and safety perceptions that often drive acceptance, regardless of the potential advantages of GM foods with nutritional benefits (Hossain & Onyango, 2004). While the increased productivity is the most important factor of the acceptance of first generation GM foods (O'Connor et al., 2006), second generation GM foods with enhanced nutritional contents points to a positive change in public perceptions, acceptance and willingness-to-pay (Canavari & Nayga, 2009; Colson et al., 2011; Gonzalez et al., 2009).

With respect to lifestyle behaviour, four studies report a link with acceptance of foods with nutritional benefits (Annunziata & Vecchio, 2010; Asselin, 2005; Bogue et al., 2005; Szakaly et al., 2012). According to Szakaly *et al.* (2012) consumers can be grouped into four lifestyle segments: rational, uninvolved, conservative and adventurous consumers. Often than not, rational consumers are health conscious (but also price sensitive), therefore market players should attach importance to this segment when launching nutritious foods. Indeed, when consumers are more aware of the role food choices play in their health status, the influence on their acceptance is significant (Annunziata & Vecchio, 2010).

c) Price, process and product attributes

Results from thirteen studies consider price (Asselin, 2005; Barrios et al., 2008; Canavari & Nayga, 2009; De Groote & Kimenju, 2008; H. De Steur, Gellynck, Feng, et al., 2012; Gonzalez et al., 2009; Markovina et al., 2011; West et al., 2002) and product quality (Gellynck et al., 2009; Hartl & Herrmann, 2009; Markovina et al., 2011; Muzhingi et al., 2008; Stevens & Winter-Nelson, 2008) as important determinants of consumer evaluation studies. Also, for nutritious foods, price-quality or “value for money” seems to be a crucial driver for consumer decision-making. This is clearly demonstrated in the auction study on folate-enriched rice, where consumers were prepared to switch to a higher price-quality level than their regular product owing to the expected health benefits of this GM crop.

However, for younger consumers this is often not the case, mainly due to their higher price (and taste) sensitivity (H. De Steur, Gellynck, Feng, et al., 2012; H. De Steur et al., 2010; Harrington, 1994; Verbeke, 2006). Furthermore, price and quality directly interact with other factors, such as health awareness and trust levels, which in some cases explains about half of the variance in attitudes and acceptance of nutritious food (Markovina et al., 2011). In one of the included studies examining trade-offs between price and nutritional benefits, participants were ready to pay a higher price for nutritional benefits, with higher values for plant than animal-based foods (West et al., 2002). These results demonstrate a positive effect of quality on willingness-to-pay for nutritious foods, which is often not the key concern of marketers or (young) consumers (Asselin, 2005; De Groote & Kimenju, 2008).

When looking at sensory attributes as a key quality parameter, 13 studies have shown that consumer acceptance of nutritious foods is largely a function of sensory preference. Taste seems to be a particular prerequisite for acceptance (Chowdhury et al., 2011; Markovina et al., 2011; Sabbe et al., 2009; Stevens & Winter-Nelson, 2008; Verbeke, 2005). Regardless of perceptions on the nutritional benefits, other sensory quality indicators, such as colour (appearance) texture and flavour, also determine one's acceptance and willingness to pay or consume (Bogue et al., 2005; Chowdhury et al., 2011). In other words, one should not neglect the importance of sensory aspects, as consumers may not accept nutritious foods if one of these aspects is negatively affected (Barrios et al., 2008; Pounis et al., 2011; Verbeke, 2006).

Two other studies postulate that the method of production, as well as product certification, has a bearing on acceptance of foods with nutritional benefits (Bech-Larsen & Grunert, 2003; Saba & Rosati, 2002). When making choices, even in the presence of higher nutrient levels, participants are often concerned about the application of production technologies, such as GM technology, although this is generally more profound in regions known to be reluctant towards such technologies, such as Europe. In addition, certifying foods with nutritional benefits seems to further increase the probability of acceptance and purchase intention, mainly due to the perceived credibility and trust associated with such labels.

d) Key socio-demographic factors

Even though socio-demographic indicators are generally included as potential determinants, they are often viewed as less powerful than the aforementioned variables. Nevertheless, about 23 studies conclude that socio-demographic factors are equally important, though there is often discussion on the direction of the effect. Key socio-demographic elements considered include: age (Bogue et al., 2005; Chowdhury et al., 2011; De Groote & Kimenju, 2008; H. De Steur, Gellynck, Feng, et al., 2012; Gonzalez et al., 2009; Hossain & Onyango, 2004; Markovina et al., 2011; Muzhingi et al., 2008; Peng et al., 2006; Sabbe et al., 2009; Stevens & Winter-Nelson, 2008; Verbeke, 2005), gender (Bogue et al., 2005; De Groote & Kimenju, 2008; Gonzalez et al., 2009; Hayat et al., 2010; Hossain & Onyango, 2004), income (De Groote & Kimenju, 2008; H. De Steur et al., 2010; Markovina et al., 2011), and education (De Groote & Kimenju, 2008; Hossain & Onyango, 2004; Pounis et al., 2011). Although other socio-demographic factors may also play a role, we have limited this overview to the main significant indicators. Some studies, for instance, pointed out potential effects from the number of young children in the household or ill family members (Peng et al., 2006). For example, one study that examined the influence of socio-demographic elements, including age, gender, education, income and ethnic group, by using a model developed to launch micronutrient biofortified food, points to a positive impact on acceptance and purchase intention.

With respect to age, older people have been shown to be generally more in favour of food with nutritional benefits (Hossain & Onyango, 2004; Markovina et al., 2011; Peng et al., 2006; Sabbe et al., 2009), which is likely to be a consequence of their higher sensitivity to, and knowledge of, dietary issues (Bogue et al., 2005). Women are more favourable towards foods that confer nutritional benefits than their male counterparts (Bogue et al., 2005; Hayat et al., 2010). This gender difference is even more pronounced when women have a large household with young children (Gonzalez et al., 2009; Peng et al., 2006; Stevens & Winter-Nelson, 2008). Nevertheless, others conclude that males are generally less risk averse than females, by which they are presumably more likely to accept and consume food even in the case of GM foods (Hossain & Onyango, 2004).

Three studies reported an inverse relationship between education and consumer evaluation of nutrient-enhanced foods. The reason for this may be that an educated person may not necessarily have acquired knowledge relating to the nutritional benefits (Pounis et al., 2011). As for most socio-demographic indicators, there is also contradictory evidence on the direction of the effect, with others stating that highly educated people are more in favour (Hossain & Onyango, 2004) and willing to pay for these foods (H. De Steur et al., 2010). Finally, income, a rarely significant determinant, had a positive effect on acceptance (Markovina et al., 2011) and willingness-to-pay (De Groote & Kimenju, 2008; H. De Steur et al., 2010) in a few studies.

2.3.5 Sensitivity analysis

Sensitivity analysis is the approach used to determine how the output of a model, study or system (numerical or otherwise) will be influenced or apportioned to different sources of uncertainty in the inputs (Saltelli, 2002). In the current review, the quality appraisal step which was performed before data extraction, resulted in the exclusion of 6 primary studies based on their deficiencies in three fronts, including: internal validity, which was defined by the quality of the research design; external validity, the outcome measures; and statistical validity, focusing on sampling criteria and statistical analyses/estimates (apart from the impact factor of the journal which was not considered as a criteria for exclusion).

In our sensitivity analysis, we determined the impact of the 6 excluded studies by recalculating the outcome of this review under the alternative assumption of using all the studies without quality appraisal. The studies present no significant shift from the findings reported in this review. First of all, the studies also correspond with our results regarding the heterogeneity of concepts measuring consumer evaluation as well as the use of different terminologies to describe these foods. Secondly, the determinants derived from these excluded studies were generally in line with those presented in this review. As such, this analysis underpins the robustness of using the quality appraisal tool in the review of primary studies in consumer research, which is consistent with previous reviews (de Beer, 2012; LJ Frewer et al., 2014; L. J. Frewer et al., 2013).

2.4 Discussion and conclusions

This comprehensive systematic review is considered the first of its kind to assess consumer evaluation of food with nutritional benefits. The paper provides an understanding of the scope (type of food and nutrient, study location) and methodologies (data collection method and measurement of acceptance) applied in the current state of acceptance studies, and presents a critical review of its main determinants, which are important for creating informed and healthy food choices. Besides, this review also reflects upon the conceptualization of consumer evaluation, by providing insights into its operationalization, and of foods with nutritional benefits.

Thereby, we call for a harmonization in terms of the definition, measurement and use of consumer evaluation and its underlying concepts such as acceptance, as well as a sound typology of, and appropriate use of terminology related to foods with nutritional benefits (versus foods with other health attributes). This could avoid confusion and misinterpretation of the results. From a methodological viewpoint, this study is, to our knowledge, among the first to develop and incorporate quality appraisal criteria for primary studies in reviews on consumer food research (LJ Frewer et al., 2014; L. J. Frewer et al., 2013).As such, we address the need to include this procedure, as highlighted in previous consumer reviews on food (Dannenberg, 2009; de Beer, 2012; J. L. Lusk et al., 2005). This is considered both innovative and crucial for ascertaining the quality of primary consumer studies in this field, and thereby hopes to further guide researchers conducting similar reviews in the future.

Evidence from 38 primary studies points to four groups of determinants of consumer acceptance of food with nutritional benefits. The first group, encompassing nutritional knowledge, information and claims, are ranked among the top explanatory factors, further emphasizing the crucial role of information provision in healthy food behaviour. It also lends support for implementing nudging towards healthy food behaviour. Once more, the group of cognitive determinants (attitudes, beliefs and perceptions), but also lifestyle and dietary behaviour seem to play an important role in consumers' decision making on nutritious foods. Together, both groups highlight the importance of integrating these elements within health promotion campaigns, school feeding programs and market promotion activities in order to increase market share, and overall consumption, particularly in at-risk populations. This corresponds with the International Food Information Council (IFIC) (Washington:, 1999).

Nevertheless, price, product (e.g. sensory attributes) and process attributes (e.g. application of technologies) have also been shown to influence acceptance and purchase intentions, while some consider them at least as important as the previous groups of determinants (Nancy M Childs, 1997; De Groote & Kimenju, 2008; H. De Steur, Gellynck, Feng, et al., 2012; Washington:, 1999), particularly for young people (H. De Steur, Gellynck, Feng, et al., 2012; Urala & Lähteenmäki, 2003). This group of internal and external product characteristics appears to be a precondition for acceptance. Consumers are, for example, affected by potential negative changes in taste, texture, flavour and colour (Chowdhury et al., 2011; De Groote et al., 2011; Verbeke, 2006) or by the GM nature of foods (Annunziata & Vecchio, 2010; Colson et al., 2011; Hans De Steur, Feng, Xiaoping, & Gellynck, 2014; H. De Steur et al., 2010), regardless of their attitude towards the nutritional benefits. Thereby, it is crucial to note that the (hypothetical) price perception, rather than the actual price perception, is often a significant determinant (N. M. Childs, 1997; Menrad, 2003; Williams, 2005).

Regarding socio-demographic variables, which are often used to develop marketing strategies targeted towards specific population segments, four key variables are distinguished, namely gender, age, income and education, in line with consumer research on functional foods (Nancy M Childs, 1997; N. M. Childs, 1997; Washington:, 1999). Whereas women are significantly more favourable towards nutritious foods, age, income and education are, in general, positively related to the consumer evaluation of foods with nutritional benefits. The greater interest by older, consumers with high income levels is especially striking, as it is young, poor people from developing regions that are considered the key beneficiaries of such health interventions. This further underlines the challenges of alleviating the burden of malnutrition, as demonstrated in the Millennium Development Goals report (Blanchfield & Lawson, 2010).

Regarding the conceptualization of foods with nutritional benefits, researchers should strive to develop a clear terminology and consistent use. Therefore, one should correctly refer to the most appropriate term within the broad spectrum of functional foods, by which foods with nutritional benefits, could be coined as a standardized, easy-to-interpret generic term such as “nutritious food”. When, for instance, referring to biofortified foods developed through GM technology as one of its applications, researchers, but also other stakeholders (e.g. policy makers, health planners, media and consumers), should aim to adopt the same terminology, e.g. GM or transgenic biofortified food. From a marketing point of view, the pooled evidence in this review shows that clearly communicating the nutritional benefits (hence the need for using the right terminology) is expected to improve understanding and most likely the acceptance of such foods. While from a researchers’ viewpoint, correctly defining and using these terms will facilitate literature searches in future studies, especially in the case of systematic reviews. However, the same accounts for the measurement of concepts related to consumer evaluation. Studies dealing with consumer evaluation often use interchangeably terms referring to one specific concept of this broad umbrella encompassing perceptions, beliefs, attitudes, preferences, choices, purchase intentions and even consumption behaviour.

While future research should further evaluate the impacts of how consumer evaluation of foods with nutritional benefits is measured (e.g., by comparing different data collection methods or analysing different ways of operationalizing concepts), a standardized approach to define and measure food consumer evaluation concepts in a consistent way is necessary for improving consumer food research. For example, none of the acceptance studies gave a clear definition of this concept of consumer evaluation. To avoid misuse, we propose the following generic definition by Vanhonacker et at., (2013), i.e. “acceptance depicts if and/or consumers exhibit positive reactions towards product, innovations or services”.

Applied to our case, the concept refers to the positive reactions exhibited by consumers towards foods, which could also vary for different stakeholders, as shown for traditional foods (Kühne et al., 2010). In this context, future systematic reviews or meta-analyses could target one of the concepts of consumer evaluation in a broader field (food consumer research) and, for instance, examine its consistent use and the most appropriate ways of operationalizing it, in line with previous reviews on different food topics (de Beer, 2012; LJ Frewer et al., 2014; L. J. Frewer et al., 2013; J. L. Lusk et al., 2005) Regarding primary studies, it is important to emphasize the limited number of studies from low income countries, particularly (Sub-Saharan) Africa, Asia and Latin America. More research to determine the most optimal (ways to introduce) nutritious foods in those areas is needed given the numerous nutrient deficiencies (Müller & Krawinkel, 2005), particularly micronutrient deficiencies (Diaz, De Las Cagigas, & Rodriguez, 2003), that can be addressed by increased intake of foods with nutritional benefits (Graham et al., 2001; D. D. Miller & Welch, 2013; Welch, Graham, & Cakmak, 2013).

Even though we consider our broad scope as one of the main contributions of this review, the heterogeneity of our concepts is the most important limitation of this literature review, which prevents us from conducting a reliable meta-analysis. Nevertheless, by following the guidelines of the Cochrane Handbook (Higgins & Green, 2005) and incorporating a quality appraisal, this review provides an important overview of consumer studies on foods with nutritional benefits. In addition, it hopes to further support filling knowledge gaps on consumer evaluation of food with nutritional benefits and, thereby, improve understanding of the key factors driving consumers.

Chapter 3 Building and testing a Conceptual Framework for Analysing Stakeholders' reactions toward biofortified Foods: A case-study on Iodine Biofortification

This chapter is established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition.* Volume 55, Issue 2 pp. 182-208.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis. *International Journal of Food Sciences and Nutrition*. Volume 67, Issue 4 pp. 355-371.

Abstract

Despite the availability of novel strategies to prevent micronutrient malnutrition, such as biofortification, limited understanding of stakeholders often hampers their adoption. Based on the existing literature on protection motivations and technology acceptance modelling as well as economic valuation of foods by consumers, an integrated PMTAM model is developed and tested as a framework for analysing stakeholders' reactions toward biofortification both on the supply and demand-side. Regarding the latter, the case of the iodine biofortified food chain is used to evaluate African households' reactions toward biofortification. All model constructs, and threat appraisal in particular, are decisive in determining the uptake of biofortification, while also social demographics and own nutrition status play an important role.

3.1 Introduction

Broadly, the food supply chain, which traditionally consists of all stages from agricultural production to consumption, is continuously confronted with a wide variety of product and process innovations which are a function of resources, competition, actors and regulations (Smith & Martindale, 2010; Yakovleva et al., 2004). Despite these growth opportunities, the rural poor who depend on agriculture face health, technical and socio-economic challenges which affect their production, consumption and well-being (Marsden et al., 2002). Therefore, innovations should also lead to food chains that are targeted to the poor in order to remain sustainable and competitive, while protecting the environment and improving the health and wellbeing of the consumer, in a dynamic world (Asenso-Okyere et al., 2009).

However, product and process related innovations and technologies in food do not occur in a vacuum and their adoption, whether they are successful or not, is stakeholder driven (Feder & Umali, 1993; Smith & Martindale, 2010; Sunding & Zilberman, 2001; Yakovleva et al., 2004). Thereby, a distinction is often made between stakeholders on the demand side, such as households and school feeding programmes, and the supply side, including smallholder farmers and retailers.

Currently, many studies have analysed the potential of innovations in food supply chains to improve the health and well-being of consumers (Asenso-Okyere et al., 2009; Smith & Martindale, 2010; Yakovleva et al., 2004), even in the case of pro-poor, pro-rural, health oriented innovations (Asenso-Okyere et al., 2009; Renting et al., 2003), which are often defined as multi-stakeholder social learning process, that generates and put to use new knowledge and which expands the capabilities and opportunities of the poor in different sectors (Berdegué, 2005). However, except for consumers, there is limited research on the perceptions of other stakeholders, including farmers, policy makers, and retailers, with respect to the uptake of novel healthy products and technologies targeted to benefit consumers, in the midst of farmer benefits, which is an important ingredient to address challenges in a food chain and subsequently the overall health of consumers in resource poor countries, such as micronutrient malnutrition.

Nevertheless, there are many theories for analysing stakeholder reactions, which alone are often insufficient due to the diversity and specific characteristics of stakeholders in the chain (H. De Steur et al., 2015; Feder et al., 1985; Feder & Umali, 1993; Munene, 2006; Siegrist, 2008; Sunding & Zilberman, 2001). Hence there is need to develop an integrated model for multi-stakeholder analysis in 'Biofortified ' food supply chains, i.e. for measuring the reactions of different stakeholder groups towards healthy products or technologies in the food chain. Findings from such an analysis would support efforts to have a successful and sustainable provision of health based dietary solutions to protect vulnerable consumers, particularly in developing countries.

As a first objective, this paper aims to develop an integrated model that allows for analysis of consumption and production oriented stakeholders in a biofortified food supply chain by building upon two key behavioural models, i.e. Protection Motivation Theory (PMT) (Ronald W. Rogers, 1975) and Technology Acceptance Model (Davis, 1989). Whereas the former is clearly oriented towards the demand side, as it analyses consumers' perceptions of a health related threat and their evaluation of health behaviour as a potential coping strategy, the latter focuses on barriers of adopting a certain (health) technology or innovation, which are mainly targeted at the supply side. As such, applying a model that integrates both models to biofortification allows analysis of stakeholders across the food supply chain. Furthermore, successful implementation of a food based health strategy requires acceptance and adoption from different members of the food chain, multi-stakeholder analysis can be considered as first step towards prevention of market failures (H. De Steur et al., 2015; Di Pasquale et al., 2011; Feder et al., 1985; Lynn Frewer et al., 2003; Mahajan et al., 1991; Smith & Martindale, 2010; Yakovleva et al., 2004).

As a second objective, we present a case to test the applicability of the model in a biofortified food chain. By focusing on the demand related part of the integrated model, we analyse the reactions of consumers towards biofortification as a novel dietary based strategy for preventing health problems that are caused by micronutrient malnutrition in three resource poor countries of Sub-Saharan Africa: Kenya, Tanzania and Uganda. Biofortification refers to the process of improving the nutritional quality of food crops through conventional or transgenic systems (Hirschi, 2009; Nestel et al., 2006; Philip J. White & Broadley, 2005; Philip J White & Broadley, 2009). It differs from industrial fortification, in that the nutrient quality of the crop is increased while growing, rather than at the stage of processing. As it is considered to be self-targeting, it could radically change the trend in micronutrient malnutrition if adopted in vulnerable populations not reached by existing programs, such as supplementation and food fortification (Hirschi, 2009; Nestel et al., 2006; Philip J. White & Broadley, 2005). Although various conventional biofortified foods are available at the market place, the use of GM technology is also being considered to enrich crops with micronutrients points to its successes when it would be implemented, both in terms of micronutrient concentration, consumer acceptance and societal health impacts (H De Steur et al., 2015).

The focus of the current study is targeted toward iodine biofortified vegetable legumes. Iodine is a highly water soluble trace element, rarely found in the earth's crust but fairly present in the sea and sea food. It is required by the human body for several physiological functions, while an inadequate intake results in a number of iodine deficiency disorders (IDD), which can be manifest in a number of ways: development of goitre, often a swelling in the neck; hyperthyroidism; and hypothyroidism, often characterised by cretinism and retarded growth (Ahad & Ganie, 2010). The link of iodine to mental retardation and stunted brain development are often associated with poor school performance and subsequently poor economic development (Bougma et al., 2013; Field, Robles, & Torero, 2008; Politi, 2010).

However, despite the successes recorded by salt iodization and supplementation, these strategies can hardly address IDDs in many vulnerable groups in the developing world, and millions of people are still at risk (Politi, 2010). Thereby, novel potential strategies like iodine biofortification have been developed to change the trend of the deficiency in these poor populations who lack access to iodine-rich sea foods and are not covered by salt iodization (ICCIDD, 2014) . In this paper, we employ the integrated model developed to analyse the reaction of stakeholders targeted at the consumption of iodine biofortified vegetable legumes in order to prevent IDDs and thereby improve the nutrition status of households and school performance of young children. Here, the stakeholders on the demand-side, including namely parents and school, influence the consumption of iodine biofortified vegetable legume of children, who are the main beneficiaries of iodine strategies.

The study was organised in two stages: (1) development of an integrated model bringing together the models of Protection Motivation Theory and Technology Acceptance, as well as an economic valuation technique, i.e. willingness-to-pay as an overall outcome indicator representing stakeholders' reactions toward biofortified foods as a health behaviour; (2) a case study validating the model when applied to analyse reactions of consumers toward iodine biofortified vegetable legumes.

3.2 Justification

Product and process related innovations and technologies in food do not occur in isolation and their success is stakeholder driven. Thereby, we build upon existing literature to make distinct stakeholders on the demand side, such as households and school feeding programmes, and the supply side, including smallholder farmers and retailers. In the case of biofortification, as an alternate to micronutrient malnutrition, the trend in uptake and adoptions across the food supply chain is a function of multiple stakeholders, both consumers and producers.

Therefore, it is important to understand the part played by each stakeholder, which necessitate the development of a conceptual framework that defines all stakeholders at a snapshot. This type of framework has the potential to significantly improve the utility of designing and launching biofortification programs in developing countries. In addition, a snapshot analysis presented by this kind of framework for stakeholders across a food supply chain, radically will make launch of biofortification in nutrition campaign and biofortification research much faster, cheaper, simpler, safer and subsequently high quality of results.

3.3 Theoretical background and rationale

For many decades behavioural change models have been used to explain human behaviour toward the changes in their health and environments, e.g. through adopting novel strategies, innovations and technologies. However, research suggests that there are significant differences between individual behaviour exhibited depending on their influence on one's health and environment, for instance health promoting practices, food substances and innovations, calling for different psychological models or a combination of models (Baranowski et al., 1999; D. N. Cox et al., 2004; Fishbein & Ajzen, 1975; Floyd et al., 2000; Prochaska & DiClemente, 1994; Rutter & Quine, 2002).

Moreover, the explanatory power of the models that are mostly applied in food consumer research is often low. For instance, in their review Baranowski et al. (1999) found that the Theory of Reasoned Action (TRA) (Ajzen, 1985); Theory of Planned Behaviour (TPB) (Fishbein & Ajzen, 1975); Transtheoretical (or Social Change) Model (Prochaska & DiClemente, 1994); Social Cognitive Theory (SCT) (Bandura, 1999); and Health Belief Model (HBM), only explain a small part of the variance (~30%) in the intention to consume certain healthy foods, such as fruits and vegetables.

Therefore, we propose to examine models that can better explain the diversity in reactions toward new food strategies, interventions and technologies, particularly in regard to stakeholder analysis of biofortified foods including Protection Motivations Theory (Ronald W. Rogers, 1975) and Technology

Acceptance Model (Davis, 1989). As the focus of the model will be on stakeholders' behaviour regarding biofortified foods, we also refer to Economic Valuation technique to measure an outcome indicator (e.g. willingness-to-pay, WTP), in addition to statements on intention or resultant behaviour. The PMT model is a health behaviour model which proposes that when a stakeholder is confronted with a health threat e.g. micronutrient deficiency, protection motivations (intention) and protection behaviour, is a function of "threat" appraisal and "coping" appraisal (Figure 5). Each construct is defined by three elements: threat (perceived severity, perceived fear, and perceived vulnerability) and coping appraisal (response efficacy, response cost and self-efficacy).

This model was originally developed by Rogers (1975) to understand fear appeals and how stakeholder cope with them. Later on, it was expanded to a more general theory of persuasive communication by incorporating cognitive processes of behaviour change (Maddux & Rogers, 1983), which has been used in personal health contexts to examine behaviours of specific target groups. The PMT model has successfully, with a very high degree of explained variance, been applied to many health promoting and lifestyle enhancing behaviours. A meta-analysis identified six major applications, namely cancer prevention (17%), healthy lifestyle (17%), smoking, aids prevention (9%), alcohol consumption (9%) and adherence to medical-treatment regimens (6%) (Floyd et al., 2000).

However, to our knowledge only few studies have applied this model to explore protection behaviour by dietary means (D. N. Cox et al., 2004; Floyd et al., 2000). Moreover, none of them have examined biofortified food consumption as (protection) behaviour to address micronutrient malnutrition.

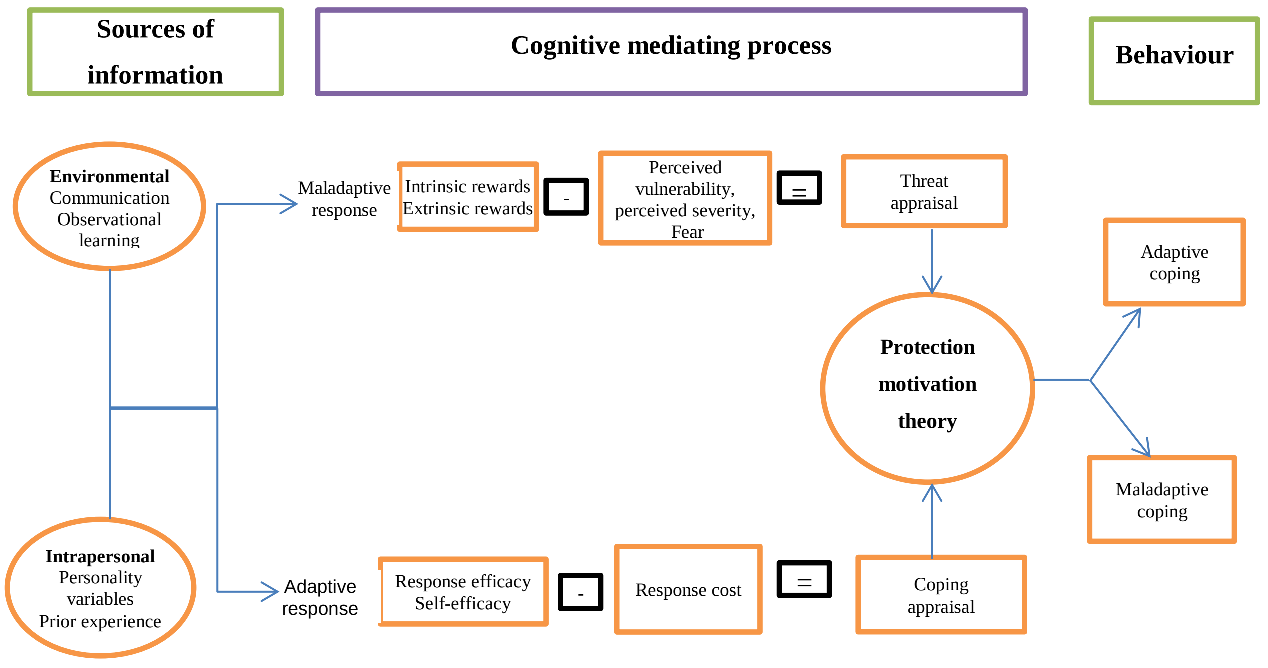


Figure 5 Protection Motivation Theory model (adapted from Rogers, 1983)

TAM is an information systems theory that explains how stakeholders accept or adopt a particular technology or innovation (Figure 6). It states that attitudes towards a novel product or technology and the subsequent behaviour of using the technology, is determined by Perceived Usefulness and Perceived Ease of Use.

TAM can be also considered as an extension of the Theory of Reasoned Action (Fishbein & Ajzen, 1975). Initially developed by Fred Davis (1989), other researchers expanded the model into the TAM 2 model (Venkatesh & Davis, 2000) and the Unified Acceptance and Use of Technology (Venkatesh et al., 2003). The original model proposes that when people are presented with a novel technology, their decision about how and when to use the technology is influenced by a number factors, notably: the degree to which the person believes using the technology will enhance their output (perceived usefulness) and the degree to which they believe using the technology would require large efforts (perceived ease of use). However, further advances in technology led to an even more expanded model, known as TAM 3, which incorporates elements of trust and risk on technology use.

This model has been widely applied to analyse the adoption of various novel technologies and innovations in many areas, including healthcare (Chen et al., 2011; Feder & Umali, 1993; King & He, 2006; Mahajan et al., 1991; Surendran, 2012) and agriculture (Feder & Umali, 1993; Holden & Karsh, 2010; Surendran, 2012). In this paper, the TAM constructs are integrated in a model for analysing the adoption of biofortification as an agriculture-based technology by stakeholders, in this case farmers in a 'biofortified' food supply chain. Thereby, both model constructs, perceived ease of use and perceived usefulness are integrated to ascertain the degree to which they reflect the adoption and use of these technologies, at the level production, that are aimed at improving health of consumers in resource poor countries (Chen et al., 2011; Feder et al., 1985; Feder & Umali, 1993; Holden & Karsh, 2010; King & He, 2006; Surendran, 2012). Nonetheless, to our knowledge, no studies have used it either alone or integrated into another model, in the field of biofortification and other interventions to tackle micronutrient malnutrition.

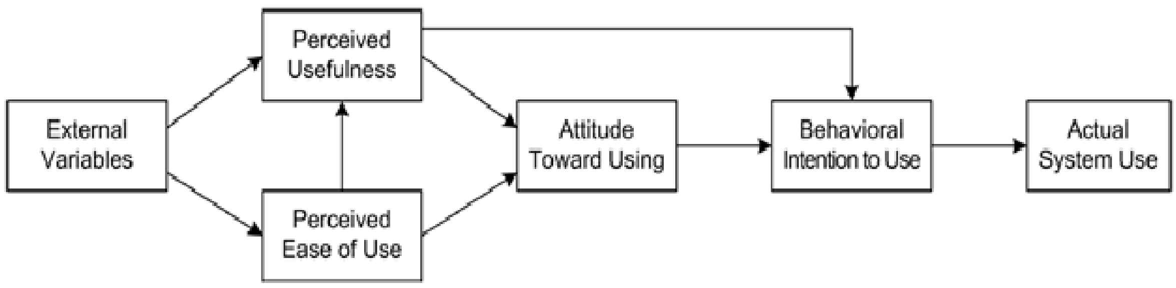


Figure 6 Technology Acceptance Model (Adopted from Davis, (1989)

Economic valuation research aims to determine the maximum value a specific actor attaches to a good or service, also referred as willingness-to-pay (Reutterer & Breidert, 2007). With respect to behavioural change studies, there is evidence for the integration of economic valuation techniques, such as contingent valuation (Barro et al., 1996; Luzar & Cosse, 1998; Whitehead, 2005a, 2005b). Contingent valuation is a common technique which involves a direct question to a person about how much they are willing-to-pay or amount of compensation they are willing to accept for a given good or service (Breidert et al., 2006).

Thereby, different methods have been developed and validated: including open-ended or dichotomous choice contingent valuation and payment card (Breidert et al., 2006; Voelckner, 2006; Wertenbroch & Skiera, 2002). Besides, there are also other non-hypothetical techniques which could be used in the case the actual products are presented to the consumer, which was not the case with the current study (Breidert et al., 2006; Reutterer & Breidert, 2007)

Despite the existence of these procedures there are limited studies that have tried to apply the combination of behaviour models and economic valuation techniques to evaluate the intention to behave or resultant behaviour as a WTP towards biofortified food. In principle, there are no studies that have utilised the linkage between behavioural change models and economic valuation to determine resultant behaviour of consumers and producers in a biofortified food supply chain.

3.4 Method

3.4.1 Model development

There is a plethora of evidence on the integration of different behavioural models while incorporating new techniques that improve their applicability in different fields and settings (Dreibelbis et al., 2013; MacKenzie, Podsakoff, & Podsakoff, 2011; Quinn et al., 2012). We carried out integration of two theoretical models: PMT (Ronald W. Rogers, 1975) and TAM (Davis, 1989), while extending their constructs and incorporating economic valuation component as an outcome measure. This is crucial in ascertaining stakeholders' behavioural intention and resultant behaviour, such as acceptance and preference (e.g. willingness-to-pay) of biofortified product. When applying either the PMT or the TAM, the focus is on the general behaviour exhibited by the target group, however incorporating the economic valuation as the indicator of resultant behaviour a more specific outcome is the focus for instance for stakeholders on the demand- and supply-side orientations.

However, by integrating both models, one can target different stakeholders in the food supply chain simultaneously. Therefore, the existing literature is used to define and evaluate the applicability of the constructs of the two original models and their extensions, and their relevance for stakeholder analysis in the case of 'biofortified' food supply chains.

Since the common denominator for the two models is actual behaviour, we have opted for a composite outcome variable based on a standardized preference measure, such as willingness-to-adopt and willingness-to-pay, of which the latter is a well-established economic valuation technique in consumer research. In the case of food supply chain, the values that stakeholders attach to biofortified products or biofortification processes can then be considered as proxies for their resultant behaviour. For consumption oriented stakeholders, it refers to preferences to buy, consume or purchase the product (e.g. consumers' willingness-to-pay biofortified foods); while for producers it represents their preferences to adopt a specific food production technology (e.g. farmers' willingness-to-adopt biofortified foods). There are many, validated ways of measuring preferences, i.e. non-hypothetical, revealed or hypothetical, stated preference methods (Breidert et al., 2006; Reutterer & Breidert, 2007; Wertenbroch & Skiera, 2002). And the selection of the most appropriate valuation method takes into account the specific study characteristics, such as research location, availability of the good, budgetary constraints and cultural aspects (T. A. Cameron & James, 1987; Voelckner, 2006).

We also integrated the exogenous variables obtained from our review (chapter 2) and previous reviews (Chen et al., 2011; EUFIC, 2005) exogenous elements that have been found to affect the original PMT and TAM models or their endogenous constructs, for integration into the resultant model. Building upon the characteristics of the food supply chain, the two theories were then combined into an integrated model bringing together PMT and TAM, using a behaviour-related component as an outcome variable. This combined model is defined as PMTAM and will be tested using a case on iodine biofortified vegetable legumes supply chain in three East-African countries.

3.4.2 Model testing: The case of the iodine biofortified vegetable legume supply chain

a) Study location, sampling and design

We test the model by presenting a case scenario applying the demand-side of the model to examine consumers' reactions toward iodine biofortified vegetable legumes. Data used for this testing was collected from rural landlocked region locations, Kisoro, Busia and Arusha located in three East-African countries, Uganda, Kenya, and Tanzania respectively. In this regions, iodine deficiency is estimated to be 2.4% Kenya, 4.2% Uganda and 41.5% Tanzania (ICCIDD, 2014). These levels are considered to be mainly for the population that is not protected from existing strategies of salt iodization and supplementation. These locations were selected in the current study due to these high levels of IDDs. According to existing data on iodine intake and IDD trends (ICCIDD, 2014) , iodine deficiency is considered a major public health problem in this region (P. Jooste et al., 2014). The East Africa region have high regard to the consumption of legumes and this informed the selection of vegetable legumes as the vehicle food for this study (de Jager, 2013).

b) Sampling and design

The target group consists of households with young children, as they are the most vulnerable to iodine deficiency and IDDs. Using multi-stage cluster sampling, data from three remote, rural landlocked locations, in East Africa: Kenya, Uganda, and Tanzania were collected, including Busia, Kisoro and Arusha respectively. These locations were identified based on iodine status of the population using the latest data from International Council for the Control of Iodine Deficiency Disorders ICCIDD (2014). The key locations in the protocol used for this study was approved by Authority in respective countries of Kenya, Uganda and Tanzania.

The first stage of sampling involved the selection of schools, representing clusters, using a regional list of schools in each country as the sampling frame. As a consequence, 120 schools were randomly selected from a list of schools obtained from each of the countries in the study resulting in a sample of 40 schools from each of the three locations (first stage). These clusters were then used as proxies from whom 9 households were selected using convenience sampling within the neighbourhood giving a total of 1080 households, which are equivalently 360 households per location (second stage). Thereby, the parents were the respondents at the household level and the school heads were recruited and interviewed for each of the schools. The sample size was determined based on the established criteria that puts into account, number of expected independent variables, with n=30 per independent variable and a possibility of less than five independent variables, and the internal consistency of the variables. Therefore, a large sample (n~1000) was required. The study was planned and carried out between April and December 2013.

Items in the integrated model developed, as described in the previous section, were presented in the questionnaire and responses from the participants were collected accordingly. The case study describes the iodine problem, for example iodine deficiency disorders, as a 'threat' appraisal, and the prevention of the deficiency through iodine biofortification as the 'coping' appraisal component. Thereby, motivations and preferences towards the use of iodine biofortified food were measured as the final reactions towards iodine biofortified food. The responses related to the model constructs were measured on a 5-point Likert scale.
Besides we have used standardized measurements with respect to other, exogenous variables, such as socio-demographic indicators, knowledge, and own iodine status.

c) Questionnaire and study variables

– Questionnaire elements

The survey questionnaire consisted of five parts: i) Demographic characteristics; ii) knowledge about iodine, iodine deficiency disorders, prevention strategies and biofortification; iii) own iodine intake status; iv) iodine biofortified vegetable legumes (IBVL) information; v) Protection Motivations and resultant behaviour (as preference and reflected as willingness-to-pay element).

– PMT independent variables constructs

The main questions were derived from previous applications of the PMT model in examining health related dietary behaviours (D. N. Cox et al., 2004; Floyd et al., 2000; Milne et al., 2000) and adapted to the case of iodine biofortified vegetable legumes. This was aimed at identifying the determinants influencing the consumption of foods with high iodine content to prevent iodine deficiency disorders and related conditions.

The information characteristic is based on four constructs of PMT that determine the intention and consumption behaviour: the severity of the iodine deficiency disorder and related health problems (severity), the vulnerability of the target group to the deficiency (vulnerability), the efficacy of the proposed behaviour to avert the deficiency (response efficacy) and the efficacy of the group to take up presented behaviour to prevent the deficiency (in this context, the consumption of iodine biofortified food). All items of the applied PMT model were measured by a 5-point Likert scale (strongly agree to strongly disagree; extremely unlikely to extremely likely).

– PMT dependent variable constructs

Two dependent variables were considered for this study: protection motivations (intentions) to consume IBVL and protection behaviour (resultant IBVL consumption behaviour as willingness-to-pay for IBVL). The original dependent variable of the PMT model, i.e. the intention to engage in a health related behaviour (protection motivation), was adapted from previous research (D. N. Cox et al., 2008; Wong & Mullan, 2009) and represents participants' intention to accept, advocate, buy as well as include IBVL in household or school meals. Furthermore, protection behaviour was represented by a willingness-to-pay question using a premium card procedure that measures a premium or discount.

Responses were converted to categorical data (1-5).The assessment of protection behaviour or the behaviour towards IBVL was hinged on the definition of behaviour formulated and presented by Ajzen (Ajzen, 2010), who refers to using Target, Action, Context, and Time (TACT) elements to define behaviour as a manifest, observable response in a given situation in reference to a given target. Therefore, willingness-to-pay (WTP) for an attitude change has been measured, which was successfully applied in previous studies (Jayson L Lusk & Hudson, 2004; Rodríguez, Lacaze, & Lupín, 2008). The TACT elements were adapted to our case, i.e. IBVL (target); willingness-to-pay (action); local market and school settings (Context); and offering a premium or discount (Time) and combined with a contingent valuation approach using payment cards.

Five items were used to assess behaviour, based on the following statements, *"If normal vegetable legumes cost US $1.5 (put in local currency) and biofortified vegetable legumes US $1.75~2.25, how much are you willing to pay for iodine biofortified vegetable legumes without viewing them expensive? Biofortified vegetable legumes…US $", "Considering the normal school meal cost US $1/day (put in* *local currency), and biofortified US $1.5~2, how much more are you willing to pay for inclusion of iodine biofortified vegetable legumes in school meal. Iodine biofortified vegetable legume in school meal....... (US $)"* The normality of the responses was then calculated to determine the reliability of the data for further analysis.

- Exogenous variables

As demonstrated in previous research the consumption of functional foods, biofortified foods and other health materials is a function of many determinants that are not included in the original PMT model, such as price, knowledge, information and own nutrition status (Verbeke, 2006)and that consumers are not likely, for that matter, to comprise some key attributes of the product for health (Verbeke, 2006). Therefore, these exogenous factors are introduced in our extended PMT model during further application. in addition, a cheap talk script was developed and incorporated in the questionnaire to, not only compel participants to participate in the entire study but also motivate them to tell the truth during the interview (Tonsor & Shupp, 2011).

In principle, this format of contingent valuation technique was used to analyse the preference for the biofortified product when offered at a premium or discount. The payment card approach (T. A. Cameron & James, 1987; Wertenbroch & Skiera, 2002), a technique that is widely used in different fields of consumer research (R. D. Rowe, Schulze, & Breffle, 1996), was used to elicit WTP for biofortified product at both levels. These values were then converted into dollars, since the currency for the three locations were different. The questionnaire was pretested with randomly selected representative household (N=10) and schools (N=5).

d) Data entry and analysis

Epidotic platform was used for data entry and documentation of all the recorded responses. Data was then exported to STATA (release 12) for further analysis. As a first step, reliability or internal consistency was obtained by calculating Cronbach's alpha of the composite variables in the consumer-oriented part of the resultant integrated model. Then, the descriptive and correlation characteristics of the sample were computed. Finally, the relationship between the variables and the behavioural intention of consumer oriented stakeholders was analysed using structural equation modelling (SEM).

Elements that were measured using different factors were subject to factor analysis and used to predict the pooled factor to be included in the SEM model. The preference variable (as willingness-to-pay, when the product was presented at premium and/or a discount) for iodine biofortified vegetable legumes is the dependent variable, while behavioural intention was considered as its precursor. The other variables of the consumption oriented part of the integrated model refer to the threat appraisal elements (3), coping appraisal elements (3) as well as the exogenous elements (3). We also used the RAMSEA procedure to assess the fitness of the model.

3.5 Results

3.5.1 Integrated model

We propose a model for measuring stakeholders' reactions through combining, (1) PMT constructs targeted towards stakeholders on the demand-side (2) TAM constructs which are targeted towards stakeholders on the supply-side. The endogenous elements of these two original models that are incorporated are: threat appraisal elements (perceived severity, perceived vulnerability, and perceived fear), coping appraisal elements (response efficacy, response cost and self-efficacy), perceived usefulness and perceived ease of use. The two parts are hinged together by the construct of resultant behaviour as measured by stakeholder preferences of biofortified foods. There is a surfeit of evidence on appropriate methods of ascertaining preference, both hypothetical and non-hypothetical (Breidert et al., 2006; Luzar & Cosse, 1998; Reutterer & Breidert, 2007; Wertenbroch & Skiera, 2002), and successful studies applying these methods to analyse the preference of biofortified foods (H De Steur et al., 2015; H. De Steur, Gellynck, Feng, et al., 2012; Di Pasquale et al., 2011; Munene, 2006; Siegrist, Stampfli, & Kastenholz, 2008), even in resource poor countries (J. Meenakshi & Tomlins, 2009; Qaim & Stein, 2009). In addition, there is evidence on the studies applying both consumer willingness-to-pay and behaviour change (Whitehead, 2005a, 2005b), as well as application of these linkages in health interventions (Trapero-Bertran, Mistry, Shen, & Fox-Rushby, 2013) and uptake of new agricultural innovations (Munthali, 2013; Tian & Li, 2012). Therefore, we integrate economic valuation techniques as outcome measures of the resultant behaviour toward biofortified foods.

In addition to the generic constructs from the two behavioural models and the economic valuation technique, key exogenous factors that have been shown to affect adoption of food and innovations in the demand- and supply-side respectively, are also incorporated, as informed by the literature and systematic review conducted (see chapter 2) and previous reviews (Chen et al., 2011; EUFIC, 2005; Feder & Umali, 1993; Masset et al., 2011). On the demand-side, the systematic review as well as findings from a review by EUFIC (2005) indicate that there are six groups of key determinants of food adoptions : 1) Biological determinants, such as hunger, appetite and taste; 2) Economic determinants such as cost, income, and availability; 3) Physical determinants, such as access, education, skills (e.g. regarding handling and cooling), and time; 4) Social determinants such as culture, family, peers and meal patterns; 5) Psychological determinants, such as mood, stress and guilt; and 6) Attitudes, beliefs and knowledge and information about food. While on the supply side, adoption of innovations are a function of cost, risk, success rate farm factors, benefits and trust (Feder & Umali, 1993; Tian & Li, 2012). Nonetheless, in a biofortified food supply chain, the crucial elements on demand-side include: knowledge, trust, attitude, information, country, own nutrition status and socio-demographics (H De Steur, Buysse, Feng, & Gellynck, 2013; Urala & Lähteenmäki, 2007; Verbeke, 2005) while cost, trust, knowledge, and information benefits, farm factors and success rate of the innovations are key factors on the supply-side (Feder et al., 1985; Munthali, 2013; Sunding & Zilberman, 2001; Tian & Li, 2012).

Since generic models address some of the factors affecting the healthy food supply side, the inclusion of own nutrition status, nutrition knowledge, nutrition information and claim as well as socio-demographics and country of origin to the consumption part (based on PMT), is inevitable due to their significant influence on the consumption of nutritious food such as biofortified food (H De Steur et al., 2013; H. De Steur, Gellynck, Feng, et al., 2012; Lynn Frewer et al., 2003; Siegrist, 2008; Urala & Lähteenmäki, 2007; Verbeke, 2005). Besides, consumers are even willing to compromise other elements, including behavioural elements such as taste and price, for their health (Verbeke, 2006) . In line with previous research (H. De Steur, Gellynck, Feng, et al., 2012; Siegrist et al., 2008; Verbeke, 2005), the final model includes the exogenous elements that are expected to influence endogenous constructs of both model.

While on the production-side, the uptake of agricultural innovations is a dynamic and volatile process (Siegrist, 2008; Tian & Li, 2012). According to a review by Feder and Umali (1993) and a study by Siegrist (2008), uptake of new innovations and technologies is a function of many elements including: perceived usefulness and perceived ease of use (i.e. TAM elements), cost, trust, benefits and neophobia and country of origin, success rate, naturalness and risk. When looking at stakeholder research on biofortification, little has been done on explaining producers' adoption of new technologies (Di Pasquale et al., 2011; Feder et al., 1985; Feder & Umali, 1993; Munthali, 2013; Sunding & Zilberman, 2001). Therefore, it is inevitable to include external elements that have been found to significantly influence the uptake of innovations and technologies by farmers: information about the innovation, cost of the innovation, country of origin, knowledge, socio-demographics of the producer (Di Pasquale et al., 2011; Feder et al., 1985; Feder & Umali, 1993; Munthali, 2013; Sunding & Zilberman, 2001; Tian & Li, 2012).Building upon the aforementioned theoretical models and the empirical studies on biofortification an integrated model, known as PMTAM, was developed (J. Mogendi et al., 2016). This is in line with previous studies that have combined different behavioural models (Dreibelbis et al., 2013; MacKenzie et al., 2011; Quinn et al., 2012). This conceptual framework then informs the development of other research studies in this thesis.

3.5.2 Case study findings

a) Descriptive statistics and correlation of the sample elements

The samples descriptive are presented in **Table 3**. Households reported high levels of WTP for iodine biofortified vegetables when offered at premium and accepted a low discount owing to the perceived health benefit of the product. Further, households generally had a high degree of protection motivations (behavioural intention) to adopt iodine biofortified vegetable legumes (4.3 out of 5). They scored high on nearly all threat and coping elements, except for the response costs. Besides, the average age of our sample was 33 years, with males having the largest share.

Table 3 Descriptive statistics of the sample used to test the conceptual framework for analysing stakeholders' reactions towardbiofortified food

Parameter/measure		**Scale/Units description**	**Household/Parent Mean N=1080**	**School Mean N=120**
Exogenous variables	Gender	Male	53.8	65.83
	Age	Years	33.29 (±7.57)	33.06±8.30
	Household/school size	Average number per household/school)	6.67	650.33
	Children 6-12 years old	Average number of these children	2.49 (±0.97)	297.38
	Satisfaction	Average in a scale of 1 to 7 point)	4.17(±2.0)	2.46±0.92
	School performance	Average marks per child out of 100%	59.82 (±17.82)	56.5±19.26
	Occupation of parent and school head	% Number in each category of occupation		
	▪ Unemployed		25.56 (276)	-
	▪ Casual worker		17.87 (193)	-
	▪ Self-employed		32.78 (354)	-
	▪ Government and others		23.80 (257)	-
	Income	($/month)	39.32 (±32.52)	-
	Frequency of children eating food provided at school	Average number of days per week	3.29 (±1.87)	2.16±0.84
	Decision making (Percentage number of decision made about household/school food/ per week)		78.98 (5.3±1.33)	95 (114)
	Education level of education of parent/Head	% Number in each category of Education		
	▪ No formal education		20.65 (223)	0.00
	▪ Primary level		20.93 (226)	0.00
	▪ Secondary level		30.28 (327)	0.00
	▪ Tertiary		20.93 (226)	93.70
	▪ University		7.22 (78)	7.30
	Knowledge level	Knowledge level on a scale of 1 to 7)	2.34(±0.58)	2.59(±0.59)
	Own iodine intake status	Intake expressed on a rate of 1 to 5 time/week	3.60(±0.63)	3.53(±0.74)
	Information	The level of information on a scale of 1 (Yes)-2 (No)	1.60(±0.06)	1.99(±0.09)
Endogenous PMT variables	Severity	1 to 7points	4.09(±0.60)	3.91(±0.77)
	Vulnerability	1 to 7 points	4.40(±0.50)	4.28(±0.58)
	Fear	1 to 7points	4.59(±0.61)	4.34(±1.14)
	Response efficacy	1 to 7points	4.27(±0.60)	4.0(±0.77)
	Response cost	1 to 7points	2.25(±1.05)	2.57 (±0.66)
	Self-efficacy	1 to 7 points	4.56(±0.61)	4.09(±0.80)
Dependent variable 1	Protection motivations		4.30(±0.49)	4.08(±0.55)
Dependent variable 2: Preference measured as willingness-to-pay for IBVL at a premium or discount (Protection behaviour)	WTP1	($)	1.89(±0.17)	1.84(±0.17)
	WTP2	($)	1.72(±0.18)	1.67(±0.20)
	WTP3	($)	0.98 (±0.21)	1.01(±0.21)
	WTP4	($)	0.67 (±0.18)	0.63(±0.11)

Notes:- IBVL: iodine biofortified vegetable legumes; PMT: protection motivation theory; WTP1; Price parents are willing to pay for biofortified legumes given normal legumes cost 1.5, WTP2; Price parents are willing to pay more for inclusion of iodine biofortified legume in the school programme cost above 1.5, WTP 3; Price parents are willing to pay for Iodine biofortified legumes given normal legume based school programme cost 1.5/da when offered at a discount, WTP4; Price parents are will to pay more for Inclusion of iodine biofortified legume when offered at a discount

The average household size was 6 members, of which about 2 members were children between 6 and 12 years old, i.e. a high-risk group of IDDs and school performance. Most of the respondents had basic education, with over 30 % having only secondary, while only 42 % primary or no education at all. Most of them are self-employed (33), unemployed (26%), or casual labourers (18%), with only a few working with the government and the private sector (24%).

b) Correlations of study variables

Table 4 displays the bivariate correlation between different variables included in the structural equation modelling. We found moderate to very strong and highly significant correlations between the protection motivation (behavioural intention) exhibited by the respondents and severity, vulnerability, fear, response efficacy and self-efficacy as well as weak and negative correlation with occupation of the household head. Equally, there was a strong correlation between behavioural intention and the preference (WTP) for biofortified food when offered at both the premium as well as when offered at a discount. Nevertheless, the constructs of the PMT model were internally correlated but not directly related to the outcome variables (protection motivations and protection behaviour).

Table 4 Correlation among the significant variables in the sample used for validating the conceptual framework (n=1080)

	Variables	1	2	3	4	5	6	7	8	9	10
1	Behavioural Intention	1.00									
2	Iodine Status	-0.07									
3	Knowledge	0.09	0.48***								
4	Severity	0.38***	-0.07	0.03							
5	Vulnerability	0.37***	-0.04	0.07	0.44***						
6	Fear	0.46***	-0.14*	0.02	0.36**	0.54***					
7	Response efficacy	0.39***	-0.05	0.09	0.31**	0.43***	0.43***				
8	Response cost	0.05	0.08	0.01	0.04	0.03	0.12*	0.03			
9	Self-efficacy	0.56***	-0.10*	0.03	0.29***	0.44***	0.60***	0.42***	0.01		
10	Gender	-0.01	-0.09	-0.13*	0.03	0.02	0.07	0.04	-0.04	0.04	0.00

Notes: *Gender coded 0=male and 1= female, *P ≤0.05; **P ≤0.01; and ***P ≤0.001*

c) Structural equation modelling (SEM)

Table 5 summarizes the results of the SEM analysis. When the iodine biofortified product was offered to the households at a premium, perceived severity, own iodine status and gender of the respondent, positively and significantly predicted protection motivations (behavioural intention), which in turn predicted preference for the product. When the product was offered at a discount, the severity, fear and response efficacy concerning IDDs significantly and positively predicted behavioural intention of willing to accept a discount and hence resultant preference for biofortified product. All other predictors, in both cases, were insignificant, but indirectly influenced behavioural intention.

Table 5 Structural Equation Modelling of the reactions of consumers (households)

Latent variable	**Observed variables**	**HH Preference (WTP) for IBVL when offered at a premium (β)**	**HH Preference (WTP) for IBVL when offered at a Discount (β)**
Dependent variable Protection motivation (Behavioural Intention)	Intention	0.02*	0.02*
Endogenous variable Threat appraisal	Perceived severity	0.03***	0.04**
	Perceived vulnerability	-0.01	-0.02
	Perceived fear	0.02	0.03*
Coping appraisal	Response efficacy	0.01	-0.04*
	Response cost	0.01	0.01
	Self-efficacy	-0.01	0.02
Exogenous variable Country	Country	0.01	-0.01
Knowledge	Knowledge	0.01	0.01
Own iodine status	Own iodine status	-0.02*	0.02
Socio demographic	HH size	0.01	0.01
	Young children (6-12 year old)	0.01	-0.01
	HH decision maker	0.01	-0.01
	Age	-0.01	0.01
	Gender	-0.03**	-0.01
	School performance	0.01	-0.01
	Education	-0.01	0.01
	Occupation	-0.01	0.01
	Income	0.001	0.01
Number of obs		1078	1078
LR chi2(20)		52.29***	32.03*
Prob > chi2		0.0001	0.0430

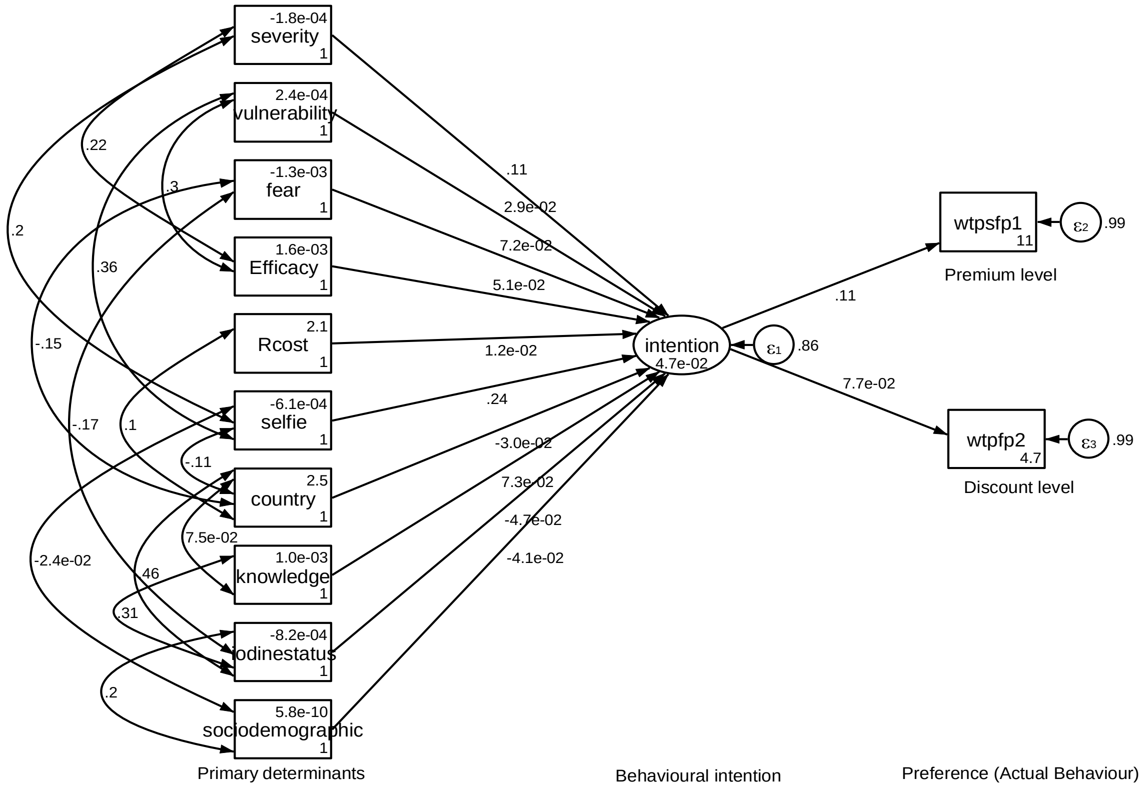
*Notes: Gender coded 0=male and 1= female, *P≤0.05; **P≤0.01; and ***P≤0.001; IBVL, iodine biofortified vegetable legumes; HH: Household; LR likelihood ratio; WTP: willingness-to-pay ;β: Preference (WTP) coefficient values.*

At both levels, perceived severity was the only significant predictor of behavioural intention (r=0.11, p <0.0001) and subsequently preference for iodine biofortified vegetable legumes. However it was also significantly influenced by response efficacy (r=0.22, p<0001) and self-efficacy (r=0.20, p<0001).

At the premium level, another positive predictor of the preference for iodine biofortified food is own iodine status. The latter, however, is significantly and positively influenced by knowledge level of the household (r=0.31, p<001), the country where the household is located (r=0.46, p<0001) and pooled socio-demographic dimensions of the household (r=0.20, p<0001) as well as negatively by fear of IDDs (r=-0.3, p<0001).

In addition, gender is another construct that significantly predicted behavioural intention and subsequently the preference for iodine biofortified food. Another important element that predicted the preference of iodine biofortified food is response efficacy, particularly when offered at a discount. However, response efficacy was also significantly and positively influenced by perceived severity (c=0.31, p<0001) and perceived vulnerability (c=0.31, p<0001, towards iodine deficiency disorders.

Figure 7 provides a graphical overview of relationships between the different constructs, as measured in the SEM analysis. The final consumer oriented model of the PMTAM model was tenable and has a good model fit at both premium ($P \leq 0.001$) and discount level ($P \leq 0.05$).



*Notes:- **Wtpsfp1:** the willingness-to-pay when iodine biofortified legumes are presented at a premium; **wtpfp2:** the willingness-to-pay when iodine biofortified legumes are presented at a discount; **Rcost:** response cost; **Efficacy:** response efficacy*

Figure 7 SEM-Structural Equation Modelling to explain determinants of the preference of iodine biofortified food

3.6 Discussion

Understanding the uptake of novel strategies and innovations, such as biofortification, in food supply chain is essential in the prevention of micronutrient malnutrition. While these novel strategies can dramatically increase the nutrient intake among the most vulnerable groups (Harrison, 2010; Nestel et al., 2006; Qaim & Stein, 2009; Rutter & Quine, 2002), their long-term success is also determined by the other stakeholders of the food supply chain (Marsden et al., 2002; Smith & Martindale, 2010; Yakovleva et al., 2004).

This paper presents a unique integrated PMTAM model for analysing reactions and preferences of stakeholders to innovations in biofortified food chains. To our knowledge this is the first integration of a combined PMT-TAM framework and the first multi-stakeholder model that aims to examine both consumers' and producers' reactions toward biofortified food and biofortification process (technologies). This addresses the need for combining theories of consumer behaviour in order to generate more consistent results (Ho, Hung, & Chen, 2013; Mosler, Blochliger, & Inauen, 2010). There is a plethora of evidence that similar integrated models have successfully been used in launching health interventions (Whitehead, 2005a, 2005b) agricultural innovations (Munthali, 2013; Sunding & Zilberman, 2001), as well as information technologies (Ho et al., 2013).

As such, the final model presented three major advantages compared to the generic models: the assessment of stakeholder reactions in the biofortified food supply chain and the combination of external and internal constructs from multiple models, linked to a common outcome variable. Besides the endogenous constructs from both models, we reviewed and integrated exogenous factors that are expected to influence the consumption and production of nutritious foods, like biofortified crops (EUFIC, 2005; Feder & Umali, 1993; Lynn Frewer et al., 2003; Siegrist, 2008). Regarding the biofortified food supply chain, it is important to integrate, knowledge, information, country of origin, own nutrition status and socio-demographics in order to understand stakeholders on the demand side (consumers), while cost, benefits, trust, country of origin, farm factor, and socio-demographics are decisive to the understanding of supply related stakeholders. This is consistent with earlier studies on biofortification (H De Steur et al., 2013; H. De Steur, Gellynck, Feng, et al., 2012; Di Pasquale et al., 2011; Munene, 2006; Qaim & Stein, 2009; Urala & Lähteenmäki, 2007; Verbeke, 2005) and other novel agricultural technologies (Feder et al., 1985; Feder & Umali, 1993; Munthali, 2013; Siegrist, 2008; Sunding & Zilberman, 2001; Tian & Li, 2012).

The integration is particularly important as it allows to explore the determinants of both models and to measure the economic value consumers and producers attach to biofortification, based on previous applications of economic valuation theory on health interventions (J. Meenakshi & Tomlins, 2009; Olsen & Smith, 2001; Trapero-Bertran et al., 2013) and agricultural innovations (Siegrist, 2008; Sunding & Zilberman, 2001).

This model and the finding thereof are important tools for designing and launching nutrition interventions as well as biofortification campaigns for alleviating the burden of micronutrient malnutrition, a major public health challenge for developing countries (Harrison, 2010; Ramakrishnan, 2002; Tulchinsky, 2010).

The case outlined in this study tries to explain the applicability of the consumer oriented portion of the model to the analysis of behavioural intention (protection motivations) as well as the resultant behaviour (economic valuation) of households towards iodine biofortified vegetable legumes. The study was organised in poor, rural mountainous and landlocked locations of East Africa. When the biofortified vegetable legumes were offered at either a premium or discount, severity was the most significant element and therefore important in launching new micronutrient interventions, such as iodine biofortification. Fear and response efficacy play an important role at the household level, while, exogenous elements, like own iodine status and gender, were also significant in predicting protection motivations and intention. However, other constructs significantly influenced protection motivations as well as willingness-to-pay, albeit indirectly.

These findings confirm previous research that demonstrated the effect of threat appraisal as well as coping appraisal components in the uptake of health practices (Baranowski et al., 1999; D. N. Cox et al., 2004; Floyd et al., 2000). Threat appraisal, particularly of severity and fear, and exogenous variables, among which the own nutrition status, knowledge and socio-demographics, are key for successful adoption of biofortification. Similar results were obtained in several studies on behavioural change (Reyna & Farley, 2006; Ruiter, Abraham, & Kok, 2001; Ruiter, Verplanken, Kok, & Werrij, 2003; Rutter & Quine, 2002). In other words, communicating the severity of the nutrition disorder related to micronutrient deficiencies has the possibility of increasing the uptake of novel nutrition intervention. Our findings, however, contradict earlier studies where coping appraisal, such as self-efficacy and response cost, are often better predictors of health behaviour (Floyd et al., 2000).

There are several limitations which may increase the risk of biases. For instance, the use of questionnaires that focus on a hypothetical situation could be associated with hypothetical bias of the respondents (Jayson L Lusk & Norwood, 2006). It is also worth noting that the use of contingent valuation technique to assess preferences of biofortified foods may also be prone to hypothetical bias where respondents may possibly overstate their true values which could have read to overvaluation of the biofortified food. This phenomenon has been demonstrated in previous studies and can be managed by adopting specific approaches (Mohammed, 2012). Regarding our specific payment card procedure, there is a challenge that the respondent could have limited their answer to only those values on the card and around ignores the extreme levels on either side. However, we have controlled for this bias by ensuring the dollar values are not truncated from above but included in the analysis, which is consistent with earlier research findings on addressing payment card biases (R. D. Rowe et al., 1996).

Another challenge is the use of self-reported data, which may affect the results. This is often associated with social desirability bias, as participant tend to answer question in a way that is most favourable in the eyes of other people, with interviewer in particular (Jayson L Lusk & Norwood, 2006). Furthermore, we carefully selected our exogenous variables, based on relevant empirical studies, but some other determinants could also have influenced the model, including environmental factors, advances in technology, traditional beliefs and practices as well as market variability.

More importantly, five major attempts have been made to minimize the risk and impact of biases in the current study. Firstly, the randomisation of participants and the unmatched techniques reduces the risk of order biases and ensures dispassionate responses. It also allows controlling for the effect of study settings, model constructs and other determinants. Secondly we have developed the questionnaire in such a way that neutrality in questioning is emphasized not to appraise participants during the interview.

Thirdly, a cheap talk script was incorporated in the current study to minimize, not only, the social desirability bias, but also hypothetical bias and ensuring honest responses and appropriate determination of preference. There is also abundant evidence that the use of cheap talk can control for attitude towards such food products and eliminate social desirability as well as hypothetical biases (Bosworth & Taylor, 2012; Di Pasquale et al., 2011). This procedure compels participants to participate in the entire study and at the same time motivates them to be truthful during the interview. Fourthly, using closely matching product concepts ensures that the hypothetical product presented mimics the actual product, since using non-commercialized products has ethical restrictions and could affect the responses. Finally, using a combination of techniques, including models, instruments, standardised interviews and statistical calibrations was intended to mitigate various biases and reduce the impact of other study limitations (He & van de Vijver, 2012).

To further test this model, it should be applied to multiple domains, in various settings, particularly resource poor and rural regions, and it should target different stakeholders. While we expect that empirical studies on the producer side will further underpin the applicability of this integration in uptake of nutrition intervention strategies, such as biofortification, across the entire biofortified food supply chain, our application to iodine biofortification in Eastern Africa, lend support for the inclusion of the consumption-oriented portion of the model and, thus, demonstrates its potential use in evaluating (future) micronutrient interventions in developing regions.

Participant on SMS bidding study-Uganda

School heads participating in the stakeholder study-

Parents at the household study -Kenya

"About eighty percent of the food on shelves of supermarkets today didn't exist 100 years ago."

— Larry McCleary

PART III EXPLORATION OF STAKEHOLDERS ON THE DEMAND-SIDE

This part was established from:

De Steur, H., Mogendi, J. B., Wesana, J., Makokha, A., & Gellynck, X. (2015). Stakeholder reactions toward iodine biofortified foods. An application of protection motivation theory. *Appetite Journal. Volume 92*, pp 295-302.Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). Modelling protection behaviour towards micronutrient deficiencies: Case of iodine biofortified vegetable legumes as health intervention for school going children. *Nutrition Research and Practice.* Volume 10(1):pp 56-66

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2015b). A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition*. Volume 55, Issue 2 pp. 182-208.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016) Integration and Validation of an SMS-Based Bidding Procedure of eliciting Consumers' Willingness-To-Pay for Food. *British Food Journal*. **(In press)**

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Experimental Auctions to Measure Willingness to Pay for iodine Biofortified Food: A Methodological and Empirical Approach. *Agribusiness: An International Journal, Under review*.

Chapter 4 An Application of Protection Motivation Theory towards Iodine Biofortified Foods in Uganda

This chapter is established from:

De Steur, H., Mogendi, J. B., Wesana, J., Makokha, A., & Gellynck, X. (2015). Stakeholder reactions toward iodine biofortified foods. An application of protection motivation theory. *Appetite Journal. Volume 92*, pp 295-302.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition.* Volume 55, Issue 2 pp. 182-208.

Abstract

To use Protection Motivation Theory (PMT) to evaluate stakeholders' intention to adopt iodine biofortified foods as an alternative means to improve children's iodine status and overall school performance. A survey was administered with 360 parents of primary school children and 40 school heads. Protection motivation is measured through matching the cognitive processes they use to evaluate iodine deficiency (threat appraisal), as well as iodine biofortified foods to reduce the threat (coping appraisal). Data was analysed through Robust (Cluster) regression analysis. Gender had a significant effect on coping appraisal for school heads, while age, education, occupation, income, household size and knowledge were significant predictors of threat, coping appraisal and/or protection motivation intention among parents.

Nevertheless, in the overall protection motivation model, only two coping factors, namely self-efficacy (parents) and response cost (school heads), influenced the intention to adopt iodine biofortified foods. School feeding programs incorporating iodine biofortification should strive to increase not only consumer knowledge about iodine but also its association to apparent deficiency disorders, boost self-efficacy and ensure that the costs incurred are not perceived as barriers of adoption. The insignificant threat appraisal effects lend support for targeting future communication on biofortification upon the strategies applied, rather than on the targeted micronutrient deficiency. According to these findings the PMT, coping appraisal factors in particular, is a potential driver and a valuable option for assessing intentions to adopt biofortified foods. Nevertheless, research is needed to understand the impact of threat appraisal factors, principally with most prevalent conditions and changing endemicity.

4.1 Introduction

Iodine deficiency, a well-known cause of preventable mental retardation, is still a major public health problem worldwide, e.g. 240.9 million school aged children are affected, of which 24% originate from Sub-Saharan Africa (M. Andersson et al., 2012). Given the profound effect of iodine deficiency on school performance (Pineda-Lucatero et al., 2008; Qian et al., 2005) and the lack of iodine rich foods East-African School Feeding Programs (Murphy et al., 2007), there is need for novel strategies to improve iodine intake levels. Although Universal Salt Iodization has successfully reduced Iodine

Deficiency Disorders (IDDs) in many countries, albeit more in developed than developing countries, a third of the world population is still unprotected, particularly in rural landlocked areas of developing regions where IDDs are still endemic (M. B. Zimmermann & Andersson, 2012).

Therefore, biofortification of staple crops with iodine is a potential strategy to fill this gap, as is the case with other micronutrients, such as folate and vitamin A (Bouis et al., 2011; H. De Steur, Gellynck, Blancquaert, et al., 2012; Lyons et al., 2004; J. V. Meenakshi et al., 2010). Increasing the iodine content of staple foods can be achieved through conventional plant breeding, provided there is genetic multiplicity, or by applying nutrient rich fertilizers to soils (Perez-Massot et al., 2013; Zhu et al., 2007). Otherwise genetic engineering is a viable alternative (Yuan et al., 2011). Nonetheless consumers are likely to have varying decisions about the acceptance and adoption of biofortified foods, once introduced to the market. Such food choices are a function of many personal factors, such as the level of health consciousness, the ability to overcome healthy eating barriers, nutrition knowledge, previous experience with similar foods, attitudes towards novel foods (technologies), and their perceived (adverse) health effects, religious and cultural beliefs, as well as external factors, such as the way these products are marketed (Mai & Hoffmann, 2012; Pounis et al., 2011; Verbeke et al., 2009).

The introduction of iodine biofortification as a novel strategy to prevent IDDs will most likely involve a cognitive process leading to a motivated decision made by consumers. Thereby, Health Behaviour Models such as the Health Belief Model (HBM), the Theory of Planned Behaviour (TPB), the Social Cognitive Theory (SCT) and the Trans-theoretical Model of Change (TTM) are often used to explain people's motivational factors to perform or not perform health oriented behaviours (Baban & Craciun, 2007). However, since these models mainly focus on threats and often only partially incorporate efficacy factors, Protection Motivation Theory (PMT) is a potential candidate for this study because it additionally looks into coping factors as crucial persuasive communication elements for maintaining or initiating health behaviours (Milne et al., 2000) as well as helps to increase the general low explained variance. In addition, though a few studies have employed PMT to analyse consumer motivations to dietary change, i.e. functional foods (David N. Cox & Bastiaans, 2007; S. Henson et al., 2008); none have been applied to biofortified foods, or in the context of poor developing target regions.

The present study therefore employs the PMT model to predict preferences of parents and school heads towards the potential use of iodine biofortified legumes in School Feeding Programs in Uganda. Many children in Uganda live around mountainous, rural areas with iodine depleted soils or further in-land without access to fish, sea food or iodized salt which are key sources of iodine (Acham, Kikafunda, Tylleskar, & Malde, 2012; Bimenya, Olico, Kaviri, Mbona, & Byarugaba, 2002; Ehrenkranz, Fualal, Ndizihiwe, Clarke, & Alder, 2011; FAO, 2010b; WHO, 2010).

4.1.1 Protection motivation theory research on stakeholders

From its advent as a fear-arousing theory (Ronald W. Rogers, 1975), PMT evolved into a more comprehensive persuasion model explaining how the cognitive process of threat appraisal interacts with coping appraisal to generate an intention to a health related behavioural change (Maddux & Rogers, 1983). Protection motivation involves a decision making process by which an individual evaluates the gravity of, and exposure to, an imminent risk and chooses a suitable alternative to deal with the threat (K. A. Cameron, 2009; K.A. Cameron & DeJoy, 2006). The PMT incorporates maladaptive and adaptive behaviour, which, respectively, constitute threat and coping appraisal. A threat follows arousal of fear for one to perceive danger (severity) and consider the extent of the risk involved (vulnerability) (Neuwirth et al., 2000). The interaction among these three components decreases the probability that a maladaptive behaviour occurs (threat appraisal). Similarly, one's confidence about the effectiveness of the proposed health behaviour to cope with the threat (response-efficacy) and one's belief about the ability to successfully undertake this health preventive action (self-efficacy) both increase the possibility that an adaptive behaviour occurs (coping appraisal), while the evaluation of the costs involved in the execution of the health behaviour (response cost) negatively affects the occurrence of the latter (S. Henson et al., 2008; R. W. Rogers & Prentice-Dunn, 1997).

This model has a superior capacity to determine and describe health preventive behaviour because it covers more components that have been underpinned by a wide array of empirical and theoretical research, especially in the field of health behaviour theory (Hodgkins & Orbell, 1998; Maddux & Rogers, 1983; R. W. Rogers & Prentice-Dunn, 1997). Therefore, the conceptualization of this model entails individuals' motivation to start or maintain, and select a specific action to protect themselves or others from a threat (Ch'ng & Glendon, 2013). Although health preventive intentions are associated with actual health behaviour (Milne et al., 2000), the latter also depends on the stability of intentions over time which is in turn affected by a number of individual factors such as feelings of remorse for not performing an adaptive behaviour (Cooke & Sheeran, 2004).

As was in the early years of its discovery, today PMT is still being used in health related research, such as genetic testing for breast cancer risk (Helmes, 2002), knowledge and risk perceptions of cervical cancer (Gu, Chan, Twinn, & Choi, 2012), consumption of omega-3 rich food (D. N. Cox et al., 2008), selenium enriched foods (David N. Cox & Bastiaans, 2007), or functional foods (S. Henson et al., 2008), and consumer compliance with dietary guidelines (S. Henson, Blandon, Cranfield, & Herath, 2010). Although both types of appraisal have shown a significant association with protection motivation intention, coping appraisal is a stronger predictor (Floyd et al., 2000; Milne et al., 2000). Thereby, self-efficacy is the strongest motivator of behavioural intention, although response efficacy may also be a crucial predictor for healthy foods, as shown by a study on foods rich in phytosterols to decrease the risk of cardiovascular diseases (Spencer Henson, Cranfield, & Herath, 2010). Cox and Bastiaans (2007), found that both appraisal constructs in the model explained no less than 36% of the variation in consumer motivation towards the use of selenium enriched foods. Still, other applications to food have reported significant effects of threat appraisal components. S. Henson et al. (2008), for example, examined purchase intention for three lycopene rich foods and showed that both appraisals positively affected the likelihood of Canadian men to consume tomato juice and the snack product but not the non-prescription pill.

Also socio-demographic characteristics, such as age (S. Henson et al., 2008) and gender (David N. Cox & Bastiaans, 2007; Renner et al., 2008), may play a role in protection motivation research on foods. Talsma et al. (2013) found that increasing knowledge about vitamin A deficiency risks boosted consumer intentions to adopt biofortified cassava in Kenya. A similar effect is demonstrated for cereal fortification in Botswana (Mabaya, Jordaan, Malope, Monkhei, & Jackson, 2010), but not for foods with lycopene (S. Henson et al., 2008). This confirms the importance of knowledge when predicting preferences for nutritious foods and, thus, when developing interventions to improve awareness (Costa-Font, Gil, & Traill, 2008; Macharia-Mutie, Moreno-Londono, Brouwer, Mwangi, & Kok, 2009). The aforementioned internal (threat and coping appraisal) and external factors (socio-demographics and knowledge) are incorporated in our conceptual framework to evaluate the reactions of parents and school heads towards iodine biofortified legumes for use in school feeding programs in order to prevent IDDs and improve school performance (see figure 8).

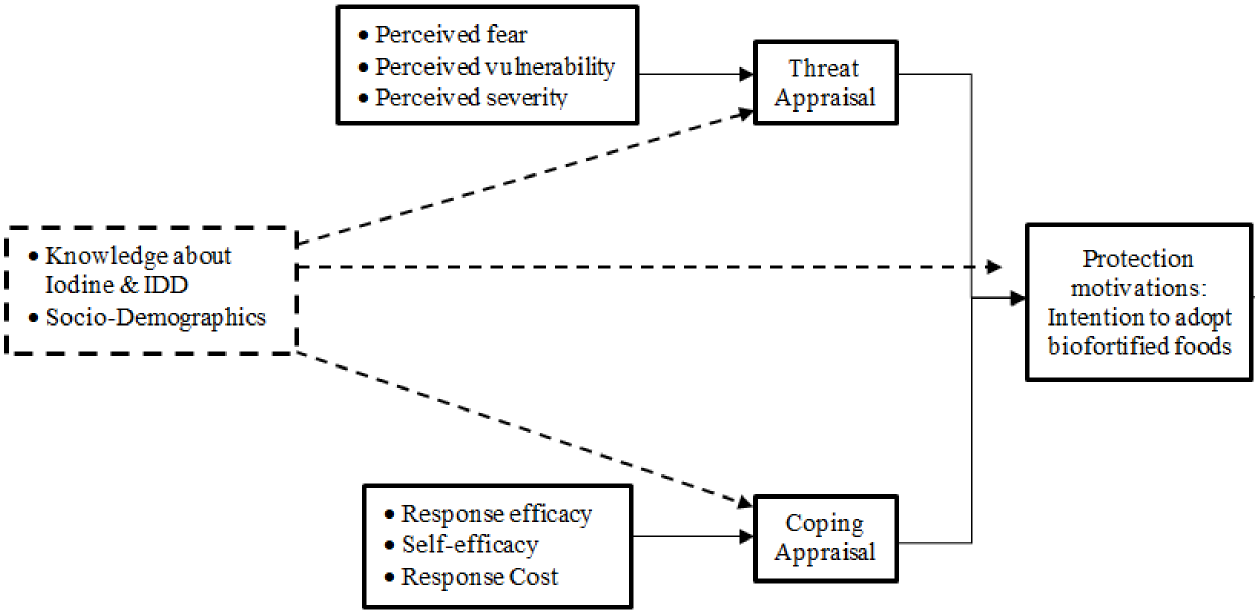
This conceptual framework hypothesizes that when an individual is first confronted with a health threat, i.e. IDDs, which in turn translates to perceived fear, vulnerability and severity, the resultant consecutive protection motivation with regard to preference of iodine biofortified food. Thereby the resultant behaviour will only be achieved when someone believes that continued practice of maladaptive behaviour is of little benefit, that iodine biofortified foods will reduce the risk of IDDs. And, further advocated adaptive behaviour is also effective in the presence of few hurdles such as time constraints and financial costs. Thereby, the high levels of threat and coping appraisal are associated with higher protection motivations, as demonstrated by a positive intention to adopt iodine biofortified food in school feeding programs.

4.1.2 School feeding programs in Uganda

Uganda has a unique structure of education with 7 years of elementary education, 6 years of secondary education (4 years of lower and 2 years of upper secondary), followed by 3 to 5 years of post-secondary education (Innocent Mulindwa Najjumba, 2013). The first school feeding programme, implemented in Uganda after the 1979 war, mainly aimed at increasing school enrolment, feeding and nutrition status of the children (Innocent Najjumba, 2013). However, though there is no explicit school feeding policy in Uganda, both the ministries of health and education have developed a working guideline that guide the school feeding practices in Uganda.

This guideline aims to: a) streamline the planning, selection, handling, preparation and service of nutritious food meals using locally available foods; b) promote adequate nutrition and feeding practices in schools; and c) provide indicators for monitoring and evaluating of school feeding programs in Uganda.

Since the introduction of Universal Primary Education in Uganda in 1997, school feeding programs have not been supported by the government except for a few extreme cases. Therefore, in rural areas feeding programs are majorly a prerogative of school heads and parents. In this case, school meals are mainly provided in order to increase enrolment, child nutrition and school performance. Unfortunately, this is not always achieved and children are susceptible to certain deficiencies. In a majority of these rural landlocked areas micronutrient deficiencies, particularly of iodine, are inevitable and well documented (M. Andersson et al., 2012; FAO, 2010a; M. B. Zimmermann & Andersson, 2012). Hence the need to understand the reactions of both the parents at the household level and the school heads in these areas, towards biofortification as a health strategy that directly affects children's school performance.



Notes:-Source: Own compilation, based on (Munro et al., 2007)

Figure 8 Conceptual Framework to determine stakeholder intentions to adopt iodine biofortified legumes in School Feeding Programmes, based on Protection Motivation Theory

4.2 Methods

4.2.1 Study location

A survey study was conducted in Kisoro District, a south-western region of Uganda and located west of the capital, Kampala. Kisoro is one of the highly mountainous and remote districts in Uganda (e.g. most areas stand at 1,980 meters above sea level), which makes access to most areas difficult. The area has rich soils that are fertile enough to support most staple crops including: maize, sweet potatoes, Irish potatoes, sorghum and vegetable legumes such as beans and lentils. Kisoro district has for a long time registered the highest prevalence of iodine deficiency based on previous urinary iodine and total goitre measurements (WHO, 2006). Therefore Kisoro is one of the key IDDs Endemic regions. Given the mountainous nature of this area that makes it prone to iodine leaching from soil in addition to the remoteness and easy accessibility to common un-iodized salt that preclude salt iodization program, IDDs have continued to devastate the lives of many people.

4.2.2 Design and sampling

Since the school feeding programs in rural areas of Uganda are a prerogative of the school heads and the parents, it is common stand to say the dietary intake and nutrition status of children are dependent on the schools and household. Therefore data was collected at the two levels: school level and household level. And the participants were therefore the school heads and parents of the children.
A cross-sectional research design was conducted among parents and school heads of primary schools in Kisoro District, Uganda. In this case a multi- stage cluster sampling technique was used for sample selection. The first stage involved systematic random selection of 40 schools (clusters) from a list of 136 eligible schools in the entire district while the second stage involved calculation of sample size required to meet the desired precision. As a consequence, we obtained 360 households which translate to 9 households per cluster (school). Using a random walk technique, 360 households of primary school children were selected.

4.2.3 Questionnaires

Two slightly distinct structured questionnaires were used to collect data as per the two levels. The questionnaires were integrated with protection motivations components and consisted of the following sections: socio-demographic profile, knowledge about micronutrients, iodine, IDDs, and interventions, and the PMT components. The two questionnaires were developed and pretested before data collection commenced. Both questionnaires were developed based on the existing literature on the PMT (D. N. Cox et al., 2008; D. N. Cox et al., 2004; S. Henson et al., 2010; Spencer Henson et al., 2010; Hodgkins & Orbell, 1998; Talsma et al., 2013) and consumer research on (GM) biofortified foods (H De Steur, Blancquaert, Lambert, Van Der Straeten, & Gellynck, 2014; H De Steur et al., 2015). However, the integration of the PMT components were also based on a stakeholder interviews and all the constructs of the PMT model included were measured as defined in the original model.

Regarding knowledge, five questions on micronutrients, iodine, IDDs and possible interventions (salt iodization and biofortification) were measured in terms of familiarity (5-points scale, 1 “not at all familiar” - 5 “extremely familiar”) as in earlier studies (P. L. Jooste, Upson, & Charlton, 2005; Mohapatra, Bulliyya, Kerketta, Geddam, & Acharya, 2001; Otieno et al., 2013). Two additional questions (1 “not at all aware” - 5 “extremely aware”) were included to assess one’s knowledge about the relationship between iodine intake and mental development or school performance. Respondents were asked about the link between living in mountainous or land locked areas and the risk of IDDs and whether they are convinced that their children's diet provided enough iodine (1 "yes" - 3 "Don't Know"). After reliability analysis, an overall knowledge construct was developed for the school heads (Cronbach's α = 0.78) as well as the parents sample (Cronbach's α = 0.84).

PMT constructs were assessed using a 5-point Likert scale based on similar studies (D. N. Cox et al., 2004; Rippetoe & Rogers, 1987). Perceived severity included three statements: "IDDs frightens you as a very serious health problem", "You know children who have suffered from IDDs" and "It is possible that children and/or school perform poorly because of iodine deficiency". Perceived vulnerability was measured by three items: "Do you feel children are vulnerable to suffer from IDD if they do not eat iodine rich foods", "Children are likely to perform poorly at school due to iodine deficiency" and "In your opinion protecting children from the risk of IDDs by opting for foods rich in iodine is important" Perceived fear had two components: "Thoughts about IDDs affect your mood" and "The school performance of children affects your mood".

The coping appraisal components were measured by 5-point Likert scales (ranging from "strongly disagree" = 1 to "strongly agree" = 5): "I doubt the cost effectiveness of biofortified foods" for response cost; "Consuming iodine rich foods will reduce the risk of IDDs" and "Iodine biofortified legumes will help improve school performance of children" for response efficacy; and "It is possible for your children to eat iodine biofortified legumes at school" and "I would agree to include iodine biofortified legumes in school meals" for self-efficacy. Behavioural intention to adopt biofortified foods was determined by four 5-point Likert scale items ("extremely unlikely" = 1, to "extremely likely" = 5) "How likely are you to accept iodine biofortified legumes as a source of iodine for your children?", "How likely is it that you will include iodine biofortified legumes in the household/school menu for the children?", "Are you likely to buy iodine biofortified legumes for the household/school?", and "I will consider advocating for inclusion of iodine biofortified legumes in school meals".

For the school heads survey, Cronbach's alpha for the composite threat appraisal (8 items), coping appraisal (5 items) and protection motivation (4 items) was, respectively, 0.71, 0.74 and 0.68. In the parents' survey, Cronbach's alphas were 0.78 for threat appraisal (8 items), 0.62 for coping appraisal (5 items) and 0.69 for protection motivation (4 items).

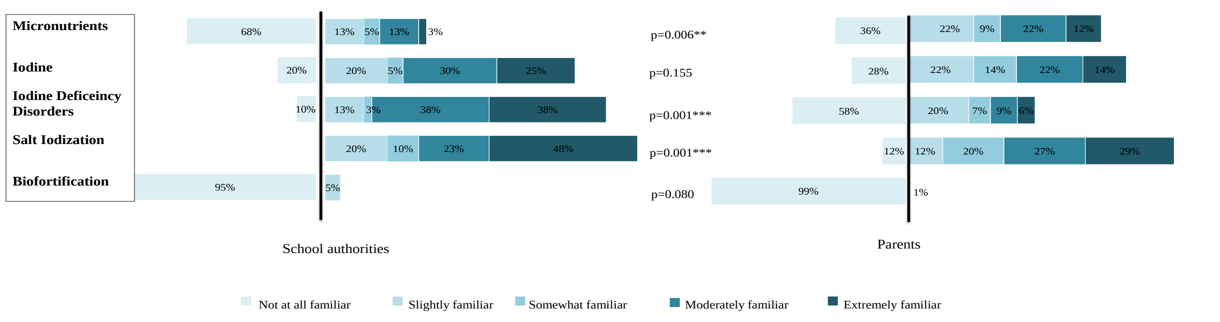
4.2.4 Statistical analysis

Regarding the sample descriptive, Chi-square (Pearson's or Fisher's exact test) and Mann-Whitney U tests were used for comparison of means. Factor analysis was applied to obtain factor scores for both the knowledge and PMT composite variables, which were validated through reliability analysis using Cronbach's alpha (K. J. Rowe, 2006). A Robust method for multiple linear regressions was performed to find out which independent variable(s) affect or are associated with each of the dependent variables. All the statistical analyses were performed using Stata IC v.12.

4.3 Results and discussion

Table 6 provides an overview of the key characteristics of both samples. A greater proportion of respondents: school sample (75%) and heads were male and parents sample (52.8%), but significantly more in the former. The average age for both stakeholder groups was more or less similar. Regarding education, however, all school heads obtained at least a secondary education, as compared to about half of the parents' sample. Whereas all school heads were either employed by the government or privately, only 1 out of 5 of parents had this type of employment. While 1 out of 2 parents were self-employed, about 23% of this sample was unemployed. Together with the relatively low parental income (174400 Uganda Shillings or 70 US$ per month), this further emphasizes the socio-economic challenges in this region. While the majority of school heads rated their children's academic performance as good (62.5%), parents were less optimistic, with nearly 42% of them rating it as poor and only 20.8% as good. Perceived academic satisfaction of (their) children between stakeholders differed significantly with parents being more represented in the extreme categories. Although 60% of schools currently ran a school feeding program, 40% had not yet implemented one. Surprisingly, nearly all schools relied on parents to contribute to this program, while the government provided help to only one school. Most schools (88%) used foods from their own farms, as compared to 60% for parents, who mainly relied on markets. Even more important is the use of iodized salt, which was very high in our selected schools, but substantially lower in the parents' sample. At home, about 1 out of 7 parents still preferred traditional salt. The mean consumption of iodized salt by children at school and home was similar, with about 6 out of 7 days per week.

Figure 9 shows the assessment of stakeholders' knowledge on salt iodization and iodine, which was high in both groups but were less familiar with IDDs, especially parents. Even though parents are more acquainted with micronutrients, familiarity with vitamins and minerals is relatively low in both samples. Despite the fact that 3 out of 5 schools have a school food program, nearly 70% of the heads were not familiar with micronutrients. Knowledge about biofortification was low for both groups.



*Notes:- *, **, *** denote significance at 0.05, 0.01 and 0.001, respectively*

Figure 9 Knowledge about micronutrients, iodine, IDD and interventions (salt iodization and biofortification), per subsample

Table 6 Characteristics of the school heads and parents sample used to analyse reactions towards iodine biofortified food

Characteristic	**Respondents** School heads (n=40)	**Parents (n=360)**	***p-value***
Gender			
Male	30 (75%)	190 (52.8%)	0.007**
Female	10 (25%)	170 (47.2%)	
Age (mean ±SD)	36.9 ±10.35	34.9 ±8.48	0.347
Education level			
No formal education	0(0%)	73 (20.3%)	
Primary education	0(0%)	114 (31.7%)	
Secondary education	(0)	83 (23.1%)	0.001***
Tertiary	40(100%)	82 (22.8%)	
University	0(0%)	8 (2.2%)	
Occupation			
Unemployed	0 (0%)	84 (23.3%)	
Casual worker	0 (0%)	11 (3.1%)	0.001***
Self-employed	0 (0%)	190 (52.8%)	
Government/private worker	40 (100%)	75 (20.8%)	
Income (mean ±SD)	-	174400 ±148850	
School/Household size (mean ±SD)	644.43 ±323.29	2.37 ±0.998	
Children's Academic performance			
Poor	0 (0%)	151 (41.9%)	
Fair	7 (17.5%)	52 (14.4%)	
Good	25 (62.5%)	75 (20.8%)	0.001***
Very good	6 (15%)	41 (11.4%)	
Excellent	2 (5%)	41 (11.4%)	
Academic performance satisfaction			
Not at all satisfied	6 (15%)	123 (34.2%)	
Slightly satisfied	9 (22%)	61 (16.9%)	0.001***
Moderately satisfied	22 (55%)	32 (8.9%)	
Very satisfied	3 (7.5%)	109 (30.3%)	
Extremely satisfied	0 (0%)	35 (9.7%)	
School feeding program			
Yes	24 (60%)		
No	16 (40%)		
Support source (n=24)†			
Parents	23 (95.8%)		
Government	1 (4.2%)		
Source of food			
Own farm	2 (8.3%)	215 (59.7%)	
Market	21 (87.5%)	134 (37.2%)	0.001***
Donation	1 (4.2%)	11 (3.1%)	
Type of salt used			
Traditional	2 (5%)	53 (14.7%)	
Industrial iodized	38 (95%)	243 (67.5%)	0.001***
Both	0 (0%)	64 (17.8%)	
Frequency of iodized salt intake	5.79 ±1.64	5.66 ±2.22	0.494

*Notes:-Proportions and means were compared using Chi-square tests and Mann-Whitney U test, respectively; Means and standard deviations are in brackets, unless indicated; †Applicable number of respondents for that particular question; **, *** denote significance at 0.01 and 0.001, respectively; SD: Standard deviation*

Table 7 demonstrates threat appraisal was generally high for both samples, mainly due to high scores on perceived fear and vulnerability. Only the latter was statistically different between the two groups. General and independent coping appraisal scores were high, but significantly lower among school heads especially self-efficacy, except for the relatively low response costs and high protection motivation intention.

Table 7 Protection Motivation constructs and the intention to adopt biofortified vegetable legumes among the stakeholders on the demand-side (school heads and parents)

PMT constructs & intention	School heads (n=40)	Parents (n=360)	
	Mean ±SD	**Mean ±SD**	***p-value***
Threat appraisal	4.37±0.46	4.35±0.46	0.610
Perceived severity	4.12±0.68	4.08±0.62	0.574
Perceived vulnerability	4.53±0.46	4.37±0.57	0.050*
Perceived fear	4.63±0.49	4.74±0.54	0.075
Coping appraisal	4.36±0.44	4.50±0.47	0.025*
Response efficacy	4.31±0.55	4.30±0.54	0.863
Self-efficacy	4.40±0.47	4.70±0.55	0.001***
Response cost	2.48±1.26	2.18±0.92	0.246
Protection motivation (behavioural intention)	4.24±0.48	4.41±0.49	0.005**

*Notes:- Means were compared using Mann-Whitney U test.; **, *** denote significance at 0.05, 0.01 and 0.001, respectively; SD: standard deviation*

Based on a robust multiple regression analysis, the effect of external variables on the PMT variables is estimated **(Table 8)**. While none of the variables was found to be significant among school heads in relation to threat appraisal, age, occupation, household size and income significantly affected parents' threat appraisal (10.4% of the explained variance). Whereas the former two had a negative impact, the latter two increased threat appraisal. Male school heads had a higher level of coping appraisal, explaining 8.7% total variance in coping appraisal. For parents, occupation, education and age negatively affected coping appraisal. Knowledge about iodine and IDDs as well as the household size were strong, positive predictors of coping appraisal. With regard to protection motivation to adopt biofortified foods, only the parents sample generated significant determinants, namely occupation and knowledge. When considering the three models at the household level, occupation negatively influenced the PMT components. Meanwhile age and household size had, respectively, negative and positive influence on both types of threat and coping appraisal. Knowledge was particularly an important predictor of coping appraisal and protection motivation. Furthermore, income and education, respectively, increased threat appraisal and decreased coping appraisal.

Table 9 depicts the effects of both external factors and all PMT components on the intention to adopt biofortified legumes. In both samples, the model accounted for a relatively large variation of protection motivation (42 - 45%). Two main effects can be distinguished. Response cost had a significant negative influence in the sample of school heads whereas self-efficacy had a significant positive effect among parents

Table 8 Multiple linear regression (Robust) of external predictors of threat appraisal, coping appraisal and intention to adopt iodine biofortified legumes among school heads and parents

Predictors	**School heads** Threat appraisal $R^2 = 0.140$		**Coping appraisal** $R^2 = 0.087$		**Protection motivation** $R^2 = 0.132$		**Parents**[a] Threat appraisal $R^2 = 0.104$		**Coping appraisal** $R^2 = 0.133$		**Protection motivation** $R^2 = 0.090$	
	β	***p*-value**	**β**	***p*-value**	**B**	***p*-value**	**β**	***p*-value**	**β**	***p*-value**	**β**	***p*-value**
Gender	0.131	0.660	0.491	0.045*	0.268	0.431	-0.073	0.493	-0.004	0.961	0.026	0.762
Age	-0.006	0.637	0.008	0.674	-0.016	0.148	-0.016	0.047*	-0.023	0.006**	-0.004	0.574
Education							-0.127	0.315	-0.291	0.019*	-0.254	0.126
Occupation							-0.628	0.001***	-0.611	0.002**	-0.571	0.006**
Income							0.004	0.002**	0.003	0.072	0.001	0.204
School/household size	0.001	0.128	0.0001	0.903	0.0003	0.460	0.084	0.028*	0.098	0.005**	-0.007	0.865
Knowledge of Iodine & IDDs	0.277	0.063	0.086	0.607	0.255	0.107	0.096	0.148	0.193	0.016*	0.160	0.017*
Academic performance satisfaction	-0.040	0.766	-0.007	0.966	0.086	0.569	0.001	0.987	-0.012	0.808	0.062	0.225

*Notes: -Except for age, income, school/household size and knowledge, all other variables were recoded into dummy variables. Abbreviations: IDD-iodine deficiency disorders; R^2: coefficient of determination, how well the data fits a statistical model, **β:** regression beta coefficients, reflect the extent of the magnitude to which the predictor variable affect the outcome variable; [a]Taking into account within and between cluster variances; Significance: *, **, *** denote significance at 0.05, 0.01 and 0.001, respectively*

Table 9 Multiple linear regression (robust) of external factors, PMT constructs of Threat and Coping appraisal as predictors of intention to adopt biofortified legumes as a dependent variable among school heads and parents

Predictors	**School heads (R^2 =0.424)**		**Parents[a] (R^2 =0.457)**	
	β	***p*-value**	**β**	***p*-value**
Gender	0.068	0.828	0.046	0.513
Age	-0.016	0.168	0.007	0.283
Education			-0.083	0.563
Occupation			-0.184	0.144
Income			-0.001	0.435
School/household size	0.0002	0.639	-0.061	0.069
Knowledge of Iodine & IDD	0.265	0.113	0.056	0.167
Academic performance satisfaction	0.116	0.462	0.063	0.181
Perceived severity	0.162	0.517	0.206	0.089
Perceived vulnerability	0.049	0.842	0.007	0.910
Perceived fear	-0.077	0.638	0.025	0.575
Response efficacy	0.137	0.532	0.141	0.120
Self-efficacy	0.172	0.416	0.475	0.001***
Response cost	-0.217	0.041*	0.022	0.548

*Notes: - [a]Taking into account within and between cluster variances; *, **, *** denote significance at 0.05, 0.01 and 0.001, respectively; SD: standard deviation; R^2: coefficient of determination, how well the data fits a statistical model,* ***β:*** *regression beta coefficients reflect the extent of the magnitude to which the predictor variables affect the outcome variable*

The high knowledge on salt iodization and iodine is most likely due to the regular use of iodized salt. This is a positive finding, as consumers' awareness of the importance of iodine may lead to satisfactory intake levels of iodized salt (Buxton & Baguune, 2012; Mohapatra et al., 2001).
Although parents could not identify a single deficiency disorder related to iodine, it does not mean that they are unaware of the existence of goitre or poor school performance among children, but they did not acknowledge lack of iodine to be the main cause of these disorders. This has also been shown in other studies where people lack knowledge about the causes of IDDs (P. L. Jooste et al., 2005; Mallik et al., 1998). Unfamiliarity with IDDs among parents signals the need for better communication efforts when marketing iodized salt. As expected, very few people have heard about biofortification, most likely those people who had participated in the orange sweet potatoes biofortification intervention in 2007 (Hotz et al., 2012), hence calling for additional awareness efforts.

Perceived vulnerability may have differed between groups because of a more negative perception of academic performance among school heads than parents. Regarding coping appraisal, self-efficacy obtained the only significant difference between both subsamples of which parents were most optimistic. This is in line with previous studies indicating a belief of parents' larger control of children with healthy food choices, while they view unhealthy preferences as short-term, modifiable options (Russell & Worsley, 2013). Finally, both stakeholders but parents in particular expressed a clear intention for protection motivation through iodine biofortified foods in school feeding programs. Despite the fact that such programs require substantial (external) support and efforts (Bundy, Burbano, Gelli, Risley, & Neeser, 2011), these figures are promising from a marketing point of view. The effect of gender with males having a higher coping appraisal contradicts previous studies in which a gender effect was lacking (David N. Cox & Bastiaans, 2007; Renner et al., 2008) or an opposite effect of gender was reported (Lowenstein et al., 2013).

The negative influence of occupation and age also contradicts previous evidence on individual PMT components that found a positive relationship between perceived severity of health problems with age and occupation status (Avila-Burgos et al., 2005). In our study, however, older and employed parents had limited experience with iodine deficiency and, therefore, did not perceive it to be a serious problem that requires prompt attention. Although previous studies associated increased knowledge about healthy foods with lower protection motivation (Spencer Henson et al., 2010; Verbeke, 2005), targeting a high-risk region of iodine deficiency, together with the general high level of iodine knowledge and the limited availability of coping strategies may explain the opposite effect in the present study. A comparable study about pro-vitamin A biofortified cassava in Kenya concluded that high awareness of children caretakers regarding vitamin A (deficiencies) significantly increased their intention to use this crop (Talsma et al., 2013). As a consequence, a successful promotion of iodine biofortified foods in target regions most likely requires an awareness campaign.

Contrary to studies stating that education enhances the acquisition of iodine related knowledge (Bornkessel, Broring, Omta, & van Trijp, 2014; Molster, Samanek, Bower, & O'Leary, 2009); our negative effect of education is somewhat surprising, especially given the positive effect of increased knowledge on coping appraisal and protection motivation. A plausible explanation may relate to parents’ past use of iodized salt, rather than the education they received. Still, it is important to note that knowledge is a prerequisite but not the only condition for a sustainable behavioural change in favour of iodine rich foods. The higher the perceived costs among school heads, the lower the intention to adopt iodine biofortified legumes. Dependence on external support seems to be a very crucial barrier. For instance, Jensen, Smed, Morkbak, Vogt-Nielsen, and Malmgreen (2013), also cited similar barriers associated with launching a School Feeding Program. Among parents, the positive effect of self-efficacy on protection motivation intention echoes their ability to undertake the proposed dietary intervention, a finding widely shared by similar studies (David N. Cox & Bastiaans, 2007; D. N. Cox et al., 2004; Spencer Henson et al., 2010; S. Henson et al., 2008).

One of the key challenges in this study is the use of self-reported data. Self-reporting is often associated with social desirability bias. We cannot rule out its presence in our study with a tendency of the participants to answer study questions in a way viewed favourable by others which would have affected the interpretation of results. However, we have attempted to minimise the risk of this potential bias in four major ways: first, we have formulated the questions in a very neutral manner, so as not to appraise the respondents. Secondly, in certain questions we used forced choice questions where two or a limited number of options were equated for their desirability. Thirdly we incorporated a cheap talk script, which has been found to blind and motivate the respondent to tell the truth during the interview, and fourthly, randomization of responses and unmatched techniques which have been found to promote honest answers during this type of interviews.

Another challenge was the small sample size for school heads producing results with low precision hence limiting possible inferences made to certain settings outside the current context. The diversity in the same area means that the data collection and feeding practices may also vary and, as such, may affect iodine intake levels, both at household and school level. It is also difficult to conclude that the dietary intake of a child is influenced at only two levels. An additional challenge is that one needs to carefully interpret these findings when developing future nutrition campaigns after a certain period as the dietary and food production practices are likely to change over time mainly due to a number of elements including: acculturation, population growth and nutrition transition. As a recommendation for future studies, it will be important to analyse the protection motivations for different elements and to assess the influence of overall nutrition status towards adopting coping strategies such as biofortification. Furthermore, the design and the multi-stage sampling and multi-stage data selection could be extended to cover other groups of children not attending primary schools in the location. It will also be important to assess the same variables in the whole population or using a bigger sample. In other words, one needs to further evaluate its external validity and the appropriateness of the model. Nevertheless, different factors have shown a considerable effect on the intention and preference to adopt biofortified foods in rural regions, further supporting the use of PMT models to evaluate reactions towards nutritious foods.

4.4 Conclusions

A PMT based framework is used to model parents' and school heads' reactions towards biofortified food. By applying this framework to the case of iodine rich legumes in a risk region of Uganda, the effect of both external and internal (coping, threat) PMT components on protection motivation intention is analysed. In general, the intention to adopt is high, a finding that is shared in previous research on nutritious products (Dannenberg, 2009; de Beer, 2012; J. L. Lusk et al., 2005) and biofortified foods (Hans De Steur et al., 2014; H. De Steur, Gellynck, Feng, et al., 2012; Gonzalez et al., 2009; J.L Lusk, 2003). Nevertheless it seems that knowledge of the health problem is still crucial for enabling protection motivation. The positive effect of knowledge, or –from a policy point of view – information, is also found in previous research on Folate and Vitamin A enriched crops (H De Steur et al., 2013; Depositario, Nayga, Wu, & Laude, 2009). Furthermore, whereas self-efficacy turned out to be a strong determinant of motivation intention among parents, response cost, a component rarely included in PMT studies, has a clear negative effect on the behavioural intentions of school heads. In addition, socio-demographics like age and gender also influence the likelihood to adopt a behavioural change towards biofortified food consumption. Thereby, a child feeding intervention based on these foods should put into perspective awareness of iodine, its importance, self-efficacy and expected costs impact.

Chapter 5 Modelling Willingness-to-pay (WTP) for Iodine Biofortified Vegetable Legumes as a Health Intervention for Iodine Deficiencies

This chapter is established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2015). Modelling protection behaviour towards micronutrient deficiencies: Case of iodine biofortified vegetable legumes as health intervention for school going children. *Nutrition Research and Practice*. Volume 10(1):pp 56-66

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2015). A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition.* Volume 55, Issue 2 pp. 182-208.

Abstract

Despite successes recorded in combating iodine deficiency, more than 2 billion people are still at risk of iodine deficiency disorders. Rural landlocked and mountainous areas of developing countries are the hardest hit, hence the need to explore and advance novel strategies such as biofortification. We evaluated adoption of iodine biofortified vegetable legumes (IBVL) using an adapted model with theory of protection motivations (PMT) and an economic valuation technique. A total of 1200 participants from three land-locked locations in East Africa were recruited via multi-stage cluster sampling, and data were collected using two, slightly distinct, questionnaires incorporating PMT constructs. The survey also elicited preferences for iodine biofortified foods when offered at a premium or discount. Determinants of protection motivations and preferences for iodine biofortified foods were assessed using path analysis modelling and two-limit Tobit regression, respectively.

Knowledge of iodine, iodine-health link, salt iodization, and biofortification was very low, albeit lower at the household level. Iodine and biofortification were not recognized as nutrient and novel approaches, respectively. On the other hand, severity, fear, occupation, knowledge, iodine status, household composition, and self-efficacy predicted the intention to consume biofortified foods at the household level; only vulnerability, self-efficacy, and location were the most crucial elements at the school level. In addition, results demonstrated a positive willingness-to-pay a premium or acceptance of a lesser discount for biofortification. Furthermore, preference towards iodine biofortified foods was a function of protection motivations, severity, vulnerability, fear, response efficacy, response cost, knowledge, iodine status, gender, age, and household head. Results lend support for prevention of iodine deficiency in unprotected populations through biofortification; however 'threat' appraisal and socio-economic predictors are decisive in designing nutrition interventions and stimulating uptake of biofortification.

In principle, the contribution is threefold: 1) potential application of the model n guiding policy formulation for biofortification based nutrition intervention programs; 2) Provide avenue for guiding stakeholders in identification and tapping niche markets created by the increased demand for biofortified food; 3) stimulation of rural economic growth around school feeding programmes.

5.1 Introduction

Micronutrient malnutrition and its adverse health outcomes are still prevalent, especially in the developing world (Ahmed et al., 2012), constituting 7% of global burden of disease with a cost of US $180 billion per year (Robert E. Black et al.). Deficiencies of the “big four” micronutrients, i.e. Vitamin A, Iodine, Iron, and Zinc, are still affect billions of people, particularly women and children. Despite considerable progress in eliminating these deficiencies through supplementation dietary diversification, and fortification, which were advocated for a long time, the goal is still far from being reached (Bhutta et al.). This has led to new approaches to improve micronutrient intake levels via biofortification, which is a strategy to enhance micronutrient concentrations in staple crops through conventional or transgenic breeding techniques. This potential strategy could radically reverse malnutrition if adopted and accepted by different populations (H De Steur et al., 2015; H De Steur et al., 2010).

The present study applies PMT model integrated with an economic valuation technique to analyse the trend in the adoption of iodine biofortified foods when offered at a premium or discount. The three core constructs of ‘threat appraisal’ and ‘coping appraisal’ components (Milne et al., 2000; Prentice-Dunn & Rogers, 1986; R. W. Rogers, 1983) are evaluated alongside the economic value consumers attach to the product as a means to tackle micronutrient deficiencies. The protection motivations (behavioural intention) exhibited by stakeholders when confronted with different scenarios of iodine biofortified product, either at a premium or at a discount are important to understanding the adoption of these products in iodine endemic areas. Threat appraisal consists of ‘perceived severity’ of the health threat, ‘perceived vulnerability’ of the person affected by the health threat, and ‘perceived fear’ of the effect of the threat (Boer, 1996). ‘Coping appraisal’, on the other hand, consists of response-efficacy, self-efficacy, and the ‘response cost’. Response efficacy describes how the health-promoting behaviour can minimize the health threat while the response cost describes the cost incurred by performing the recommended behaviour (negative to coping appraisal). ‘Self-efficacy’ refers to the individual’s belief that they will succeed in the recommended behaviour to cope with the health threat. Previous research has mostly used part of the model and identified fear, severity, vulnerability, self-efficacy, response efficacy, and response cost as crucial in predicting intention and behaviour (Boer, 1996; H. De Steur et al., 2015; Prentice-Dunn & Rogers, 1986).

Although the PMT Model was initially perceived as a model providing a clear understanding of fear appeals (Ronald W. Rogers, 1975), it soon became a general theory of persuasive communication explaining cognitive processes that mediate (health) behavioural changes (R. W. Rogers, 1983). As such, it has been successfully applied to many health promotion activities (Floyd et al., 2000; Milne et al., 2000). According to a meta-analyses by Floyd et al (2000) and Milne et al (2000), applications of PMT broadly fall into six topics: cancer prevention (17%), exercise/ diet /healthy lifestyles (17%), smoking (9%), aids prevention (9%), alcohol intake (8%), and medical treatment adherence regimens (6%). In more recent studies, attempts have also been made to use this theory for predicting consumers' intention to consume functional foods and supplements (David N. Cox & Bastiaans, 2007; D. N. Cox et al., 2008; D. N. Cox et al., 2004; Park et al., 2011). No studies yet have applied this theory for predicting micronutrient-enriched foods. By using iodine biofortified lentils (IBVL), this study applies the PMT model to predict stakeholders' intention to protect children against iodine deficiency by consuming biofortified foods.

As discussed elsewhere in this thesis, iodine deficiency could prevent children at different levels from attaining their full intellectual potential and subsequently overall school performance (Bougma et al., 2013). As a consequence, two stakeholder groups, parent and schools, which are directly involved in determining meal composition and therefore iodine uptake by the vulnerable groups at both the household and school levels are the focus of this study. This is often informed by the fact that these disorders can be corrected by adequate dietary supply of iodine (Bhutta et al., 2008; Francois Delange, 2000; The, 2008).

Therefore, this study evaluated the potential preferences for biofortified foods as an alternative health protection strategy to improve iodine intake at the household and the school feeding programs. Iodine biofortified crops refer to crop materials that have been modified to enhance iodine content and thereby increase dietary iodine when consumed.

5.2 Subjects and methods

5.2.1 Data collection

Using multi-stage cluster sampling, data from three remote, rural landlocked countries in East Africa (Kenya, Uganda, and Tanzania) were collected. These locations were identified based on iodine status of the population using the latest data from the International Council for the Control of Iodine Deficiency Disorders ICCIDD (2014). The protocol used for this study was approved by respective authorities in Kenya, Uganda, and Tanzania. The first step in sampling involved selection of schools, representing clusters, from a regional list of schools in each country as the sampling frame. In total, 120 schools participated in the study, with 40 from each location. These clusters were then used as proxies from which nine households within the neighbourhood were randomly sampled (second stage), resulting in a total of 1080 households with 360 per location.

Due to the focus on two target groups, i.e. schools versus households, data were collected by using two types of questionnaires: one for school heads and another for household heads (responsible for food purchases). Although both questionnaires focused on children (home versus school consumption) and consisted of five common blocks (knowledge, information, iodine status, PMT and behaviour, and socio-demographics), there was a slight variation between both in the sense that school heads answered from the school perspective (e.g. school feeding programme) while the household questionnaire collected data on the household level. The questionnaire was pretested with randomly selected representative households (N=10) and schools (N=5).

5.2.2 Questionnaire

Both survey questionnaires consisted of five parts: a) knowledge about iodine, iodine deficiency disorders, prevention strategies, and biofortification; b) iodine intake status; c) IBVL (information); d) Protection Motivations and resultant behaviour (as preferences and reflected as willingness-to-pay element). The main questions were derived from previous applications of the PMT model in examining health-related dietary behaviours (D. N. Cox et al., 2004; Floyd et al., 2000; Milne et al., 2000) and adapted to the case of iodine biofortified vegetable legumes to identify determinants influencing consumption of foods with high iodine contents to prevent iodine deficiency disorders and related conditions.

The message characteristic was based on four constructs of PMT that dictate intention and consumption behaviour: severity of iodine deficiency disorder and related health problems (severity), vulnerability of the target group to the deficiency (vulnerability), efficacy of the proposed behaviour to avert the deficiency (response efficacy), and efficacy of the group to perform the presented behaviour to prevent the deficiency (in this context, consumption of iodine biofortified foods). All items of the applied PMT model were measured by a 5-point Likert scale (strongly agree to strongly disagree; extremely unlikely to extremely likely).

Two dependent variables were considered for this study: protection motivation (intention) to consume IBVL and protection behaviour (IBVL consumption behaviour). The original dependent variable of the PMT model, i.e. intention to engage in a health-related behaviour (protection motivation), was adapted from previous research (D. N. Cox et al., 2008; Wong & Mullan, 2009) and represents participants' intention to accept, advocate, buy, as well as include IBVL in household or school meals. Furthermore, protection behaviour was represented by a willingness-to-pay question using a premium card procedure that measures a premium or discount. Responses were converted into categorical data (1-5). Assessment of protection behaviour or behaviour towards IBVL hinged on the definition of behaviour formulated and presented by Ajzen (2010), who refers to using Target, Action, Context, and Time (TACT) elements to define behaviour as a manifest, observable response in a given situation in reference to a given target.

Therefore, willingness-to-pay (WTP) for an attitude change, which was successfully applied in previous studies (Jayson L Lusk & Hudson, 2004), was measured. TACT elements were adapted to our case, i.e. IBVL (target); willingness-to-pay (action); local market and school settings (Context); and offering a premium or discount (Time), and combined with a contingent valuation approach using payment cards. Five items were used to assess behaviour, based on the following statements: *"If* *normal vegetable legumes cost US $1.5 (put in local currency) and biofortified vegetable legumes US $1.75-2.25, how much are you willing to pay for iodine biofortified vegetable legumes without viewing them expensive? Biofortified vegetable legumes…US $", "Considering the normal school meal cost US $1/day (put in local currency), and biofortified US $1.5-2, how much more are you willing to pay for inclusion of iodine biofortified vegetable legumes in school meal. Iodine biofortified vegetable legume in school meal…US $".* The normality of the responses was then calculated to determine the reliability of the data for further analysis.

As previous research has demonstrated that consumption of functional foods, biofortified foods, and other health materials is a function of many determinants that are not included in the original PMT model, such as price, knowledge, information, and nutrition status (Verbeke, 2005, 2006), and that consumers are not likely to comprise key attributes of the product for health (Verbeke, 2006), we introduce these exogenous factors in our extended PMT model (Figure. 11).

The questionnaire was pretested with randomly selected representative households (N=10) and schools (N=5).

5.2.3 Data analysis

We used the EpiData platform to enter the data. EpiData enabled error detection, such as double entry verification as well as data coding. All data were analysed using STATA. Cronbach's alpha was calculated to determine reliability of the items of the original PMT model, and only items with $\alpha > 0.6$ qualified for inclusion in the study. The responses for protection behaviour (continuous variables) were treated as continuous variables to determine the participant's WTP when IBVL are offered at a premium and at a discount. Using these two scenarios, Maximum Likelihood range WTP modelling was performed to estimate the final willingness-to-pay for IBVL.

Pathway analysis modelling (PAM) was conducted to identify the underlying effect of dependent variables on the WTP for IBVL. Pathway analysis modelling is often a form of structural equation modelling (Baumgartner & Homburg, 1996) and is an extension of the general regression model used to test the fit of the correlation matrix against causal models or relationships, which are of interest (Baumgartner & Homburg, 1996; Duncan, 1966). In the current study, the model was applied to test the fit of the correlation matrix or relations between endogenous and exogenous variables within the PMT model as well as their subsequent effect on WTP for IBVL. Regression was carried out for each variable as a dependent variable of all other variables included in the study (Duncan, 1966; Land, 1969), which are believed to be causative: threat appraisal, coping appraisal, and protection motivations (intention). More often than not, the model is particularly sensitive to model specifications and therefore requires adherence to the usual regression assumptions (Land, 1969). The model attempts to: 1) understand patterns of correlation among the variables and 2) explain this level of variation as much as possible within the specified model. It is often distinct from other statistical testing techniques such as multiple regression and ANOVA, in that it mainly focuses on a decision about the whole model with three expected outcomes: reject, modify, or accept (Lynch & Walsh, 1998).

In the current study, pathway analysis modelling was undertaken at three different levels: "protection motivations (intention) to consume IBVL)" as the dependent variable with endogenous (PMT) variables and exogenous variables as the independent variables (1); "protection behaviour" (WTP) as the dependent variable with all other variables together and the primary variable (intention) as the independent variables (2); similar to the second level but using WTP as a dummy variable. Thereby, goodness of fit for the model was analysed using RMSEA. Before running the model on the entire dataset, it was applied for each gender and country to detect any significant variations. We also conducted Tobit modelling to determine the likelihood levels of each element presented in the path analysis with regard to the willingness-to-pay for IBVL. The Tobit model, which also censors regression modelling, is a type of model designed to estimate the overall linear relationship between variables when there is either left or right-sided censoring of the dependent variable (Hallahan, 1989; Tobin, 1958), also known as censoring from below and above, respectively (Tobin, 1958). In the current study, censoring from above means willingness-to-pay lower than the market price of the product (discount), whereas censoring from below means willingness-to-pay above market price (premium). All variables are then modelled around each censoring to determine their relation with the final value (McDonald & Moffitt, 1980), which is the case for WTP. This procedure often allows for amelioration of biased coefficients in the model, when WTP is subject to changes due to diversity in consumer segments (Hallahan, 1989; McDonald & Moffitt, 1980). Although Tobit modelling is superior to classical analysis of multidirectional data, its limitations and appropriate applications are an important consideration which informed use in the current study (McDonald & Moffitt, 1980).

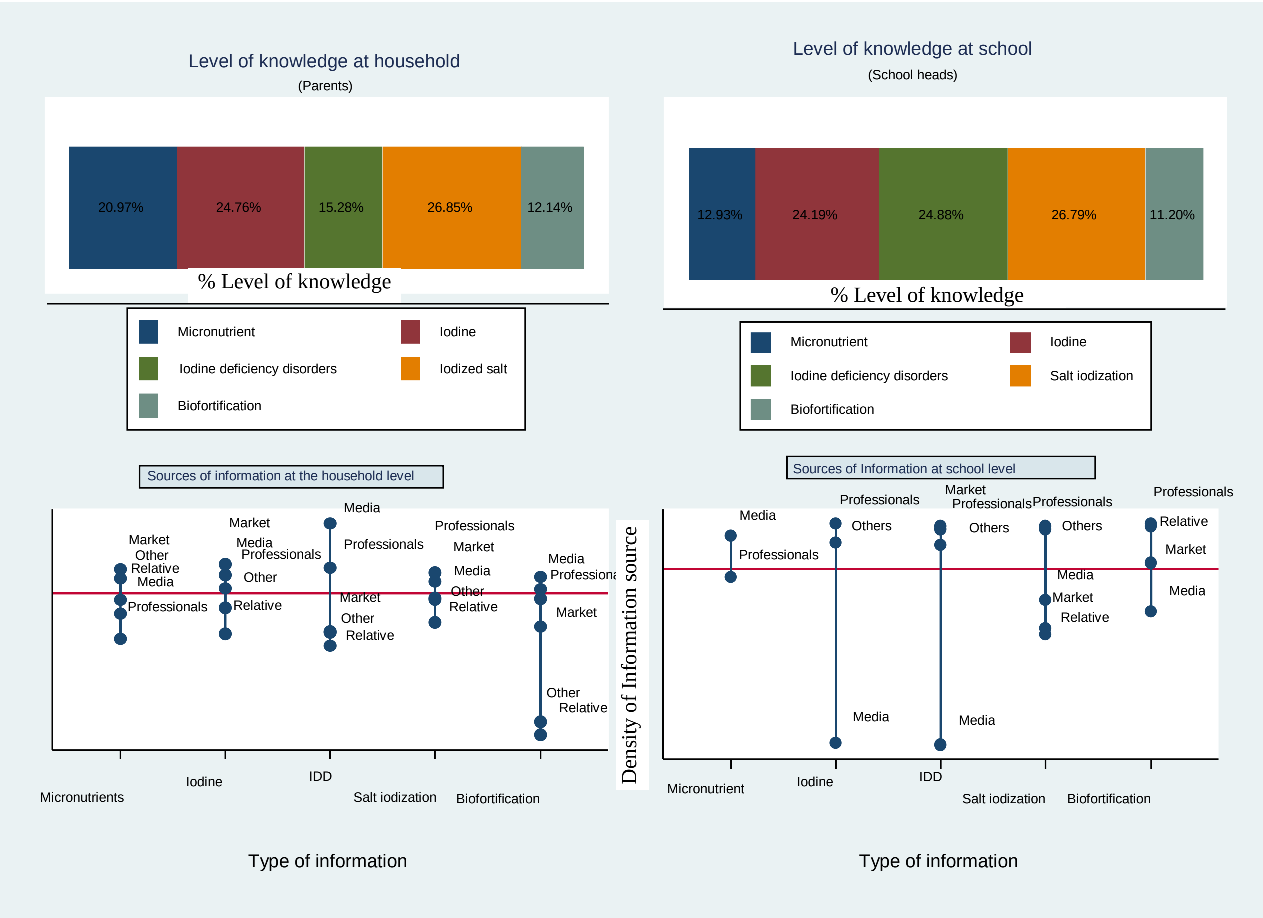
5.3 Results

5.3.1 Variable definitions and descriptive statistics

Sample definitions and descriptive statistics for this study are presented in **Table 3**. Two samples were successfully recruited from each of the three countries at the school (40 participants) and household levels (360 participants). Based on the targeted stakeholder, our sample consisted of 1080 (households) and 120 respondents (schools). In both samples, a Cronbach's alpha (α) value above 0.60 was reported for all variables, which justifies the development of composite variables. The two samples collected were different in many respects and, as expected, socioeconomic status and education level of school heads were higher than those of parents. In both cases, most of the participants were males: 53.8% and 65.83% at the school and household levels, respectively. As expected, males were more involved in managing schools. There were small age differences between both samples. The high number of children in households, on average six per household and about 650 per school, indicates that this was a highly populated region.

Among the participants, an average of two members per household and a total of 297.38 were children aged 6-12 years who showed high susceptibility to iodine deficiency disorders. Low income and education levels at the household level underline the socio-economic challenges in these regions. The average school performance of children in households was 59.82% (SD±17.82) and 56.5% in schools. Despite the negatively perceived performance of the children, satisfaction level (1-5) of the respondents at the household level was twice as high as at the school level. Regular consumption of food through function school feeding programmes was common, with households indicating that their children consumed food at school more than three (SD±1.87) times a week while school heads indicated school feeding programmes in operation for more than 2 years on average.

Figure 10 depicts the knowledge and average consumption of foods rich in iodine. The level of knowledge influenced PMT responses, knowledge about deficiency, consumption of iodine, and information about available alternates (iodine biofortified).



Notes: - IDD: iodine deficiency disorders

Figure 10 Overview of knowledge and information vis-à-vis average consumption of foods rich in iodine at both the household and school level

Regarding PMT components, respondents at the household level reported higher values (above 4 on a 1-5 scale) for severity, vulnerability, fear, response efficacy, self-efficacy, and protection motivation than school heads. However, the response cost was slightly higher at the school level.

The preferences, in form of willingness-to-pay (WTP), of household and school heads in regard to IBVL were examined against regular vegetable legumes. Given that the latter cost US $1.5, WTP for IBVL was US $1.89 (SD ±0.17) and US $1.84 (SD±0.17) at the household and school levels respectively, when offered at a premium. However, values were slightly lower when respondents were asked if they are willing to pay to include it permanently in the school feeding programme, i.e. US $1.72 and US $1.67 for household and school heads, respectively. Moreover, when examined as a discount, respondents at the household level were eager to accept a larger discount (US $0.98) than at the school level (US$ 1.01). Values were even lower when respondents were asked to include IBVL in the school feeding programme, US $0.67 and US $0.63, respectively.

Table 4 (Ch. 3) contains the bivariate correlations between all study variables that are inserted into the path analysis model of the household sample. These table present correlations among variables for the sample (n=1,080) used to investigate the protective reactions towards (willingness-to-pay a premium or discount) iodine biofortified food by stakeholders on the demand-side. There were weak to strong positive correlations between protection motivations (behavioural intention) to consume IBVL moderate positive correlations and the following PMT model variables, including severity (38%), vulnerability (37%), fear (46%), response efficacy (39%) and self-efficacy (56%). Nonetheless, the protection motivations (behavioural intention) were negatively correlated to the occupation of the respondents (-18%).

5.3.2 Path analysis modelling

The results of path analysis modelling, which describes the directed dependencies among the study variables, are displayed in Table 10. The model links exogenous variables (knowledge, socio-demographic indicators, and iodine status) to endogenous (PMT) variables (threat and coping appraisal elements) and subsequently to the dependent variable (protection motivations, also behavioural intention). Two exogenous variables, knowledge and occupation, significantly influenced the intention of households to consume IBVL. Furthermore, severity, fear, and self-efficacy significantly predicted intention to consume IBVL. However, threat appraisal was a function of individuals' iodine status, the presence of vulnerable children in the household, response efficacy, response cost, and self-efficacy. On the other hand, coping was influenced by iodine status, severity, vulnerability, and fear. In other words, threat appraisal influences coping, and vice versa, in order to increase uptake of IBVL.

Table 10 Path analysis with endogenous, exogenous, and dependent variables in the path analysis model (standardized regression coefficients and the model fit)

Variable Category	**Predictors/Variables**	**Stakeholder 1-Parents**			**Stakeholder 2- School Official**		
		Behavioural Intention	**Threat appraisal**	**Coping appraisal**	**Behavioural Intention**	**Threat appraisal**	**Coping appraisal**
Exogenous variables							
Knowledge	Knowledge	0.11***	0.06	0.05	0.11	-0.04	-0.14
Own status	Own iodine status	-0.07	-0.12***	-0.08 *	-0.06	0.13	0.07
Socio-demographics and other variables	Age	0.04	0.03	-0.04	0.06	-0.08	0.02
	Gender	0.02	0.02	0.02	-0.01	-0.05	0.03
	Occupation/parent support	-0.073*	-0.01	0.00	-0.03	0.09	0.05
	Education level	-0.03	0.01	-0.03	0.19	0.00	-0.04
	Income/support	-0.02	0.03	0.02	-0.03	0.09	0.17
	Satisfaction level	-0.02	-0.00	-0.02	-0.14	-0.08	0.00
	Information	-0.02	-0.02	-0.03	0.05	-0.10	-0.05
	Children 6-12	-0.03	0.07*	0.04	-	-	-
	Household /school size	-0.05	-0.05	-0.01	-0.08	0.23	0.08
	Country	-0.04	0.02	-.06	-0.20	-0.34***	-0.23
Endogenous variable							
Threat	Severity	0.11***	-	0.12***	-0.08	-	0.17
	Vulnerability	0.02	-	0.29***	0.31*	-	0.17
	Fear	0.09**	-	0.26***	0.06	-	-0.07
Coping	Response efficacy	0.05	0.23***	-	-0.02	0.18	-
	Response cost	0.01	0.06*	-	0.03	-0.15	-
	Self-efficacy	0.25***	0.37***	-	0.27*	0.10	-

*Notes: - Significance levels: *P<0.05, **P<0.01, ***P<0.001*

At the school level, the intention to consume or include IBLV in school feeding programmes is mainly a function of vulnerability and self-efficacy. In addition, the targeted country significantly influenced threat appraisal, whereas no significant effects were observed regarding coping appraisal. All potential determinants of the intention to consume IBVL were included in two-limit Tobit modelling to determine their effects on WTP for IBVL at the school and household levels.

5.3.3 Two-limit Tobit modelling

Table 11 shows the results of a series of two-limit Tobit regression modelling, in which the dependent variable is WTP for IBVL as protection behaviour, censored at the premium or discount level. The analysis elucidated highly significant effects of protection motivations ($P<0.001$), severity ($P<0.001$), and gender ($P<0.01$) towards IBVL when offered at a premium. However, when asked about their willingness-to-pay to include IBVL into the school feeding programme, when offered at a premium, response efficacy and the country of the household were the most significant elements. Furthermore, protection motivations and response cost were very significant when IBML was presented at the school level. On the other hand, protection motivation is only significant when IBVL was included in a school meal, whereas the response cost was only significant when IBVL was permanently included in the school programme.

Table 11 Maximum optimization and decomposition of two-limit Tobit regression coefficients estimating the influence of PMT and external .variables on WTP a premium or discount

Group/stakeholder	Parents				School			
Presentation	**WTP to include IBVL in the household meal**		**WTP for inclusion of IBVL in school programme**		**WTP to include IBVL in the school meal**		**WTP for inclusion of IBVL in school programme**	
Level	Premium (WTP1) **β** (*P*)	Discount **β** (*P*)	Premium **β** (*P*)	Discount **β** (*P*)	Premium **β** (*P*)	Discount **β** (*P*)	Premium **β** (*P*)	Discount **β** (*P*)
Protection motivation (Intention)	0.03***	0.02	0.00	-0.06	-0.11**	-0.01	-0.08	-0.01
Severity	0.04***	0.04***	0.02	-0.01	0.03	.00	0.05	-0.05*
Vulnerability	-0.00	-0.02	0.01	0.13*	0.05	-0.17**	0.04	-0.04
Fear	0.02	0.04**	0.00	-0.10	0.01	-0.05*	-0.02	-0.01
Response efficacy	0.02	-0.06***	-0.04**	-0.16*	0.98	-2.49	-0.98	5.73**
Response cost	0.01	-0.00	0.01	-0.06	-0.01	-0.013	-0.05*	0.02
Self-efficacy	-0.00	0.02	0.01	0.03	0.00	-0.03	-0.01	0.02
Knowledge	0.00	0.01	0.01	-0.09	-0.00	0.06	0.06	-0.06**
Own iodine status	-0.02	0.02*	0.01	0.03	-0.02	-0.01	0.00	0.01
Gender	-0.04**	-0.01	-0.01	-0.13*	-0.04	-0.12*	0.06	0.02
Age	-0.00	0.00	-0.00	-0.01*	-0.00	0.01*	-0.00	-0.00*
Satisfaction level	0.00	-0.00	0.00	-0.02	-0.01	0.01	0.03	0.02
Education level	-0.01	0.01	-0.01	-0.03				
Information	0.00	0.01	0.00	-0.02				
Household/school size	0.00	0.01	0.00	0.01	0.00	-0.00	0.00	0.00
Children 6-12yrs	0.02	-0.01	-0.00	0.01				
Decision making	0.00	-0.00	0.01	0.06*	-0.09	-0.02	0.12	0.00
Occupation	-0.00	0.01	-0.01	0.01	-0.03	-0.15	-0.09	-0.01
Income/school support	-0.00	0.00	0.00	0.00	-0.04	0.02	-0.02	-0.02
Country	0.01	-0.01	0.02*	0.32***	-0.02	-0.03	0.06	0.00
Number of obs	1078	1078	1078	1078	75	75	75	75
LR chi2(20)	52.29***	32.03*	50.45***	87.29***	18.19	25.92	26.94*	31.42**
Prob> chi2	0.0001	0.0430	0.0002	0.0000	0.3772	0.0759	0.0589	0.0117
Log likelihood	-172.50	159.92	-261.21	-330.98	26.40	-2.06	1.05	30.97

*Notes: - Significance level: *P<0.05, **P<0.01, ***P<0.001; LR: likelihood ratio;* ***β:*** *regression beta coefficients, reflect the extent of the magnitude to which the predictor variable affect the outcome variable; WTP: willingness-to-pay; IBVL: iodine biofortified vegetable legumes; PMT: protection motivation theory*

When IBVL was presented at a discount, severity, fear, response-efficacy, and iodine status had significant effects on preference of IBVL in household meals. Additionally, preference of the household to include IBVL in the school programme is determined by perceived vulnerability to IDD and response efficacy of the alternatives provided, as well as age, gender, decision maker, and the country of the respondent. However, at the school level, WTP for IBVL offered at a discount is a function of perceived vulnerability and fear of IDD in addition to age and gender. Furthermore, inclusion of IBVL in the entire feeding programme is dependent on severity, response efficacy of the proposed alternatives, knowledge about IDD and biofortification, as well as the age of the respondent. In principal, our model has a significant degree of fit and maximum level of willingness-to-pay for IBVL.

5.4 Discussion

The aim of the current study was to analyse how well factors exogenous and endogenous to the PMT model predict protection motivations (intention) and subsequent protection behaviours (consumption). The study presents a case of IBVL to protect households and their children from iodine deficiency disorders and improve school performance of children.

Over the years, knowledge about nutrients and nutritious foods, such as biofortified foods, and their links to health has been insufficient (Axelson, Federline, & Brinberg, 1985). Although attempts have been made to draw significant associations between nutritional knowledge and nutrient intakes, very few studies have demonstrated these links, and significance levels are far from being realized(Wardle, Parmenter, & Waller, 2000). The findings of the current study are no different. Knowledge about iodine, its link to iodine deficiency disorders and poor school performance, as well as available prevention strategies such as salt iodization and biofortification was insufficient and lower in less educated than highly educated groups.

The responses regarding a set of questions evaluating nutritional knowledge about micronutrients, iodine, iodine deficiency, salt iodization, and biofortification differed significantly between different groups. Nutritional knowledge of less educated household respondents was relatively low compared to more educated respondents at the school level. Figure 10 shows that knowledge about iodine, health threats arising from deficiency of iodine, and the subsequent novel strategy of food biofortification was very insufficient. Nevertheless, many previous studies have presented elements that largely account for the low influence of nutritional knowledge on dietary changes to increase nutrient intake for health and nutrition well-being (David N Cox, McKellar, Reynolds, Lean, & Mela, 1998; Wardle et al., 2000). These findings demonstrate the likely importance of including biofortification knowledge in designing biofortification campaigns, particularly in the prevention of iodine deficiency disorders and poor school performance, through novel strategies such as biofortification. Knowledge about nutrient-related deficiency disorders and approaches for preventing these disorders are very important elements for consideration (H De Steur et al., 2013).

Furthermore, for nutritional education campaigns to be successful, it is worth considering the types, sources, and modes of communicating nutritional messages such as nutrients, sources, health threats, and available prevention mechanisms (Kozup, Creyer, & Burton, 2003). Figure 10 demonstrates that the market, media, and professionals are the most effective avenues. Even though media is effective in highly educated groups such as school heads, use of professionals and markets are more effective in less educated groups such as households.

In predicting protection motivations (intention) to consume biofortified foods (IBVL) as a means of preventing IDD and improving school performance of children, the study results provide some support for endogenous and exogenous elements in the PMT model. At the household level, in contrast to our hypothesis, only two exogenous elements, knowledge and occupation, and three endogenous elements, severity, fear, and self-efficacy, were able to directly and significantly predict protection motivations (intention). Accordingly, iodine status and presence of young children (6-12-years-old) indirectly predicted behavioural intention through ‘threat’ appraisal and ‘coping’ appraisal. Further, at the school level, in contrast to our hypothesis, only two endogenous, vulnerability and self-efficacy, and one exogenous variable, country of origin, significantly predicted intention to consume IBVL.

These findings are consistent with results from earlier studies predicting intention and interventions in health behaviour, particularly dietary behaviour (Milne et al., 2000). Self-efficacy, an endogenous element of the coping appraisal construct of PMT, was found to be the most important predictor of intention to consume biofortified foods at both the household and school levels. This is consistent with earlier studies predicting dietary behaviours regarding nutritious foods that reported self-efficacy as a decisive factor in nutritional education campaigns for dietary changes (David N. Cox & Bastiaans, 2007; D. N. Cox et al., 2004; Otieno et al., 2013). However, severity, fear, and vulnerability from the PMT threat appraisal construct as well as exogenous elements knowledge and occupation had direct and significant effects on intention of biofortified foods. Still, other exogenous elements such as iodine intake status and presence of young children aged 6-12 years had significant effects, albeit indirectly.
These findings point to a more pronounced effect of threat appraisal combined with exogenous elements, which differs from earlier studies that demonstrated ‘coping’ appraisal as having the most important effect on intention to consume and nutritious foods (David N. Cox & Bastiaans, 2007; D. N. Cox et al., 2004).

Therefore, it is a precarious undertaking to ignore ‘threat’ appraisal as well as exogenous elements in the prevention of micronutrient deficiencies through biofortified foods such as IBVL. The combined effect of these elements is highly significant and important, which contradicts the conclusion that self-efficacy is the most important in health and nutritional promotion. Therefore, to increase protection motivations (intention) to consume a healthy diet or nutritious foods such as biofortified foods, communication of the ‘threat’ appraisal and exogenous elements is worthwhile. Programmes targeted to vulnerable groups both at the household and school levels (school feeding programme) should include these elements in their nutritional promotion campaigns and in launching novel preventive strategies such as biofortification.

The focus of the path analysis modelling in the current study was to assess elements that influence and predict protection motivations (intention) to consume nutritious foods, particularly biofortified foods (Table 10). However, two-limit Tobit modelling (Table 11) was used to evaluate the effect of endogenous and exogenous variables to the PMT model that influence protection behaviours or preference for adopting biofortified foods (in this case IBVL). The preference was presented as a willingness-to-pay component when the biofortified product was offered at a premium or discount at both the school and household levels. An attempt was also made to examine the elements influencing preference for this product for inclusion in a school feeding programme.

Results from Table 3 show that households are willing to pay an average US $1.89 (premium, US $0.39) and US $1.72 (premium US $ 0.22) for IBVL meal and inclusion of IBVL into a school feeding programme to protect their children. Consequently, school heads are willing to pay US $1.84 (premium US $0.34) L and US $1.67 (US $0.17) for IBVL and inclusion into a school feeding programme, respectively. However, when the product was offered at a discount, parents were willing to pay US $0.98 (discount, US $0.52) and US $0.67 (discount US $0.83) for IBVL and inclusion into a school feeding programme, respectively. These results demonstrate a willingness-to-pay a premium and acceptance by both the parent and school for accruing nutritional benefits. This is consistent with earlier studies examining willingness-to-pay for foods with health benefits, particularly nutritional benefits (David N Cox et al., 1998; De Groote et al., 2011; H. De Steur, Gellynck, Feng, et al., 2012; Gonzalez et al., 2009; J. Meenakshi et al., 2012). Respondents were willing to accept fewer discounts when the iodine biofortified product was offered at a discount due to the envisaged nutritional benefits, albeit more at school level than in households due to the attachment of children to their parents.

Table 11 shows results from the Tobit model. A total of two sets of Tobit models were developed. First, model estimated exogenous and endogenous PMT variables influencing preference for IBVL when offered at premium. Protection motivation (behavioural intention) was the most important factor that directly and significantly influenced willingness-to-pay for iodine biofortified foods at both the household and school levels. At the household level, other elements, severity, and gender were very significant. However to include the product into school meals, response (product) efficacy and country of the household are important at the household level, whereas response cost was important at the school level. These results are in tandem with previous findings examining the link between protection motivations (intention) and resultant protection behaviour (preference as defined by willingness-to-pay) in regard to health intervention (in this case Biofortification) (Park et al., 2011; Prentice-Dunn & Rogers, 1986; R. W. Rogers, 1983). Therefore, these elements should form part of health and nutritional promotion programmes for prevention of micronutrient deficiencies, in this case IBVL for iodine deficiency and improved school performance.

For instance, households are likely to pay a premium to protection their children from iodine deficiency disorders and improve their performance if nutritional campaigns communicate the severity of the threat, and mothers are more involved and their motivation towards the proposed product is high. In essence, schools are likely to pay more when convinced that proposed behaviour will protect their children against iodine deficiencies and improve school performance. Second, a model evaluated exogenous and endogenous PMT variables influencing the preference for IBVL offered at a discount at both the household and school levels. Severity, fear, response efficacy, and iodine status were the most important and significant factors influencing preference for IBVL when offered at a discount to households. When the product was offered at a discount at the school level, vulnerability, fear, gender, and age were the most significant factors. However, for inclusion of the product into the school feeding programme, households are likely to accept that it can be significantly influenced by vulnerability, response efficacy gender, age, decision maker of the household, and the country in question. While the amount of discount schools are likely to accept in order to include the IBVL into the school feeding programme, in the long-term is a function of severity, response efficacy, knowledge level, and age of the respondent.

These findings are consistent with earlier results that have examined willingness-to-pay for nutritious foods (in this case biofortified foods), particularly in resource poor countries (De Groote et al., 2011; Gonzalez et al., 2009; J. Meenakshi et al., 2012). When nutritious products were offered at a discount, the protection behaviour (preference) was shown to be a function of the health threat and socioeconomic factors such age, gender, and knowledge level. Consumers, at either the household or school level, were more likely to accept fewer discounts (pay more for the proposed prevention measure) if the health threat in question was more important to them and their children. Therefore, these elements should be incorporated into nutrition campaigns to be successful.

Although consumers are likely to pay for various discounts depending on the perceived value of the product and its health benefits, they are not likely to composite taste for health (Verbeke, 2006). These findings points to the fact that households are more sensitive to health threat and are likely to accept a lesser discount in order to protect their children.

In principle, our results extend earlier findings and contribute to the growing body of literature on the prevention of micronutrient deficiencies through biofortification. The findings point to the growing need to consider endogenous PMT variables, particularly ‘threat’ appraisal constructs as well as exogenous elements such as age, gender, and knowledge, in decision-making and in designing nutritional intervention campaigns for micronutrient deficiencies. The preference (willingness-to-pay) and factors that influence this protection behaviour are very important in understanding the adoption of biofortification as a novel strategy in prevention of micronutrient deficiencies (Birol, Meenakshi, Oparinde, Perez, & Tomlins, 2015; H De Steur et al., 2014). These demonstrate the importance of enhancing policies for establishing local markets for iodine biofortified food and subsequently improving their availability.

Since consumers are willing to pay more for biofortified products, such as IBVL, these findings are central to guiding policy formulation targeted to the entire agro-food chain as well as producers (farmers) and investors. Equally, the level of discount acceptable by consumers to protect themselves and their children through biofortification is fundamental to governments, investors, implementers of programmes, and donors in regard to the level of subsidy and policy framework necessary. In essence, the policy direction reflected from these findings points to the potential of biofortification in prevention of micronutrient deficiencies as well as growth of the rural economy around school feeding programmes.

Therefore, if IBVL have potential to minimize iodine deficiency and improve school performance in children, a systematic strategy should be formulated based on these and other findings, which hinge on the delivery system, particularly through school feeding programmes and household food consumption. The proposed delivery system should focus on pricing, marketing, and distribution and take into account protection motivations and preference (willingness-to-pay) at both the household and school levels.

Chapter 6 Experimental Auctions: A Methodological and Empirical Exploration of Willingness-to-pay for Iodine Biofortified Food

This chapter is established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Integration and Validation of an SMS-Based Bidding Procedure of eliciting Consumers' Willingness-To-Pay for Food. *British Food Journal.* **(In press)**

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Experimental Auctions to Measure Willingness to Pay for iodine Biofortified Food: A Methodological and Empirical Approach. *Agribusiness: An International Journal, Under review*.

Abstract

Preference for micronutrient rich food is increasingly used as a means of ascertaining the value consumers attach to foods that improve their health. This paper evaluates the preference for iodine biofortified food using the Becker-Degroot-Marschak (BDM) method. An attempt is also made to validate the use of the short messaging service (SMS) in BDM auctions. We conducted a longitudinal auction, with a sample of 180 participants from open-air markets in 3 different locations in East Africa. Data on willingness-to-pay was collected using standard BDM and SMS-based BDM in five treatment scenarios. In addition, socio-demographics, trust, attitude, and product characteristics were collected.

Results provide insights into the impact of different treatments on willingness-to-pay and communicating an individual's iodine status has a more significant effect than using production and product characteristics. SMS-based bidding was found to yield high validity values and could consistently be used for accurate results in the most convenient, attractive, faster, cheaper, and reliable way. This is in line with novel ways of purchasing food. Evidence points to the potential of technologically sound systems in conducting experimental auctions and highlights the importance of communicating iodine status, health benefits, and improvement methods when launching nutrition intervention programmes that utilise biofortified food.

6.1 Introduction

Iodine deficiency, together with the resulting series of functional and developmental abnormalities - the iodine deficiency disorders (IDD) - are considered to be a major global public health challenge (François Delange, de Benoist, Pretell, & Dunn, 2001; Swanson & Pearce, 2013), particularly in the developing world (De-Regil & Initiative, 2014; François Delange et al., 2001; Michael B Zimmermann, Jooste, & Pandav, 2008). This is of particular concern in rural landlocked locations in Sub-Saharan Africa (Peterson, 2000). Inadequate intake of iodine is associated with numerous conditions, mostly involving the functionality of the thyroid gland. These include goitre, hypothyroidism, impaired growth, stillbirths and miscarriages (Carlé et al., 2014; Chung, 2014; Lopes et al., 2012).

Nonetheless, the primary motivation for the current global campaign to eliminate iodine deficiency is its devastating toll in terms of brain damage and associated mental and neurological disorders (François Delange et al., 2001; Prado & Dewey, 2014; Redman, Ruffman, Fitzgerald, & Skeaff, 2015). These factors are often associated with poor school performance and economic advancement (Halim, Spielman, & Larson, 2015).

Furthermore, over 35% of the population in developing countries still live in iodine deficient areas (Dunn, 1996; Gaitan & Dunn, 1992; Müller & Krawinkel, 2005), making them more susceptible to iodine deficiency disorders despite the successes recorded with salt iodization and iodine supplementation (Michael B Zimmermann, 2014). The latter is an expensive venture for iodine deficient areas where salt iodization is ineffective (Angermayr & Clar, 2004; Fiore, Tonacchera, & Vitti, 2014). Therefore, the potential for novel strategies, such as biofortification, needs to be explored. Radical change can be achieved if such strategies are adopted and utilized by stakeholders in these endemic areas (H. De Steur et al., 2015; Johnson et al., 2015; McDermott, Johnson, Kadiyala, Kennedy, & Wyatt, 2015; Stein, 2014).

Biofortification is the process of increasing the nutritional value of the most frequently consumed/staple food to improve their micronutrient content e.g. iodine (Stein, 2014; Sully, 2014). Consequently, iodine biofortification is the process of increasing the iodine content of staple crops and subsequently overall nutrition when consumed by the target group (Fiedler & Puett, 2015; Johnson et al., 2015). Numerous procedures exist for this purpose, including both transgenic and conventional methods (Maria L Loureiro & Bugbee, 2005; Sully, 2014). Nevertheless, with regard to iodine biofortification, this process is at an early stage and more attention needs to be given to its overall implementation with at risk populations in iodine deficient areas. Additionally, there is limited understanding of consumer reaction to these products, particularly those highly susceptible to iodine deficiency (H. De Steur et al., 2015), and no evidence exists on their actual willingness-to-pay for iodine biofortified food.

The current study analysed the preference for iodine biofortified food particularly among the most vulnerable groups living in rural, landlocked and iodine deficiency endemic areas of three East African countries: Kenya, Uganda and Tanzania. According to ICCIDD (2014), a global body tasked with monitoring trends in iodine deficiency, these locations constitute some of the hardest hit areas in the world, with the unprotected population standing at 36% (Kenya), 25% (Tanzania), and 16% Uganda.

A well-established experimental auction procedure, Becker-Degroot-Marschak (BDM), was used for this analysis (Becker et al., 1964). The Becker-Degroot-Marschak (BDM) auction, named after three researchers, Gordon M. Becker, Morris H. Degroot and Jacob Marschak for their work entitled 'Measuring Utility by a single- Response sequential method' (Becker et al., 1964), is a specific type of auction and the only one that measures WTP on an individual basis (Breidert et al., 2006). Since its inception, it has been widely used in experimental economics to measure WTP (Breidert et al., 2006; K. M. Miller et al., 2011; Noussair et al., 2004), especially in developing countries and a resource-poor context (De Groote et al., 2011), notwithstanding several improvements and variations (Berry et al., 2011; Keller et al., 1993). This procedure is an example of an incentive compatible method, whereby participants submit a bid for an auctioned item and then a market price is randomly determined by drawing from a uniform distribution of prices (Keller et al., 1993; Jayson L Lusk et al., 2004; Noussair et al., 2004). The participants are obliged to purchase the item if their bid is equal to or above the market price, albeit they are only required to pay the market price for the item (Berry et al., 2011; Kaas & Ruprecht, 2006).

In addition, attempts have been made to integrate an SMS system with BDM to improve its effectiveness and coverage in a faster, cheaper, technologically sound and safer way. SMS, commonly known as ‘text messaging’ (Gayomali, 2012; Kew, 2010; Trosby et al., 2010), is the process of sending text messages through mobile phones and the web and is gaining support for application in behavioural and economic research (Kew, 2010; Reimers & Stewart, 2009). According to the world bank, this is one of the innovative pro-poor systems widely adopted in the developing world (Kew, 2010; Manji, Jal, Badisang, & Opoku-Mensah, 2015; World_Bank, 2014), which is a key motivation for our current study. To our knowledge, this is the first attempt to apply and validate this procedure for elicitation of willingness-to-pay (WTP) in experimental auctions. A standard protocol commonly used in validation of medical diagnostic tests (Budczies & Kosztyla, 2012; Mayasari & Lestariana, 2014; ten Bosch & Angmar-Mansson, 2000), was used to validate the integration of the SMS system into the standard BDM procedure.

Five treatment scenarios, were presented to participants to assess their overall influence on the preference/overall willingness-to-pay for iodine biofortified food: First, the product and product characteristics, the composition of a food product and its general characteristics has a bearing on the willingness-to-pay for it (Simonson & Drolet, 2004), including foods with additional nutritional benefits (De Groote et al., 2011; H De Steur et al., 2013; Oparinde, Banerji, Birol, & Ilona, 2014; Roosen et al., 2015; Xue, Mainville, You, & Nayga Jr, 2009a) or functional benefits (Nakaweesa, 2006). Iodine biofortified products and their characteristics are no exception to this. Second, the health threat is important. Research shows that the presence of a deficiency or vulnerability, fear and its severity have a significant effect on the reactions of stakeholders/consumers (H. De Steur et al., 2015). Therefore, it is important to understand how the health threat to vulnerable groups can influence their willingness-to-pay for iodine biofortified food. Third and fourth, the type of product improvement, points to a surfeit of evidence that consumers’ willingness-to-pay for food varies between conventionally and genetically modified products. (Bredahl, 2001; Costa-Font et al., 2008; Gifford, Bernard, Toensmeyer, & Bacon, 2005; Kontoleon, 2003; Maria L Loureiro & Bugbee, 2005). Previous research points to divergence between conventionally biofortified and genetically biofortified products (Costa-Font et al., 2008; Larue, West, Gendron, & Lambert, 2004; Maria L Loureiro & Bugbee, 2005; Naico & Lusk, 2010). It is important to estimate the influence of these two elements on the overall willingness-to-pay for iodine biofortified food. Fifth, the health and in particular nutrition status of an individual influences their reaction towards food meant to restore their optimal nutrition (Batte, Hooker, Haab, & Beaverson, 2007; Capps Jr & Schmitz, 1991; Nakaweesa, 2006; Xue, Mainville, You, & Nayga Jr, 2009b). It is therefore important to explore the impact of a low or high iodine status to the willingness-to-pay for iodine biofortified food when offered to consumers who are vulnerable to IDD.

In addition to the five scenarios, it is important to understand the overall attitude of the target groups towards iodine biofortified food and their trust in the key sources of information and institutions in the healthy food value chain as an alternative for preventing IDD. Attitude is often a positive or negative evaluation of people, objects such as food, events, activities, and ideas (Pickens, 2005) and it is important to explore people's overall attitude towards iodine biofortified food and other novel products to explain the volatility of willingness-to-pay, as demonstrated in previous research (Bredahl, 2001; Hossain & Onyango, 2004; Moon & Balasubramanian, 2004). According to Daniel Katz (KATZ, 1960), attitude serves particular functionalities for individuals or groups, and it is important to understand why individuals or groups hold particular attitudes or attitudes in general. Therefore, this research shows that attitude serves four different functions including: instrumental, adjustive or utilitarian; ego-defensive; value-expressive; and knowledge.

Therefore, the functional view of attitudes suggests that for attitude change (via persuasion to adopt or buy biofortified food); appeals ought to be made directly to the function(s) that a particular attitude serves in respect of the target individual or group. To understand this phenomenon in relation to attitudes towards food, researchers have developed a number of different tools. However, with regard to iodine biofortified food, the most appropriate tool is the food neophobia scale, which seeks to determine the degree of reaction, such as fear, towards a given food i.e., iodine biofortified food (P. Pliner, 1994). The scale is often presented as 10 statements about the food and scaled on a 5 point Likert scale.

On the other hand, trust, which is one of the key under-developed constructs used extensively in social sciences, describes a psychological state of an individual or group (Dierks & Hanf, 2006; Ding, Veeman, & Adamowicz, 2013; Lewis & Weigert, 1985). In this study, we attempt to explore the significance of trust in the sources of information about the biofortified food, as well as trust towards institutional players as key players in the food supply chain. Accepting the version of definition offered by Rousseau et al. (1998) , that "trust is a psychological state that comprises the intention to accept vulnerability based upon positive expectations of the intention and behaviour of another''. Therefore, the word trust indicates that a promise, either verbally or otherwise, can be relied upon. In the current study it is important to understand the dictate of the information sources about biofortified food and trust in the institution presenting the information about biofortification. These elements have been found to present significant influence over the overall willingness-to-pay, when the product is offered in the market (Roosen et al., 2015). It is crucial to explore and provide an understanding as to the overall character of trust towards willingness-to-pay for iodine biofortified food, particularly in resource-poor countries.

In the next sections of this study we present: the methodology for both the validation and the experimental auction; the results and discussion as well as the limitations; and the practical implications of this study, the conclusions as well as recommendations for future research.

6.2 Subjects and method

6.2.1 Case study characteristics

The study was carried out in inland, resource-poor, landlocked and mountainous areas, often far from the sea and other water bodies, in three East African countries: Kenya, Uganda, and Tanzania. Iodine deficiency is endemic in these locations owing to the limited availability of iodine-rich food such as seafood and aquaculture products, as well as iodine depleted soils which result in low iodine levels in locally available food (Dunn, 1996; Gaitan & Dunn, 1992; Vitti, 2008). According to ICCIDD (2014), over the last decade these locations have suffered some of the highest levels of iodine deficiency disorders, despite numerous supplementation and salt iodization programs (François Delange et al., 2001; Fiore et al., 2014; Müller & Krawinkel, 2005; Michael B Zimmermann, 2014).

In particular, the study targeted key districts of Kisoro (Uganda), Busia (Kenya), and Arusha (Tanzania) which have recorded the highest levels of IDD according to the latest findings by ICCIDD (2014). In Sub-Saharan Africa, the East Africa region is considered to have some of the poorest and most vulnerable groups and one of the highest growth and malnutrition rates in the world (De-Regil & Initiative, 2014; Müller & Krawinkel, 2005). Again, according to the global hunger index (GHI) published regularly by the International Food Policy Research Institute (IFRI), this region is classified as one of the hardest hit areas with the hunger situation being classified between extremely alarming to very serious over the last two decades (IFPRI, 2015). Additionally, even in the case of iodine-rich food, high food prices have often hit the highest level of almost 70% leading to high levels of malnutrition, both in terms of micronutrients, protein and calorie deficiency (Meerman & Aphane, 2012), again compounding the problems in the region.

6.2.2 Subjects and study design

A longitudinal panel study (Cherry, 2015; Laurie, 2013) was conducted among household decision-makers from randomly selected open-air markets in East Africa (Annex 9). The interviewer approached the participants and introduced himself as a researcher with a local University based in the region. The participants were asked for their participation and it was verified that each participant was an adult and a key decision maker regarding foods consumed in their household. After completing the general sections of the questionnaire covering general information, socio-demographics, and the food product used in the study, as well as its current market value/price, the group was split into two for the experimental auction. A two-level between-participant design was used to randomly assign participants to one of the two elicitation procedures, elicitation by standard BDM (Becker et al., 1964) and elicitation via SMS-based BDM.

Variable descriptions and summary statistics for experimental auction participants and their households are presented in Table 13. We report sample means and standard deviation for continuous variables while frequencies and percentages are reported for dichotomous variables.

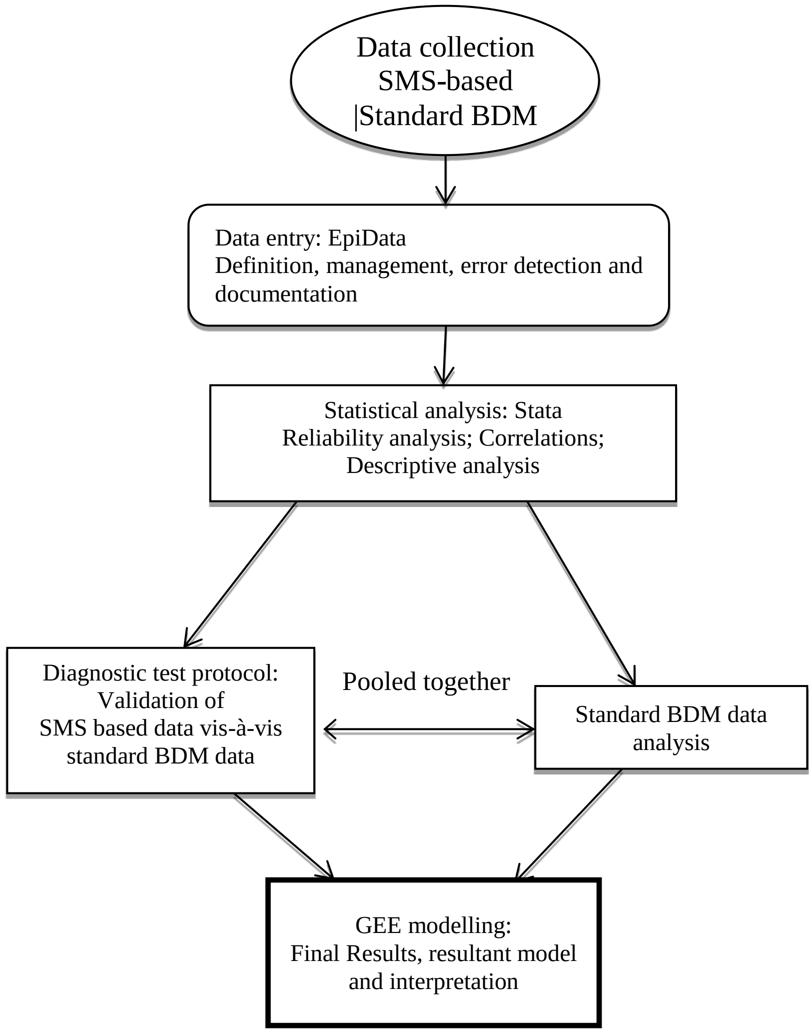


Figure 11 Study flow diagram for experimental auction on consumption oriented stakeholders

6.2.3 Experimental auction design and procedure

180 randomly selected household decision makers participated in the auction study, with 90 participants each for standard-BDM and SMS-based BDM. We ensured comparability and control for stable conditions for the study when running the experiment in four major ways: conducting the study at the same time interval, in the same weather conditions, with the same interviewer and SMS number and an equal sample in each group. Five auction rounds were conducted in each of the groups, albeit with different information treatments and presentation formats, standard or SMS-based BDM. The five scenarios created for the auction are described in table 12.

Table 12 Auction treatment scenarios depicting the prevailing market conditions that influence WTP for iodine biofortified food

Scenario	**Variable**	**Description**	**Assessment**
Scenario 1	Product characteristics	Provide general information about the product used for this auction and its general composition without exposing them to how the iodine was included (see scenario 3 and 4)	The participants were provided with general information on the biofortified food and were asked how much they are willing to pay more for the product compared to the ordinary product.
Scenario 2	Health threat	Provided a statement on what happens in the case of deficiency, symptoms and overall impact of iodine deficiency	Participants were exposed to information about the health threat associated with low intake of iodine and were expected to place/formulate a bid.
Scenario 3	Type of product improvement	GM product improvement-biofortification	Information on transgenic technology (GM) to improve the nutrient contents of staple food was given to participants and they were expected to formulate a bid afterwards.
Scenario 4		Conventional product improvement-biofortification	The participants were exposed to alternative forms of biofortification, using existing knowledge and asked to formulate a bid.
Scenario 5	Iodine intake level	The iodine intake status of the participants and their household.	The iodine intake levels were collected as the intake of certain types of food rich in iodine, on a 3-day recall type of questioning and participants were categorized as either low, moderate/normal to high intake, after which they were expected to place a bid on iodine biofortified food

BDM procedure: Although there have been many variations of BDM elicitation since its inception, we used one common way of allowing the participants to formulate a bid on the product at each level of treatment scenario and then compared the bid with a randomly determined price (Keller et al., 1993). If the subjects' bids are higher than the price, they are obliged to pay the price and receive the product, otherwise they pay nothing and receive nothing (Becker et al., 1964; Keller et al., 1993; Noussair et al., 2004). We recorded the final price offers, the random price at each level and compliance with the purchase obligations for each participant.

BDM auction versus SMS-based BDM auction:

In comparing the two procedures used for data collection, we applied indices commonly used in the medical field to evaluate the performance of a new diagnostic test against a Gold standard (Mayasari & Lestariana, 2014; ten Bosch & Angmar-Mansson, 2000) (normally an existing clinical method). These included: Sensitivity, Specificity, Precision or Positive predictive value (PPV), Negative predictive value NPV, Positive likelihood ratio (LR+) and Negative likelihood Ration (LR-). Post-test probability plots were also generated from the sensitivity values given for the positive and negative values of willingness-to-pay, around a randomly generated market value for each scenario created during the auction.

In the SMS-based BDM auction, a cheap talk script was first read to participants to ensure they responded truthfully to the auction (Silva, Nayga Jr, Campbell, & Park, 2011). Instructions were read to the participants and a test / demonstration auction conducted using an ordinary product without any specific treatment or obligation to pay. In each round, the participants were provided with product characteristics for a pack of vegetable legumes for their household and asked to formulate a bid. A random price was generated from all the participating centres and participants with a bid higher than this price were obliged to pay and take the pack, and vice versa. The procedure was repeated for each of the other four treatments: health threat (Scenario 2); product improvements [GM (scenario3) and then conventional (scenario 4) biofortification]; and their iodine status (scenario 5). At each level of treatment, the participants were asked to place a bid which was then compared with a random price generated for that particular product characteristic, with an obligation to pay, at least the market price of the product.

SMS-based auction: We followed the standard BDM procedure as described above. However, in the SMS-based BDM the auction was conducted through SMS (Gayomali, 2012; Kew, 2010). In the first instance, a cheap talk script was sent as a text followed by a second text providing short instructions about the auction. Then, the first round provided the product characteristics and the participant was asked to formulate a bid. A random price was then determined and only those participants whose bid was higher than the price were sent an SMS to pay for the product they had won. The procedure was repeated for the other four treatments and a participant was only obliged to pay if they won the bid.

6.2.4 Attitude and trust on sources of information and institutions

Numerous measurements and scales have been used to examine attitudes towards food. This is often because attitude is a difficult element to measure due to its arbitrary nature, meaning participants have to give a scale to measure attitude, and the hypothetical nature of attitudes means that its constructs cannot be observed directly (Lubian, 2010). Therefore, there are both direct and indirect measures for examining attitudes towards novel foods such as biofortified food (Nakaweesa, 2006). In the current study the food neophobia scale (FNS) was used to assess the overall attitude of auction participants (P. Pliner, 1994). The FNS scale consisted of a list of ten statements on the different characteristics of the product and the participants were asked to rate their perception and feeling about each particular statement on a 5 point Likert scale and all the responses were collected for analysis.

Trust, on the other hand, plays a very vital role in decision making about novel products, such as biofortified food, where there is uncertainty. More often than not, it is based on the expected behaviour of the key stakeholders and institutions (Lewis & Weigert, 1985; McEvily, Radzevick, & Weber, 2012). Despite the fact that, in the social sciences, trust is mostly determined by attitudinal questions, in this study we use choice-based metrics which are very commonly used by consumer research scientists and economists (McEvily et al., 2012). Thereby, in determining the influence of trust on the willingness-to-pay for biofortified food, participants were asked to rate the level to which they trust the key institutions, as well as the sources of information, about biofortified food including: the food industry, scientific community, professional experts, pharmaceutical industry, authorities, and others. All the responses were then recorded for analysis.

6.2.5 Data entry and statistical analysis

The EpiData platform was used to document the responses collected from the auction and analyses were conducted using STATA software for statistical analysis (version 12) (Hamilton, 2012). Sample means and standard deviation were used to report continuous variables, while frequencies and percentages were reported for dichotomous variables. As there were no significant differences between the two procedures, the data was pooled together and used in the subsequent analysis. It would be otherwise inevitable to use data from the traditional BDM procedure, which is well underpinned in research.

The second part of the analysis involved the descriptive and correlation analysis for all the variables in the study, using the Stata statistical package release 12. The Spearman`s correlation analysis was run to assess the relationship between willingness-to-pay and all the variables included in the study, as well as the relationships between the variables themselves (Research, 2013). Spearman`s correlation was considered over Pearson`s correlation, in that the later requires conformity with the principle of linearity for all variables and is silent on non-parametric variables, which was not the case for the collected data.

Selection of statements, from the FNS which had the highest contribution was done using Cronbach’s alpha (Tavakol & Dennick, 2011). The statements that produced high alpha values were selected and factor analysis was subsequently applied to pool the significant statements and obtain an overall attitude value, for the participants, towards biofortified food. These values and the overall distribution in the study regarding participants’ attitudes towards biofortified food was summarized using dot plots and also included in subsequent modelling of the study variable against the WTP. A dot plot is a statistical chart that consists of points on a fairly simple scale, commonly using filled in circles. In the current study, the points represent the participants’ attitude levels for a list of statements presented regarding biofortified food. We used a version of dot plot commonly used in consumer research and described by William S. Cleveland (1993). These charts represent the distribution of attitude levels obtained from the FNS and plotted on a single scale. The dot plot has wide application for both continuous, qualitative and univariate data and requires labelling accordingly. In addition, factor analysis was conducted on trust in the institutions and information sources about the biofortified product to predict overall trust subsequently included in the GEE model and to determine its influence on willingness-to-pay for iodine biofortified food.

Kernel density estimation (KDE) (Botev, Grotowski, & Kroese, 2010) were used to analyse and present the strength of willingness-to-pay for biofortified food for each scenario. This estimation is a non-parametric process that provides the overall density function for a given variable. The construction of this type of estimation often has diverse interpretations, even in other fields outside density estimation and statistics, including consumer research and economics. Nevertheless, the findings in this current estimation were presented as kernel density estimates which highlight the strength of willingness-to-pay for biofortified food as a result of the respective scenarios created in the auction.

Finally, a generalized estimation equation (GEE) modelling was conducted to explain the elements that significantly influence the value of WTP across different treatment scenarios and correlated variables (Hanley, Negassa, & Forrester, 2003; Tan, 2009). For all the tests, a probability level of 0.05 and a 95% confidence interval were used for ascertaining significance levels (Ballinger, 2004).

6.3 Results

6.3.1 Variable definitions and descriptive statistics for auction participants

The results for variable definitions, descriptive statistics for auction participants and their households are presented in Tables 12 and 13, while table 14 presents details of validations comparing the two methods. In the validation there were no significant differences between the sample from the SMS-based BDM and the standard BDM ($p>0.05$). Therefore, the sample results presented are from a pooled sample from the SMS-based and standard BDM. 180 participants were included in this study and were responsible for an average of 5.6 out 7 (80%) of the decisions regarding food consumed in the households. There were more female, 95 (51.63%) than male participants.

The participants were all adults, approximately 45 years old with a relatively low level (0.30) of education (no formal education or having an elementary level of education). The majority of the auction participants were casual workers (45%) or self-employed (26%), with only a small proportion working for the government (20%) and the rest unemployed (9%). In terms of annual household income, based on the income of the household breadwinner, the majority lived on an average of less than 2 dollars/ day (0.21). In addition, the majority of the households had low iodine status as deduced from their dietary intake of iodine-rich food over the auction period.

Table 13 Descriptive statistics of the auction sample

Category	Variable	Description of the variables	Standard BDM (0)	SMS-BDM (1)	Total	P* /χ^2
Socio-demographics and sample characteristics	Sample size	0=field sample standard BDM 1= Integrated SMS-based-BDM (%)	90 (50)	90 (50)	180 (100)	0.05
	Gender (Female)	Gender of the participant (0=male; 1 female)	49 (52.13)	46 (51.11)	95 (51.63)	0.43
	Age	Participants age at time of Auction (years)	45.78±9.49	44.43±9.82	45.12±9.65	
	Education	Level of education of participant(0= Low-no formal education or elementary level 1=High-secondary/Tertiary/University	0.30± 0.46	0.31±0.47	0.30±0.46	0.41
	Occupation	Engagement of the participant Unemployed	9 (9.57)	7 (7.78)	16 (8.70)	0.34
		Casual worker	40 (42.55)	43 (47.78)	83 (45.11)	
		Self employed	24 (25.53)	24 (26.67)	48 (26.09)	
		Government worker	21(22.34)	16 (17.78)	37 (20.11)	
	Income	The income of the household breadwinner 0<2dollars/day>1	0.24±0.43	0.18±0.38	0.21±0.41	0.06
	HH decision Making and purchase Mean (SD)	The extent to which they decide on the intake of the food in the household (1-7 days)	5.63±0.88	5.58±1.10	5.60±0.99	0.33
	Nutrition status	The level nutrition affects their behaviour |(0=low to moderate, 1=Average and normal and high intake	0.13±0.34	0.2±0.40	0.16±0.37	0.05
Variables related to the product	Product and familiarity	The extent to which they know and have used the food product Common beans	17 (18.09)	14 (15.56)	31 (16.85)	0.34
		Lentils	45 (47.87)	51(56.67)	96 (52.17)	
		Runner beans	11 (11.70)	10 (11.11)	21 (11.41)	
		Velvet beans	15 (15.96)	9 (10.00)	24 (13.04)	
		Others: cowpeas, chickpeas…	6 (6.38)	6 (6.67)	12 (6.52)	
	Ordinary Market price of food products (USD)	Average prices of the product in different markets in the region	1.21±0.02	1.21±0.02	1.21±0.02	0.47
	Baseline value for GM versus Conventional (USD)†	The value of GM products	1.21±0.03	1.21±0.03	1.21±0.03	0.68
		The market value of conventional products	1.19±0.03	1.20±0.03	1.20±0.03	0.00
	Attitude level	Attitude towards the product (pooled attitude level-FNS*) Attitude 1	5.64±0.8	5.56±0.94	5.60±0.87	0.26
		Attitude5	2.80±1.32	2.58±1.2	2.69±1.27	
		Attitude 6	5.31±1.23	5.20±1.17	5.26±1.2	
		Attitude 7	4.55±1.46	4.59±1.4	4.57± 1.42	
	Trust , N (%)	Trust sources of information Food industry	19 (20.21)	12 (13.33)	31 (16.85)	
		Science/Professionals	30 (31.91)	35 (38.89)	65 (35.33)	
		Authorities/Agencies	24 (25.53)	28 (31.11)	52 (28.26)	
		Pharmaceutical industry	14 (14.89)	10 (11.11)	24 (13.04)	
		Other: leaders, religious groups, activists	7 (7.45)	5 (5.56)	12 (6.52)	
Willingness-to-pay (WTP) for iodine biofortified food	WTP1: Scenario 1	Product characteristics	1.27±0.03	1.27±0.03	1.27±0.03	0.37
	WTP2: Scenario 2	Health threat treatment	1.29±0.04	1.29±0.04	1.29±0.04	0.24
	WTP3: Scenario 3	GM Biofortification	1.26±0.02	1.25±0.02	1.25±0.02	0.02
	WTP4: Scenario 4	Conventional biofortification	1.26±0.02	1.27±0.02	1.27±0.02	0.96
	WTP5: Scenario 5	Nutrition status= Iodine status treatment	1.27±0.02	1.26±0.02	1.26±0.02	0.98

*Notes:- * P value two group and mean comparisons testing: Significance levels: *P<0.05, **P<0.01, ***P<0.001; FNS) = Food Neophobia scale used to ascertain the attitude of the participants, this figure is then pooled together to predict the overall attitude; † Prices collected in local currency and converted to USD based on the latest exchange rate of (1$=KSh.92.00=Uganda shilling. 2500.00= Tanzania Shilling (TSHs). 1600.00); Sample SMS-based and standard BDM; Trust Sources of information and institutions presenting the information; Treatment rounds: - BDM=same questionnaire content, one at the field auction the other script sent through SMS and responses evaluated*

A dot plot presentation of the distribution of attitudes about biofortified foods drawn from a list of statements in the FNS are illustrated in figure 12. It is important to note that attitude levels for biofortified food were significantly higher for all the positive statements and lower for the negative statements. From the dot plot, it is clear that more than 65% of the responses about positive statements on iodine biofortified food ranged between agree to strongly agree (reference line 4.5) and vice versa for all negative statements.

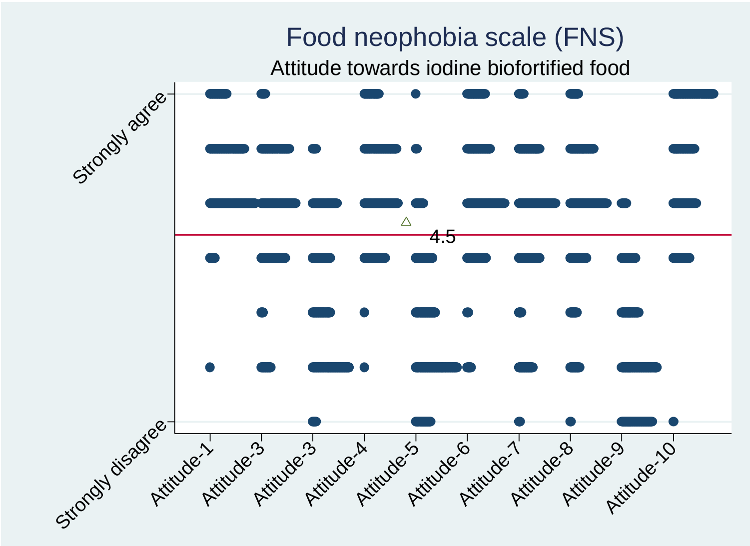


Figure 12 Trends in attitudes towards iodine biofortified food based on the Food Neophobia Scale (FNS)

6.3.2 Validation of SMS-based BDM Procedure

The results on the validation of the SMS-based BDM when compared to the 'gold' standard BDM are presented in table 14. The SMS-based elicitation exhibited high values for validity indices when its performance was compared with a standard BDM elicitation, including: Sensitivity (89%-95%), Specificity (63% to 73%), Precision (40 to 60), NPV (92 to 98), LR+ (2.6 to 3.3) and LR- (0.08 to 0.2). Additionally, the post-test plot indicates that the novel procedure is particularly consistent in ascertaining positive and negative valuations for a new food product.

In addition, post-test probability plots are presented in figure 13. The plots demonstrate that SMS-based BDM has a high probability of discriminating between the positive and negative outcome of a test around a specific cut-off value (random market value) i.e. it has a high probability of consistently and accurately identifying those willing to pay more for the product and those not willing to pay more for the product when offered at a given price value. This trend was consistent for all the five scenarios created in the auction.

Table 14 Validation of SMS-BDM performance against a standard 'gold' BDM procedure

Validity measure	WTP1	WTP2	WTP3	WTP4	WTP5
Sensitivity	0.893 [0.785 to 0.95]	0.939 [0.835 to 0.979]	0.939 [0.835 to 0.979]	0.857 [0.743 to 0.926]	0.947 [0.827 to 0.985]
Specificity	0.726 [0.641 to 0.797]	0.664 [0.58 to 0.739]	0.672 [0.588 to 0.745]	0.726 [0.641 to 0.797]	0.634 [0.552 to 0.709]
Precision or Positive predictive value (PPV))	0.595 [0.488 to 0.694]	0.511 [0.41 to 0.612]	0.511 [0.41 to 0.612]	0.585 [0.477 to 0.686]	0.409 [0.312 to 0.514]
Negative predictive value NPV	0.938 [0.87 to 0.971]	0.967 [0.907 to 0.989]	0.968 [0.909 to 0.989]	0.918 [0.847 to 0.958]	0.978 [0.924 to 0.994]
Positive likelihood ratio (LR+)	3.256 [2.411 to 4.397]	2.795 [2.174 to 3.593]	2.859 [2.221 to 3.68]	3.126 [2.303 to 4.244]	2.587 [2.058 to 3.253]
Negative likelihood Ration (LR-)	0.148 [0.069 to 0.317]	0.092 [0.031 to 0.278]	0.091 [0.03 to 0.275]	0.197 [0.103 to 0.377]	0.083[0.021 to 0.322]

*Notes: - Significance levels: *P<0.05, **P<0.01, ***P<0.001*

Therefore, the validity of the SMS-based BDM was not significantly different between the auction scenarios created (WTP1 to WTP). These findings demonstrate the accuracy and consistency of this procedure in determining willingness-to-pay, when compared with a well-established 'gold' standard procedure' (standard BDM). Therefore, the data from both procedures were pooled together in the subsequent analysis (GEE modelling), in this study.

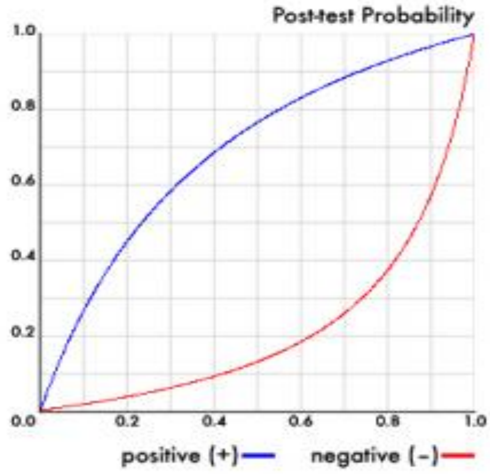
6.3.3 Results of the experimental auction and kernel density estimation (KDE)

a) Average WTP for IBVL during the five scenarios

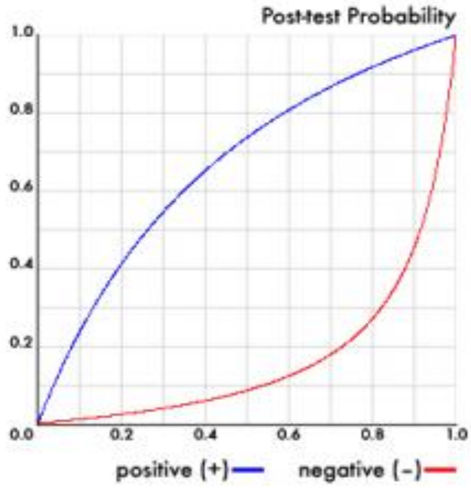
Table 13 summarizes the WTP for the five scenarios created during the auction. The average willingness-to-pay values do not differ significantly between the SMS-BDM and the standard BDM ($p>.05$), except for the WTP3 for the third scenario where participants were given information on GM biofortification as a way to improve the nutrient value of the crop ($p=.02$).

The average WTP1, when the participants were provided with product characteristics, was $1.27; WTP2, when participants were provided with information on the health threat relating to the nutrient deficiency it was $1.29; WTP 3 when GM biofortification was provided as a form of product improvement it was $ 1.26; WTP, when conventional biofortification information was provided as a form of product improvement, it was 1.26; and WTP 5, when the participants were informed of their iodine intake status, it was $1.26. The average auction bids were almost identical when participants were exposed to information treatment on product improvement, either GM or conventional, and their iodine status: WTP3=WTP4=WTP5.

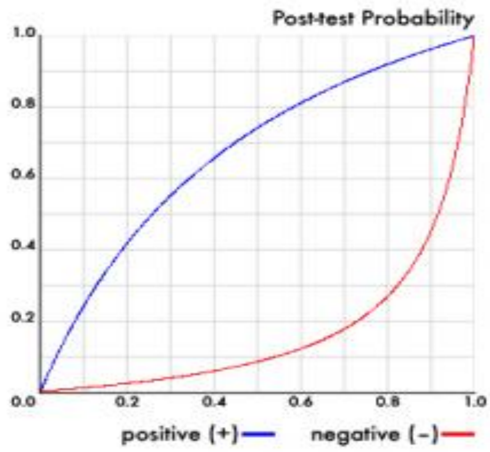
WTP1



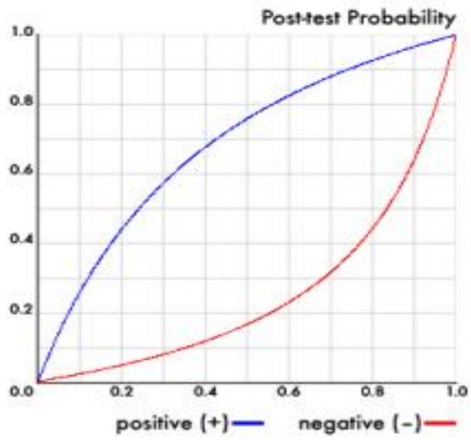
WTP2



WTP3



WTP4



WTP5

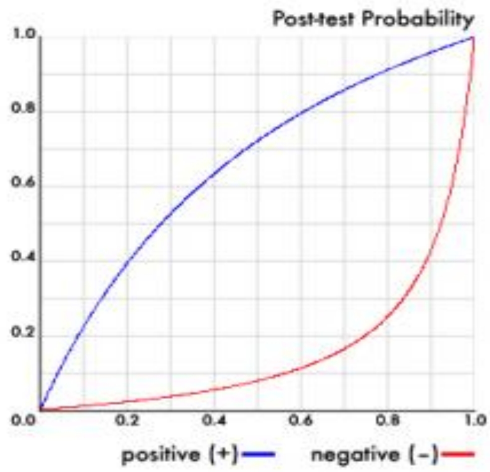


Figure 13 Post-test probability graphs for all treatment rounds comparing the SMS-Based BDM with the standard BDM during experimental auctions on consumption oriented stakeholders

b) Kernel density estimation of the willingness-to-pay (KDE)

The kernel density estimation (KDE) is shown in figure 14 below. In the current study, this density estimate function is equivalent to willingness-to-pay amount for biofortified product when presented at the respective auction scenarios created. The trend demonstrated by kernel density estimates for the willingness-to-pay obtained for each scenario around the market price of the biofortified product as the reference figure is shown to be around the market price of the product. Therefore the density is high when the willingness-to-pay is examined for scenario 3, 4 and 5, while scenario 1 and 2 produced very low KDE values.

The density estimates obtained show that each scenario varies in bandwidth in relation to the market price reference. Therefore, in scenarios 3 and 5, when GM as a method of production and the iodine status of the participants were respectively communicated, the KDE was very high. However, the willingness-to-pay was lower than the reference market price. Nevertheless, when information about the product characteristics, the health threat and conventional method of biofortification were communicated, the KDE was low, but this had significantly higher levels of WTP for the biofortified product. Therefore, Kernel density estimates are a clear way of demonstrating the trend in the willingness-to-pay for iodine biofortified products as a snapshot when different conditions prevail in the market.

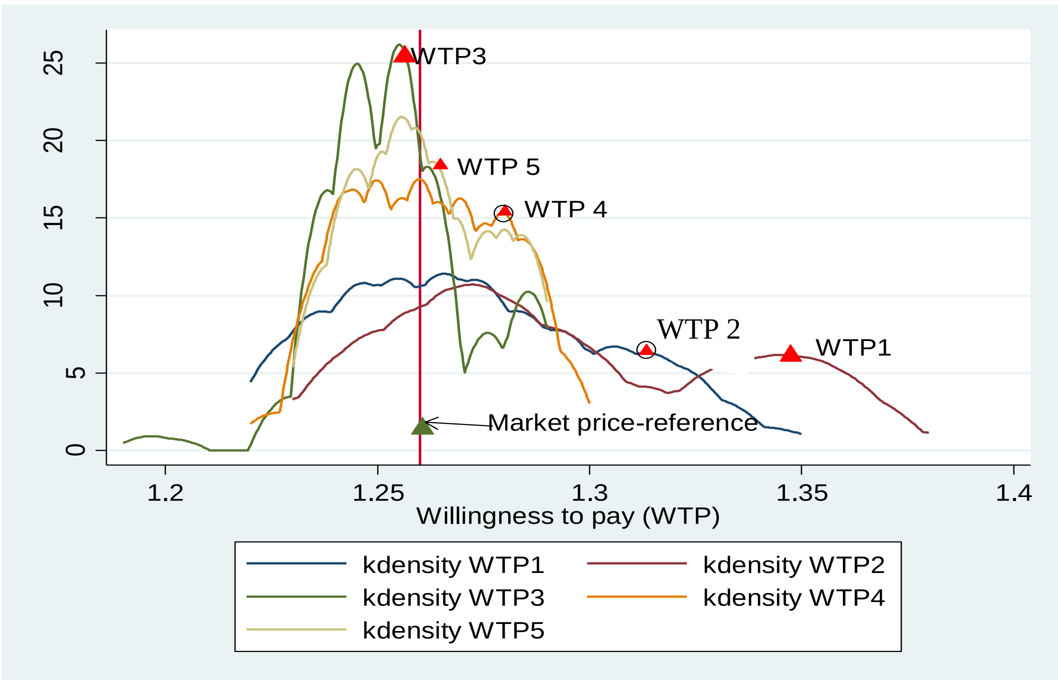


Figure 14 Kernel density estimation plot on average willingness-to-pay for iodine biofortified food for five different treatment scenarios: product characteristics, health threat, product improvement (GM or Conventional), and iodine intake status

6.3.4 Correlation of study variable for GEE modelling

The Spearman's correlations between all study variables included in the study, and for GEE modelling of WTP, are displayed in Table 15. The table shows that there were no significant correlations of the study variables in the first scenario (WTP1), when only the product characteristics were communicated to the participants. However, in the second scenario (WTP2), when the health threat was communicated, there was a strong positive correlation of the method applied in elicitation ($\mathbf{r_s}$ = 0.22, *p=0.01*), and the willingness-to-pay values.

Further, in the third scenario (WTP3), when the type of product improvement was communicated as GM biofortification, there were moderate and negative correlations between WTP and the local ordinary price of the product ($\mathbf{r_s}$ = -0.16, *p=0.05*), method of biofortification ($\mathbf{r_s}$ = -0.18, *p=0.05*), country in question ($\mathbf{r_s}$ = -0.17, *p=0.05*), as well as a positive correlation with occupation of the participant/household head ($\mathbf{r_s}$ = 0.15, *p=0.05*). In the fourth scenario (WTP4), when the method of product improvement was present as conventional biofortification, there was a moderate and negative correlation between the WTP and the gender of the household head ($\mathbf{r_s}$ = -0.15, *p=0.05*). In the last scenario (WTP), where participants were given their approximate iodine status (low or high), there was a strong positive correlation between the WTP recorded and the country of ($\mathbf{r_s}$ = 0.17, *p=0.05*), the household as well as a negative correlation with the familiarity of the product to the participant ($\mathbf{r_s}$ = -0.17, *p=0.05*).

Table 15 Correlation matrices of study variables relating to the five auction scenarios (WTP)

Variables	WTP1	WTP2	WTP3	WTP4	WTP5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Ordinary product market price	-0.03	-0.10	-0.16*	-0.03	-0.06	1.00														
2. GM biofortified market price	-0.06	0.12	0.06	-0.12	-0.08	-0.07	1.00													
3. Conventional product market value	-0.01	0.03	-0.18*	0.03	-0.08	-0.05	0.02	1.00												
4. Country	0.06	-0.07	-0.17*	-0.07	0.17*	0.20**	-0.04	0.00	1.00											
5. HH size	-0.01	-0.07	0.04	0.07	0.00	-0.05	-0.05	0.05	0.00	1.00										
6. Vulnerable children (6-12yr)	-0.12	-0.08	0.02	-0.10	-0.09	-0.05	-0.08	0.13	-0.22**	0.42***	1.00									
7. HH decision making	0.01	0.10	-0.05	0.01	0.00	-0.01	0.05	-0.02	-0.18*	-0.04	-0.07	1.00								
8. Age	0.07	0.01	-0.06	0.10	-0.01	-0.03	-0.09	0.04	0.07	-0.11	-0.15	0.09	1.00							
9. Gender	0.00	0.08	0.01	-0.15*	-0.02	-0.03	0.12	0.03	0.10	-0.11	-0.06	0.09	0.01	1.00						
10. Occupation	0.05	-0.05	0.15*	-0.04	0.03	0.01	0.04	-0.05	-0.02	0.13	0.12	-0.06	-0.06	-0.18	1.00					
11. Product familiarity	0.04	0.06	-0.02	-0.03	-0.17*	-0.02	0.04	-0.07	-0.01	-0.07	-0.02	-0.06	-0.03	0.12	-0.18*	1.00				
12. Trust (institution/source)	-0.04	0.0	-0.11	0.02	0.06	0.13	0.01	0.06	-0.03	0.02	0.01	-0.00	0.17*	-0.08	0.04	-0.02	1.00			
13. Education	0.01	0.11	-0.00	-0.08	-0.07	0.04	0.16*	-0.02	0.03	-0.09	0.04	0.02	0.04	0.06	0.04	-0.01	-0.02	1.00		
14. Income	0.01	0.14	-0.03	0.02	0.00	-0.09	0.07	-0.13	-0.02	-0.01	-0.01	0.07	0.04	0.00	0.07	0.01	0.01	0.01	1.00	
15. Iodine status	0.12	0.07	0.07	0.04	-0.03	0.05	0.08	-0.05	-0.13	-0.00	0.10	0.11	-0.01	0.05	0.12	-0.05	0.00	0.07	0.03	1.00
16. Sample	0.03	0.22**	-0.02	-0.06	-0.09	-0.02	0.05	0.07	0.00	-0.08	-0.05	0.01	-0.07	0.02	-0.03	-0.02	0.01	0.01	-0.08	0.11

*Notes: - Significance levels: *P<0.05, **P<0.01, ***P<0.001; HH: household; WTP: willingness-to-pay*

6.3.5 Generalised estimation equation modelling

Results of the GEE modelling can be found in table 16. For the first scenario of the auction, when participants were exposed to general information about the product and product characteristics, their iodine status significantly predicted their willingness-to-pay (WTP1) for iodine biofortified vegetable legumes (e=0.015, p<0.05). Further, when participants were exposed to information on the health threat associated with iodine deficiency (scenario 2), the household size significantly predicted their willingness-to-pay (WTP2). However, when participants were exposed to information on GM as a method of product improvement to increase iodine content (scenario 3), the country of residence, market price of the product and trust were the decisive determinants of their willingness-to-pay for iodine biofortified food (WTP3).

Table 16 Generalised estimation equation modelling of WTP for each treatment scenario

Variable	**WTP1**	**WTP2**	**WTP3**	**WTP4**	**WTP5**
Country	0.002	-0.002	-0.004*	-0.002	0.004*
HH size	0.001	-0.005*	0.001	0.002*	0.000
Children6to12yrs	-0.004	-0.000	-0.000	-0.004*	-0.002
HH decision making	-0.001	0.003	-0.002	-0.000	0.000
Age	0.000	-0.000	0.000	0.000	-0.000
Gender	-0.002	0.003	0.001	-0.005*	-0.001
Occupation	0.001	-0.004	0.002	-0.001	0.000
Product familiarity	0.001	-0.003	-0.000	0.000	-0.002*
Market price	-0.107	-0.120	-0.128*	0.006	-0.102*
Trust	-0.001	0.002	-0.002*	-0.000	0.002
Attitude	0.004	0.005	-0.002	0.003	-0.004*
Education	-0.000	0.004	-0.001	-0.002	-0.002
Income	-0.001	0.009	-0.002	0.001	0.000
Iodine status	0.015*	0.005	0.002	0.002	-0.001
Wald chi2 (14)	13.64	19.23	22.95	17.22	20.39
Scale Parameter	0.00	0.00	0.00	0.00	0.00
Prob > chi2	0.4766	0.1564	0.0610	0.2445	0.1183

*Notes: - Significance levels: *P<0.05, **P<0.01, ***P<0.001; HH: household; WTP: willingness-to-pay*

In addition, when participants were exposed to information on conventional procedures as a method of product improvement to increase iodine content, the household size, the participant's gender and the presence of young children in the household who are more vulnerable to iodine deficiency were significant predictors of willingness-to-pay (WTP4). Consequently, exposing the participants to the information on their overall iodine intake status, low or high, their attitude towards the product, product familiarity, the market price and their country of residence were significantly decisive in their willingness-to-pay (WTP5) for iodine biofortified food. Nevertheless, in all the scenarios created during the auction, other predictors included did not achieve significance. For the five models developed, Wald Chi2 values ranged between 13.64 and 22.95, even though they were not statistically significant (p>0.05). Therefore we accept the hypothesis that some of the predictors in the model were equal to zero and did not have any influence on the willingness-to-pay reported by the participants (Bruin, 2006).

6.4 Discussion

Understanding the preference for biofortified food is important in designing nutrition intervention programs geared to preventing iodine deficiency disorders (Angermayr & Clar, 2004; Peterson, 2000; Michael B Zimmermann, 2014), particularly among the at risk population (ICCIDD, 2014), living in iodine deficiency endemic areas where salt iodization and supplementation is largely ineffective (François Delange et al., 2001; Fiore et al., 2014; Halim et al., 2015; Peterson, 2000; Michael B Zimmermann, 2014). Adoption of new strategies, such as biofortification, in developing countries (Stein, 2014; Sully, 2014) is mainly influenced by the preference levels exhibited by the vulnerable target group (Birol et al., 2015; H. De Steur et al., 2015; Johnson et al., 2015). If the stakeholders' preference for this type of strategy is not well quantified and incorporated within the design of nutrition intervention programs, then biofortification will be unsuccessful as a strategy for preventing iodine deficiency (Johnson et al., 2015; Waized, Ndyetabula, Temu, Robinson, & Henson, 2015). Consequently, the procedures applied for this process need to be validated to ensure that the results are consistent and reproducible.

The findings from the current study were twofold. In the first instance, validation of the auction procedure was conducted to explore the potential for integrating technology-based systems i.e. the short messaging service (SMS), into the elicitation in experimental auctions, i.e. the BDM procedure, to improve validity in a faster, cheaper and technologically sound and safer way. Although, determination of willingness-to-pay has often employed experimental auction procedures that are well established and even numerous improvements for use in resource-poor countries (Morawetz, De Groote, & Kimenju, 2011), to our knowledge the integration of technologically driven systems is limited. An SMS system was integrated into the conduct of an experimental auction using BDM bidding.

The SMS-based procedures produced significantly high values of validity indices (see table 14). The procedure was also consistent in determining both premium and discount values, as demonstrated by the post-test plots around a given market price (see figure 13). These findings indicate that there are no significant differences between the standard BDM and the SMS-based bidding. Nevertheless the SMS-based procedure is more accurate, convenient, attractive, faster, safer, cheaper, technologically sound and safer compared to the standard BDM procedure. Therefore, the data collected with both standard procedures and the SMS-based procedure was pooled together for subsequent analysis of the willingness-to-pay. The findings of this validation are consistent with other validations of novel tests and procedures alongside existing procedures, more so in the medical field (Budczies & Kosztyla, 2012; ten Bosch & Angmar-Mansson, 2000), including Nutrition (Mayasari & Lestariana, 2014).

Nevertheless, to improve the applicability of this resultant SMS-based BDM procedure in consumer research it is inevitably important to determine its reliability in different contexts and its most effective use. To our knowledge, this is the first study to apply and test the validity and subsequent applicability of an SMS-based procedure in economic valuation studies, and in experimental auctions in particular (Jayson L Lusk, Alexander, & Rousu, 2007; Morawetz et al., 2011). Our study lends support for the validity of this method through several indicators: sensitivity, specificity, precision, NPV, LR+ and LR-, across five different auction scenarios, including product characteristics, health threat, type of product improvement: GM or conventional, as well as the nutrition (iodine) status of the consumer. The post-test probability plots further underline that the procedure can accurately and consistently ascertain the probability of those willing to pay more (premium) or less (discount) for the new product around a given random price cut-off.

This phenomenon is in line with the validation of medical tests to differentiate between those with a medical condition and those not affected (Budczies & Kosztyla, 2012; Mayasari & Lestariana, 2014; ten Bosch & Angmar-Mansson, 2000). Furthermore, one of the key limitations to the application of the SMS-based approach is that, not everyone had access to a mobile phone, the internet or other media for text messaging at all times during the auction. In addition, variations in real time responses and commitment to the auction make it difficult to observe strict timelines. However, the costs related to the actual presence of the interviewer are drastically minimized. In principle, this integration of the SMS system to the elicitation of preferences for a new product can be considered an important technologically driven step in experimental auctions to obtain accurate and consistent results in a faster, cheaper and reliable way. However, research is inevitable to validate the integration of SMS-based approaches in other elicitation procedures (e.g. group-based auctions), using different products and in varied settings. Therefore, the availability of free text messaging platforms, such as WhatsApp, Skype, and IMO for smartphones, as well as group messaging formats, can be considered as alternative mobile phone-based bidding procedures.

In the second instance of this study, we pooled the data from the two procedures, as informed by the validation protocol, to explore the trends in the willingness-to-pay for biofortified foods under different circumstances/scenarios. Willingness-to-pay for iodine biofortified food by vulnerable groups, living in iodine deficiency endemic areas, has been analysed for five different scenarios with the aim of establishing the potential of iodine biofortification as an alternative intervention for iodine deficiency disorders for these endemic areas.

The summaries of willingness-to-pay, presented using the kernel density plot, indicate the impact of each of the treatment scenarios created. (See figure 14). The kernel density estimates reveal that all the treatment scenarios contribute significantly to the bidding behaviour, in the form of WTP, exhibited by the target group. And each of the treatments led to some behaviour, i.e. WTP, which is significantly distinct from each other. These findings are consistent with previous studies that have demonstrated the volatility of willingness-to-pay behaviour in the presence of different information treatments

(Gifford & Bernard, 2011; Simonson & Drolet, 2004), including for food with additional nutrition benefits (H De Steur et al., 2013; Oparinde et al., 2014). Therefore, the five scenarios created, including: product characteristics; health threat; product improvement (GM or conventional); and the iodine status of the target group, depict the characteristics of an ideal market that has the potential to impact on the uptake of biofortification (Stein, 2014).

We used GEE to model the influence of this volatility in WTP for biofortified food across the five scenarios (Table 16). When participants are confronted with details on the biofortified product characteristics, their iodine status was significantly decisive with regard to their willingness-to-pay for the new product. All other variables did not achieve significance. This demonstrates that, when the nutrition benefits in the products are communicated to the target groups their willingness-to-pay is a function of their overall nutrition status, in this case their iodine status. These findings are in line with previous findings that have shown a direct correlation between the consumers` knowledge about a food product (product characteristics) and their willingness-to-pay for the product (Gil & Soler, 2006; Mesías Díaz, Martínez-Carrasco Pleite, Miguel Martínez Paz, & Gaspar García, 2012), particularly for nutrition-related characteristics (Hossain & Onyango, 2004) (Capps Jr & Schmitz, 1991; De Groote et al., 2011; Naico & Lusk, 2010). Therefore launching nutrition intervention campaigns to prevent IDD and communicating the product characteristics should indicate the available added value with regard to iodine. Furthermore, programs using iodine biofortified products should communicate the characteristic of the high level of iodine obtained through the biofortification process.

However, in scenario 2, when details about the health threat – iodine deficiency disorder - were communicated, the main concern to the participants was the number of people in the household (household size) that are susceptible to the deficiency. The higher the number of people susceptible to the health threat significantly and positively influences the WTP for biofortified food in order to protect them. Although other findings did not achieve significance, this finding is in tandem with previous research that has shown that the number of people in a household (household size) influences the willingness-to-pay (Radam, Yacob, Bee, & Selamat, 2010), more so for foods with health benefits (Batte et al., 2007; Capps Jr & Schmitz, 1991), albeit more in the case of nutrition benefits (De Groote et al., 2011; Nakaweesa, 2006; Xue et al., 2009a, 2009b).

Nevertheless, unexpectedly the findings did not discriminate for the presence of the most vulnerable groups, including young children in the household, in terms of the willingness-to-pay, which has been reported in other studies (J. Meenakshi et al., 2012; Segrè et al., 2013).Further, when participants were provided with information about how the biofortified food was produced their mixed reaction was based on the two methods of food production/improvement, either GM or conventional. Bids in scenario 3 are significantly reduced if GM technology was the method of product improvement (biofortification) compared to conventional methods of improvement/biofortification (scenario 4).

This is a very important finding, as it shows that there is a positive perception about conventional biofortification compared to GM technology. This is consistent with previous studies that have shown a preference for non-GM over GM technologies by consumers (Costa-Font et al., 2008), even when potential benefits are present (Gifford et al., 2005; Larue et al., 2004; Maria L Loureiro & Bugbee, 2005). The finding shows that communicating GM as a method of biofortification significantly reduced the WTP and was a function of country of residence, the market price at which the product is offered, and the level of trust in the key institutions and sources of information about GM technology. This finding is consistent with studies that have shown that reactions or attitudes towards GM vary between countries (Bredahl, 2001; Costa-Font et al., 2008; Mucci, Hough, & Ziliani, 2004), the market price (Costa-Font et al., 2008; Kontoleon, 2003) and trust in the information sources (Huffman, Rousu, Shogren, & Tegene, 2004) and institutions (Kontoleon, 2003; Moon & Balasubramanian, 2004).

However, when the conventional method of improvement/biofortification is communicated to the participants the bids significantly increase depending on the household size, and reduce significantly in the presence of young children in the household and also in terms of the participant's gender. With regard to the household size, this finding is consistent with previous studies that have shown household size increases willingness-to-pay for food to protect the household (Chowdhury et al., 2011). Nevertheless, the study contradicts earlier studies that have shown that the presence of vulnerable groups such as young children in the household increases willingness-to-pay for biofortified food (Chowdhury et al., 2011; Oparinde et al., 2014). This could be largely because the consumers often consider food items of a conventional nature to supply the complete range of nutritional needs and hence they see no reason to pay more for them.

In addition, the results are consistent with earlier studies that show gender is a critical element and that women are more concerned for the welfare of their children and the entire household than their male counterparts, which is why they are willing to pay more for biofortified products (Chowdhury et al., 2011; De Groote & Kimenju, 2008).Therefore, if iodine biofortification programs are to be successfully implemented it is important that they are also designed to target women.

Finally, when participants were examined and informed about their nutrition (iodine) status, the willingness-to-pay for iodine biofortified food was significantly volatile. The WTP increased significantly as a function of country of residence, but significantly declined based on product familiarity, market price for the product and the attitude towards iodine biofortified products. This finding is consistent with previous studies that have reported an increase in the willingness-to-pay for biofortified products in developing countries where there are more vulnerable people (Birol et al., 2015; Chowdhury et al., 2011).

In addition, the findings are also in tandem with studies that have shown the negative relationship between the market price for biofortified products, attitudes and product familiarity (Chowdhury et al., 2011; H. De Steur, Gellynck, Feng, et al., 2012; Gilligan, 2012; Qaim et al., 2007).

Therefore, when launching iodine biofortified food as part of nutrition intervention programs in these endemic areas, it is crucial to provide details of individual iodine status and to enlighten the masses about the different alternatives available, offer the product at pocket-friendly prices and focus on designs that boost their attitudes towards the product. The estimated trend in the value of WTP values when different conditions prevail in the target community are vital in launching iodine biofortification as an alternative nutrition intervention for iodine deficiency disorders among the vulnerable population, who are not protected by salt iodization and supplementation (François Delange et al., 2001; Fiore et al., 2014; Halim et al., 2015).

Uptake of this novel strategy by vulnerable groups, could make a substantial contribution to the fight against the devastating toll of iodine deficiency disorders in terms of brain damage and associated mental and neurological disorders (François Delange et al., 2001; Prado & Dewey, 2014; Redman et al., 2015). This is the primary motivation for the current global campaign. When launching iodine biofortification amidst the presence of salt iodization, in locations where consumers or vulnerable groups are well informed about the product with elevated levels of iodine, the overall information regarding their iodine status should be incorporated into the nutrition campaign as a means to increase their willingness-to-pay for the product. However, when information about nutrient (iodine) intake status is provided to the vulnerable groups other elements come into play, as shown by scenario 5.

6.5 Implications for future research and conclusions

The findings from this research present two broad viewpoints about a methodological and empirical approach on willingness-to-pay for iodine biofortified food. In the first instance, the findings from the validation of integrating a technological system, SMS, into the standard methods of elicitation of WTP demonstrates that an SMS-based approach can be used to strengthen the validity of BDM and provides a feasible, reliable, attractive, accurate, cheaper, technologically sound and safer procedure for conducting experimental auctions. These are crucial attributes for the conduct of consumer research and a breakthrough in the conduct of consumer research in resource-poor countries. Besides, it is an important contribution to the many limitations to data collection that are associated with standard BDM. The findings from the validation stage show that the SMS-based procedures compared favourably with the standard BDM. This points to the potential for replication of the procedure in other studies and opens an avenue for similar approaches to improve the effectiveness of standard procedures for conducting experimental auctions, particularly for novel products and services. This can improve research output and quality, not only in consumer research but also other fields sceptical to the dictates of technology in modern research.

In the second instance, findings from the willingness-to-pay auction, demonstrate that consumers in iodine deficiency endemic areas are willing to pay more for iodine biofortified food as an alternative for preventing IDD and protecting their households. Over the last decade there has been substantial progress towards elimination of iodine disorders in the developing world, through salt iodization and supplementation. However groups living in iodine deficient areas are still susceptible and these findings demonstrate the potential for designing intervention programs that increase their overall iodine intake through novel strategies such as biofortification. In the presence of information about the product, the health threat (IDD), the product improvement protocol (GM vs conventional biofortification), and the details on the iodine intake status in these areas, eight elements are decisive for the success of iodine biofortification as an alternative intervention program: household size, the country, presence of vulnerable groups in the household, gender, product familiarity, market price of the product, trust in key information sources and institutions, attitudes, and their iodine intake status.

These elements are significantly associated with willingness-to-pay for the novel intervention and subsequently its success in the long term. Therefore, addressing these issues at the design and policy stage creates a very competitive niche market and demand for this novel product which can succeed in preventing IDD and associated problems with mental and neurological development.

The challenge now is the timely design of an appropriate protocol for launching iodine biofortified food in endemic areas of developing countries, mainly due to the diversity of feeding patterns and ecological configurations. In addition, improvements are needed in appropriate methods for monitoring the impact of these programs and approaches by tracking progress effectively. Nevertheless, findings points to the potential of improving the local economy, since the groups living in these areas, the smallholder farmers and institutions, are also likely to benefit from an attractive, demand-driven market associated with the increased willingness–to-pay for iodine biofortified products, particularly if the program is well designed and developed.

In principle, the research findings presented in this study are a first step towards informing the development of various iodine intervention programs applying novel strategies targeted at iodine deficiency endemic areas, particularly in resource-poor locations in developing countries, where the current programs are largely ineffective. However, it would be important to amplify these findings with additional research through improved methodologies and incorporating more market drivers that directly impact on the willingness-to-pay for iodine biofortified food and its overall adoption.

Categories of seed consumed in EA

Smallholder farmers participating in the adoption study

"When you concentrate on agriculture and industry and are frugal in expenditures, Heaven cannot impoverish your state" — Xun Zi

PART IV EXPLORATION OF STAKEHOLDERS ON THE SUPPLY-SIDE

This part was established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Farmers' perceptions and willingness-to-adopt Biofortification: An Application of Technology Acceptance Modelling to Iodine Biofortification. *International Journal of Agricultural Sustainability, Submitted*.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2015b). A Novel Framework for Analysing Stakeholder's Reaction in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition.* Volume 55, Issue 2 pp. 182-208.

Chapter 7 Farmers' Perceptions and Willingness-to-Adopt Biofortification: An Application of Technology Acceptance Modelling to Iodine Biofortification

This chapter is established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). A Novel Framework for Analysing Stakeholders' Reaction in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition.* Volume 55, Issue 2 pp. 182-208.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Farmers' perceptions and willingness-to-adopt Biofortification: An Application of Technology Acceptance Modelling to Iodine Biofortification. *International Journal of Agricultural Sustainability, Submitted.*

Abstract

The use of biofortification has been proposed as a potential strategy in the fight against micronutrient malnutrition, which affects more than 2 billion people. Previous research shows that adoption of new strategies and innovations, such as biofortification, across the food supply chain, is stakeholder driven. The current chapter employs a conceptual framework for analysing stakeholders' reactions toward iodine biofortification by smallholder farmers. The second part of the PMTAM model, which integrates technology acceptance modelling and an economic valuation technique, was used to analyse various factors that drive the adoption of biofortification at the farm level. Our findings suggest a significant and consistent heterogeneity of individuals, TAM and mediating factors in influencing, not only WTP, but also the intention to use, attitudes towards, as well as the frequency of adoption at both household and farm level.

The findings show that thirteen elements have a significant effect on WTP and potential frequency of adoption including: intention, perceived ease of use, perceived usefulness, trust, attitude, group/community driving factors, age, household size, education, children, income, marital status, farm size and decision making by the farmers. Meanwhile, results also suggest that gender and occupation have significant moderating effects on WTP for biofortification, albeit through attitude and intention to adopt. This is an important observation in the formulation of policies, programs and for launching new interventions. These findings offer insights into the efficient promotion and adoption of biofortification strategies which could improve iodine intake among the most vulnerable groups in endemic areas where existing strategies are ineffective.

7.1 Introduction

In spite of numerous agricultural innovations and technologies that aim to improve the nutritional value status in humans (Masset et al., 2011), the potential application of biofortification as a novel strategy for reversing the trend in micronutrient malnutrition has been enormous (Bouis & Welch, 2010; Qaim et al., 2007; Saltzman et al., 2013), albeit more for developing countries (Bouis & Welch, 2010; Stein, 2014).

Micronutrient malnutrition affects close to 2 billion people across the world (R. Black, 2003; R. E. Black, Caulfield, Bhutta, & Victora, 2008; Cafiero & Gennari, 2011; Ramakrishnan, 2002), the majority of whom are located in resource-poor, iodine deficiency endemic locations in Sub-Saharan Africa and South East Asia (Tulchinsky, 2010; WHES, 2015).

Whereas, biofortification is the process of increasing the micronutrient level of staple food at the production level, iodine biofortification is a form of biofortification that increases the iodine level in the food at the farmer level. This can often be achieved through GM technology (Zhu et al., 2007) or conventional procedures, e.g. fertilization with iodine-enriched fertiliser, spraying vegetables with iodine-rich sprays or crossbreeding (Caffagni et al., 2011; Hong et al., 2008; Weng et al., 2008).
Previous research shows that stakeholders across the food supply chain significantly influence the adoption of innovations and technologies, i.e. biofortification (H. De Steur et al., 2015; Doss, 2006; Feder & Umali, 1993). However, research regarding the uptake of biofortification has largely been conducted on the consumption of biofortified foods by consumers, even in the case of iodine biofortification (H. De Steur et al., 2015). Therefore, there is a need to understand trends in the adoption of biofortification processes by producers such as smallholder farmers. Often, the benefits accruing from biofortification are largely perceived to be inclined towards consumers, a misconception that fails to underline the potential of biofortification as an avenue for creating new niche markets to benefit smallholder farmers and their households. These benefits derive from an increased market for their produce based on the elevated demand and willingness-to-pay for biofortified food, as well as constituting a source of nutritious food for protecting their entire household.

In the current study, the PMTAM conceptual model for analysing stakeholders uptake of biofortified foods and biofortification (J. Mogendi et al., 2016) is used to explore the adoption of iodine biofortification among smallholder farmers in iodine endemic areas drawn from three East African countries. The framework in the second part of the model, brings together technology acceptance modelling and an economic valuation technique, to analyse the willingness, ability to and frequency of adopting iodine biofortification. An attempt is also made to explore decisive determinants of farmers' adoption of iodine biofortification.

The study applied the second part of the uniquely adapted framework for analysing stakeholders' reactions toward biofortified food and biofortification, the PMTAM model (J. Mogendi et al., 2016). The model consists of three key sections: a consumption-oriented part, based on protection motivation theory (PMT), for analysing the stakeholders on the demand-side; the production-oriented section, based on technology acceptance modelling (TAM), for analysing stakeholders on the supply side; and an economic valuation part for quantifying the overall value the stakeholders attach to the item in question, in form of willingness-to-pay and/or adopt.

The present study is targeted towards the applied production-oriented section of the model, which is based on the TAM (see figure 6) to explore the role of different constructs in the adoption of, and WTP for iodine biofortification as a novel strategy for preventing IDD. The TAM model (Davis, 1987) has been demonstrated to significantly explain user behaviour towards a new technology, not only in the information technology sphere (King & He, 2006) but also in the agricultural sector (Adrian et al., 2005; Rezaei-Moghaddam & Salehi, 2010).

The model demonstrates that the resultant behaviour of using a technology or innovation is influenced directly or indirectly by the user's behavioural intentions, attitudes, perceived usefulness and perceived ease of use towards the innovation or technology. It also demonstrates that external factors play an important role in the overall intentions, attitudes and subsequent behavioural action exhibited, albeit directly or indirectly through perceived usefulness or perceived ease of use. Thereby, this explains the application of the model to analyse the adoption of iodine biofortification among smallholder farmers. Figure 6 (Ch. 3) depicts the original TAM according to Fred Davis (Davis, 1987)

Nevertheless, according to the conceptual framework, this model is integrated with an economic valuation technique to quantify the willingness-to-pay to adopt the technology, i.e. biofortification. Although numerous economic valuation techniques exist (Rusche et al., 2013), the current study incorporated the contingent valuation technique (Bishop & Heberlein, 1990), notwithstanding the challenges and controversies that surround its application (Carson et al., 2001). However, to improve its validity a premium card method was used in place of the dichotomous procedure (Breidert et al., 2006). The resultant value is the amount the smallholder farmers are willing to pay to adopt and/or the frequency of adopting biofortification. These outcome indices were used in addition to the other indices of resultant behaviour towards adoption of biofortification in endemic areas, obtained from the TAM constructs.

7.2 Subjects and methods

7.2.1 Study area

The study was conducted in three locations in the East African countries of Kenya, Tanzania and Uganda. The region represents some of the poorest locations in sub-Saharan Africa. The communities living in this area are mainly smallholder subsistence farmers, and most of the food produced is consumed in the household with the excess only sold to supplement household income.

The locations selected are mountainous, rural, landlocked areas which present the perfect conditions for iodine deficiency. This purposive selection was also due to the fact that the areas have some of the highest levels of IDD, according ICCIDD (2014) and the largest population unprotected by the existing intervention programs. The most common crops in these areas are mostly the staples ranging from fruit and vegetables, animal-derived food, cereals and legumes and forest products. The soil in these areas has depleted iodine levels due to erosion and therefore very little iodine is present in these staple foods.

The smallholder farmers in these areas practice both traditional and in some cases new food production systems depending on the type of crops and technology available. It is evident from previous research that adoption of agricultural innovation and technologies in developing regions is one of the highest in the world (Feder et al., 1985; Feder & Umali, 1993; Yakovleva et al., 2004). This therefore demonstrates that there is potential for target stakeholders such as smallholder farmers to adopt iodine biofortification in order to protect their loved ones from the problem of iodine deficiency, as well as tapping into the demand market created by increased demand for biofortified food by consumers.

7.2.2 Research design

A cross-sectional survey was conducted during the first and second quarter of 2015, using a face-to-face interview with smallholder farmers. A multi-stage cluster sampling was used to select smallholder farmers living in select locations within the target areas in East Africa. At the higher level, the locations were randomly selected based on their iodine status data (ICCIDD, 2014) as well as the distances from water masses or sources of iodine-rich food, while a list of strategically located schools in the area was used to randomly select smallholder farmers living in the neighbourhood. To pick individual farmers we used a standard simple random sampling (SSRS). Data were collected from the farmers after an initial stage of pre-testing and adjusting the questionnaire appropriately to remove invalid and protest responses/questions. Before the actual data collection, the consent of selected farmers was sought verbally after a brief introduction by the interviewer, as a researcher from a local university, and upon their agreement the interview guide and questionnaire was administered.

7.2.3 Questionnaire

A semi-structured interview was conducted to gather information on the adoption of biofortification by smallholder farmers from select locations in three East African countries. The questionnaire was based on the constructs from the conceptual framework that integrates technology acceptance modelling and an economic valuation technique (J. Mogendi et al., 2016) . The literature on TAM constructs was based on the findings from the original TAM model developed by Fred Davis (Davis, 1987), while the economic valuation technique was based on the contingent valuation technique type questioning (Bishop & Heberlein, 1990; Rusche et al., 2013).

Thereby, five groups of constructs were included in the questionnaire and used to elicit information about the adoption of biofortification by smallholder farmers, including: individual drivers and farm-related factors; attitudes and trust factors; technology acceptance factors (perceived usefulness, perceived ease of use); intention to use biofortification; and resultant adoption, as willingness-to-pay/adopt, for biofortification as a novel technology.

This questionnaire was developed based on research conducted by Fred Davis and related reviews on the TAM model (Biggs, 1990; Davis, 1987; King & He, 2006), the review on methods of economic valuation (Bishop & Heberlein, 1990; Breidert et al., 2006) and findings on attitudes using the Food Neophobia Scale (FNS) developed by Pliner and Hobden (1992).

7.2.4 Sampling and data collection

Using the Multistage cluster sampling, a total of 174 smallholder farmers were selected, representing 58 SHF from each of the three EA countries. The data was collected directly from each of the SHF who was more informed and literate or had crucial information about the household farm. The interview guide required translation into local languages in the case of illiterate SHF, with utmost care considering that translation can alter the meaning, which could lead to biases in the study. Prior to administering the questionnaire, an information script, a cheap talk script (Silva et al., 2011) commonly used in consumer research, was included to ensure the responses from participants were as truthful as possible and to the best of their knowledge.

Data from individual and farm characteristics were continuous variables and registered directly at the initial stage. Data on the attitudes and perceived usefulness and perceived ease of use of biofortification by SHF was recorded as a rating of their opinion using a 7-point Likert scale, ranging from *1=Strongly disagree to 7=Strongly agree*. Statements correcting opinion or measuring intention to use biofortification were recorded and registered using a 7-point Likert scale, ranging from *1=Very Unlikely to 7=Very Likely, as defined.* These were adopted from the intention measures developed by Davis et al. (1989).

The resultant adoption or willingness to adopt was recorded via three statements: two statements were based on the frequency of adopting the technology, using a 7-point Likert scale while the third statement used the contingent valuation technique to determine the value SHF attach to biofortification.

The former two statements used the following scales: *1 – Never ; 2 – Rarely, in less than 10% of the chances when I could have ; 3 – Occasionally, in about 30% of the chances when I could have ; 4 – Sometimes, in about 50% of the chances when I could have ; 5 – Frequently, in about 70% of the chances when I could have ; 6 – Usually, in about 90% of the chances I could have; and 7 – Every time;* while the latter used the payment cards method to determine how much more SHF are willing to pay to adopt biofortification, given an arbitrary market price for biofortification, in response to the question: *On average, If normal farming adoption cost $120 per acre, how much more are you to pay to implement biofortification on your farm?*

7.2.5 Data entry and analysis

The data obtained was entered and documented using the EpiData platform, which also facilitated basic analysis and error detection. Then Stata software: Release12 was used to statistically analyse both descriptive and inferential statistics, and facilitate the modelling of the key variables in the study appropriately. Some hypotheses were also examined using chi-square analysis. Cronbach's alpha was used first to compute the reliability of the data using the constructs from TAM mediating factors, as well as attitudes from the food neophobia scale Pliner and Hobden (1992). Cronbach's alphas were examined to test the reliabilities of the key items in the model, prior to further analysis. The Cronbach's alpha was calculated as shown in equation 1 below:

$$\propto = \frac{K}{K-1}\left(1 - \frac{\sum S_i^2}{S_i^2}\right) \quad \textbf{(1)}$$

In which K is the number of items in the scale used, S_i^2 is the variation coefficient of the items in the given construct while $\sum S_i^2$ is the variation coefficient of all the items.

Usually, a value of more than 0.60 for Cronbach's alpha is considered adequate reliability (Tavakol & Dennick, 2011) and items can be included in further analysis. In addition, factor analysis was conducted to predict the resultant factors from a list of statements, and to validate and predict the overall factors influencing how participants perceived the statements from the two constructs of the TAM model: PU and PEOU. Ordered logistic regression analysis, Tobit regression and frequency counts were used to analyse the data obtained from the questionnaires.

Ordered logistic regression modelling (Torres-Reyna, 2012), supposes that the element to be examined in this case intention to adopt biofortification or attitude towards biofortification, denoted as $\boldsymbol{y}^*$, is characterized as below:

$$\boldsymbol{y}^* = x^{'}\beta + \varepsilon_{'} \quad \textbf{(2)}$$

In this case, $\boldsymbol{y}^*$is the exact but observed dependent variable (i.e. intention to adopt biofortification) , which could be a direct match with the line of questioning adopted during this study; $x^{'}$is the independent variable(s) included in the study, i.e. the TAM constructs, individual and group driving factors; β is in essence the vector or value that is of interest, which corresponds to the magnitude of the effect associated with the independent variable ($x^{'}$); and the $\varepsilon_{'}$ to the random error term or random influences to the relationship between dependent and independent variables. Since we cannot observe $\boldsymbol{y}^*$ the categories of y responses, often collected from the study are of the following format, overall 'y' will therefore have the following flow of responses:

$$y = \begin{cases} 0\ if \quad y^* \le u_1, \\ 1\ if\ u_1 < y^* \le u_2, \\ 2\ if\ u_2 < y^* \le u_3, \\ \quad . \\ \quad . \\ N\ if\ \ u_N < \ \ y^* \end{cases} \quad \textbf{(3)}$$

Therefore during analysis, since we recorded the categories of responses, the final ordered logistic technique will fit the parameter coefficients (β) which are our main interest, using the observations on **y** which are often a form of censored data collected as categories of responses on $\boldsymbol{y}^*$

Tobit models (Amemiya, 1984), on the other hand , statistically describe the relationship between a non-negative dependent variable $\boldsymbol{y}_i^*$ and independent variables $\boldsymbol{x}_i$. In our current study, the model was used to describe the relationship between the resultant adoption of biofortification and independent variables: individual driving factors, group/community driving factors and TAM constructs. It supposes that there is a linear relationship between the independent variables and the latent variable (i.e. unobservable variable). In addition, there is always a normally distributed error term designated as$\boldsymbol{u}_i$**,** that often captures the random effect influences occurring in this relationship (see equations 4 and 5 on the tobit model).

Tobit models are a type of censored regression model, where a model captures the variation in a particular direction where variables are observable under certain set conditions alone. Often $\boldsymbol{y}_i^*$ is defined as equal to the latent variable whenever it assumes a value above zero and zero otherwise. The model used in this study was based on the resultant values of adoption of biofortification as defined by the formula below.

$$y_i = \begin{cases} y_i^* \; if \; y_i^* > 0 \\ 0 \; if \; y_i^* \leq 0 \end{cases} \qquad \textbf{(4)}$$

Where $\boldsymbol{y}_i^*$ in our current study is equal to the latent variable referring to the resultant adoption of biofortification by smallholder farmers. Hence, the final Tobit model applied in this study I to examine the influence of independent variables and the random effect on the resultant biofortification is as shown below:

$$y_i = \beta x_i + \mu_i, \mu_i \sim N\;(0, \sigma^2) \qquad \textbf{(5)}$$

Since ours is the positive adoption of biofortification we use a model that is censored from below, to depict only the values above the existing level of adoption (above zero).

7.2.6 Research hypotheses

A slight modification to the TAM model was implemented based on the influence of other factors on the adoption of innovation in agriculture and biofortification in particular such as, trust and attitude, as well as socio-economic elements at the farm level such as farm size, decision making, and group/community driving factors, as well as individual driving factors including: age, gender, education level, occupation, marital status, household size, and the presence of young children in the household. The hypothesis revolves around testing each of these variables (independent variables) against the willingness for, and frequency of, adoption of biofortification at both the household and farm level, by the smallholder farmers.

7.3 Results

7.3.1 Descriptive statistics and frequency counts for individual driving factors

The descriptive statistics and frequency counts for individual driving factors for the smallholder farmers are shown in table 17. The table shows the frequency and descriptive statistics for smallholder farmers included in the study based on their gender, age, education, occupation other than farming, income over a period of 6 months, marital status, farm size and overall decision making in regard to food production and consumption in the household. The finding demonstrates that men were the most dominant in the reporting and, on average, slightly older people are included, with an average age of 48.81 years. In addition, the table shows the average household size was 7 with an average of 2 young children aged 6-12 years who are often considered vulnerable to iodine deficiency disorders.

Table 17 Results of descriptive statistics and frequency count for individual SHF driving factors

Variable	Definition	Items/ scale	Frequency	%	Mean/Mode
Gender of the SHF	Gender of the farmer N=174	Male	100	57.47	Male
		Female	74	42.53	
Age	Age of the farmers	21-30 years	3	1.72	48.81 years
		31-40 years	34	19.54	
		41-50 years	33	18.97	
		51-60 years	96	55.17	
		>60years	8	4.60	
Household size	Household size: How many members live with you in the household		-	-	7 (2)
Children	Children (Vulnerable children) How many children (6-12years) live with you in the household		-	-	2 (0.5)
Education level of the farmer	Education level of the farmer	College education	3	1.72	Elementary education
		Some college diploma	7	4.02	
		High school diploma	25	14.37	
		Elementary education	60	34.48	
		No formal education	79	45.40	
Income of the SHF	Income of the Farmer mid-year (6months)	<100	25	14.37	$100-200
		100-250	71	40.80	
		250-400	46	26.44	
		400-650	17	9.77	
		>650	15	8.62	
Occupation	Occupation- other occupation of the farmer Respondent`s other occupation that directly impacts on farming	None (Unemployed)	52	29.89	Casual worker
		Casual worker	64	36.78	
		Self-employed-none farm	34	19.54	
		Government worker	24	13.79	
Marital Status	Marital Status	Single	52	30.06	Married
		Married	107	61.85	
		Widowed	14	8.09	
Farm size	Farm size: The size of the farm cultivated by SHF	<0.5Ha	10	5.75	1Ha of land
		1ha	80	45.98	
		2ha	26	14.94	
		3ha	32	18.39	
		4ha	26	14.94	
Decision Making	Decision Making: In the farm, how often are you involved in deciding the food production for the household	5days	77	44.25	5 days a week
		6days	37	21.26	
		7days	60	34.48	

Notes:-SHF: smallholder farmer;

Most of the smallholder farmers included had only an elementary level of education which again explains the average income level of $100-200 and highlights the poverty levels in the target location where the households mostly depend on their farm produce for survival.

7.3.2 Descriptive and reliability analysis of TAM and moderating factors

Table 18 depicts the descriptive statistics for the TAM and the moderating variables, together with their reliabilities. The findings suggest that the average means of all constructs were greater than 5 out of 7. These findings show that our sample responded positively to adopting and applying biofortification as part of their farming practices.

Table 18 Descriptive and reliability analysis of TAM and moderating factors (n=174) used in farmers' iodine biofortification adoption study

Factor/construct	**Item**	**Mean/SD**	**[e]Cronbach's α**
Group and community driving factors [a]	G11	5.80 (0.92)	0.71
	G12	5.67 (0.91)	
	G13	5.69 (0.98)	
	G14	5.34 (1.17)	
	G15	5.22 (1.12)	
	G16	5.43 (1.06)	
	G17	5.17 (1.33)	
Attitudes[b]	A18	5.54 (1.03)	0.83
	A19	5.42 (1.07)	
	A20	5.34 (1.09)	
	A21	5.37 (1.04)	
	A22	2.29 (1.05)	
	A23	5.09 (1.24)	
	A24	5.33 (1.08)	
	A25	1.97 (1.09)	
	A26	5.44 (1.03)	
	A27	2.25 (1.12)	
	A28	5.06 (1.40)	
	A29	5.27 (1.12)	
	A30	5.23 (1.19)	
Perceived usefulness (PU)[c]	PU33	5.36 (1.16)	0.67
	PU34	5.46 (1.15)	
	PU35	5.45 (1.11)	
	PU36	5.38 (1.08)	
	PU37	5.67 (1.12)	
Perceived Ease Of Use(PEOU)[c]	PEOU38	5.26 (1.31)	0.70
	PEOU39	5.70 (1.04)	
	PEOU40	5.47 (1.21)	
	PEOU41	5.60 (1.06)	
	PEOU42	5.40 (1.14)	
	PEOU43	5.39 (1.16)	
Intention to use biofortification as a novel technology[c]	Intention44	5.51 (1.13)	0.69
	Intention45	5.50 (1.11)	
	Intention46	5.39 (1.13)	
	Intention47	5.51 (1.13)	
	Intention48	5.30 (1.14)	
	Intention49	5.42 (1.15)	
Resultant adoption[d]	Actual50	5.59 (1.14)	0.65
	Actual51	5.39 (1.19)	
	Actual52	3.83 (2.45)	

Notes: - [a]Based on TAM for external driving factors; [b]Based on integration of FNS; [c]Based on TAM Model; [d]Based on the integrated contingent valuation technique with premium card.; [e]Cronbach alpha scale used: α ≥ 0.8 Excellent; 0.8 > α ≥ 0.7 Good; 0.7 > α ≥ 0.6 Acceptable; 0.6 > α ≥ 0.5 Questionable; 0.5 > α Poor and unacceptable

The deviation was in the range of 1 to 1.5 which showed good consistency across the responses. The results in table 18, outline the key variables included in the current study, as well as the reliability and consistency of the test items included in each case, the minimum alpha value was recorded in the case of resultant adoption but which is still within the acceptable levels of above 0.60 for adequate reliability, and subsequent inclusion in the analysis.

Most of the smallholder farmers were not employed (52, 29.89%) or were engaged as casual labourers (64, 36.78%) to supplement their incomes. They were mostly married with stable families, to which they were responsible for more than 5 days per week with regard to food production and consumption in the household. However, the land available for food production was very small, with more than 50% of the SHF having less than 1Ha, which is consistent with the characteristic of smallholder farming. However, although the sample of smallholder farmers used in this was large enough to address the issue of representativeness attention should be put to the generalisation of the findings.

Furthermore, the correlation coefficient from the Spearman's correlation analysis, as shown in table 19, demonstrates that the scale used had a good collinearity, and there were weak to strong correlations between the variables included.

Table 19 Correlation of the variables used in regression modelling in farmers' iodine biofortification adoption study

Variable		**1**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	Intention	1.00***														
2	PEOU	0.04														
3	PU	-0.01	-0.00													
4	Trust	0.12	0.16*	0.05												
5	Attitude	-0.08	-0.00	-0.15*	0.07											
6	GCDF	0.00	0.10	-0.06	-0.10	0.03										
7	Gender	0.12	-0.01	-0.01	-0.05	-0.15*	-0.15*									
8	Age	0.12	0.19*	0.03	0.14*	0.05	0.08	0.04								
9	Household size	0.08	0.03	0.05	0.03	-0.08	-0.06	0.08	0.08							
10	Education	0.14*	-0.03	-0.02	-0.02	0.03	0.05	-0.01	0.00	-0.04						
11	Children	-0.04	-0.10	-0.10	-0.08	-0.14	0.09	0.07	-0.12	-0.09	-0.01					
12	Income	0.07	0.11	0.04	-0.05	-0.06	0.12	-0.03	0.04	-0.02	0.03	0.02				
13	Occupation	-0.10	0.12	0.07	-0.11	0.03	0.02	0.07	0.06	0.03	0.04	-0.03	0.01			
14	Marital status	0.01	0.10	0.03	-0.04	-0.08	0.23**	0.05	0.05	0.01	-0.04	0.30***	0.09	0.04		
15	Farm size	-0.13*	-0.05	-0.04	-0.07	-0.00	-0.04	0.05	-0.04	-0.03	0.00	0.02	0.06	-0.06	0.04	
16	Decision making	-0.23**	-0.05*	0.03	-0.05	-0.00	0.10	-0.02	-0.04	-0.04	-0.09	-0.02	-0.02	0.05	-0.08	0.12

*Notes: *P<0.05; **P<0.01; and ***P<0.001; PEOU: Perceived ease of use; PU: Perceived usefulness; GCDF: Group and community driving factor*

Further, the second model examining the decisive factors on farmer attitudes is also shown in table 20. PU (-0.61, $p<0.05$), gender of the farmer (-0.51, $p<0.05$), and presence of young children in the household (-0.31, $p<0.05$), had a significantly negative effect on the attitude of the smallholder farmers toward biofortification. Therefore, our hypothesis was not supported for all other variables which did not achieve significance.

Table 20 Ordered regression model for the intention and attitudes towards biofortification

Variable	**Intention** β **(SD)**	**Attitude** β **(SD)**
Perceived Ease Of Use	-0.05 (0.23)	-0.22(0.24)
Perceived Usefulness	-0.15 (0.30)*	-0.61(0.29)*
Attitude	-0.27 (0.20)*	-
Trust	0.57 (0.61)	0.59(0.60)
Group and community driving factors	0.18 (0.26)*	0.01(0.27)
Gender	0.54 (0.28)*	-0.51 (0.28)*
Age	0.02 (0.02)	0.01 (0.02)
Household	0.09 (0.10)	-0.08 (0.10)
Education	0.21 (0.15)	0.08 (0.14)
Children	-0.10 (0.19)	-0.31(0.20)*
Income	0.12 (0.12)	-0.08 (0.13)
Occupation	-0.19 (0.14)*	0.13 (0.13)
Marital status	-0.04 (0.24)	-0.12 (0.24)
Farm size	-0.19 (0.12)*	-0.00 (0.12)
Decision making	-0.42 (0.16)**	-0.02 (0.15)
Number of obs	**174**	**174**
LR chi2(15)=	**25.37**	**15.59**
Prob > chi2=	**0.0452**	**0.3389**
Pseudo R2	**0.0145**	**0.0088**

*Notes:- *P<0.05; **P<0.01; and ***P<0.001*

7.3.3 Tobit modelling for resultant willingness to adopt biofortification

Results of the Tobit modelling between the resultant adoption of biofortification as a dependent variable vis-à-vis the individual, group and TAM constructs as independent variables are shown in Table 21. Three levels of resultant adoption of biofortification by SHF were examined, resulting in three Tobit models: Tobit model explaining the resultant adoption at the household level, resultant adoption at the farm level and resultant willingness-to-pay for the adoption of biofortification.

From the three levels of adoption, three Tobit models were created to explain resultant adoption:$y_{willingness\ to\ pay\ for\ adoption\ of\ biofortification}$; $y_{Actual\ adoption\ frequency\ at\ household\ level}$; and $y_{Adoption\ frequency\ at\ the\ farm\ level}$

The results from the model are shown in table 21 below. When SHF were asked how much more (a premium) they were willing to pay for the adoption of biofortification on their farm, the following elements had a significant effect on their willingness-to-pay for adoption: intention to adopt biofortification (0.35, $p<0.05$), the perceived ease of using biofortification (0.54, $p<0.05$), trust in the source of information and institutions involved (-2.51, $p<0.05$), the age (0.04, $p<0.05$), presence of young children in their household (0.36, $p<0.05$) and the size of their farm (0.01, $p<0.05$).

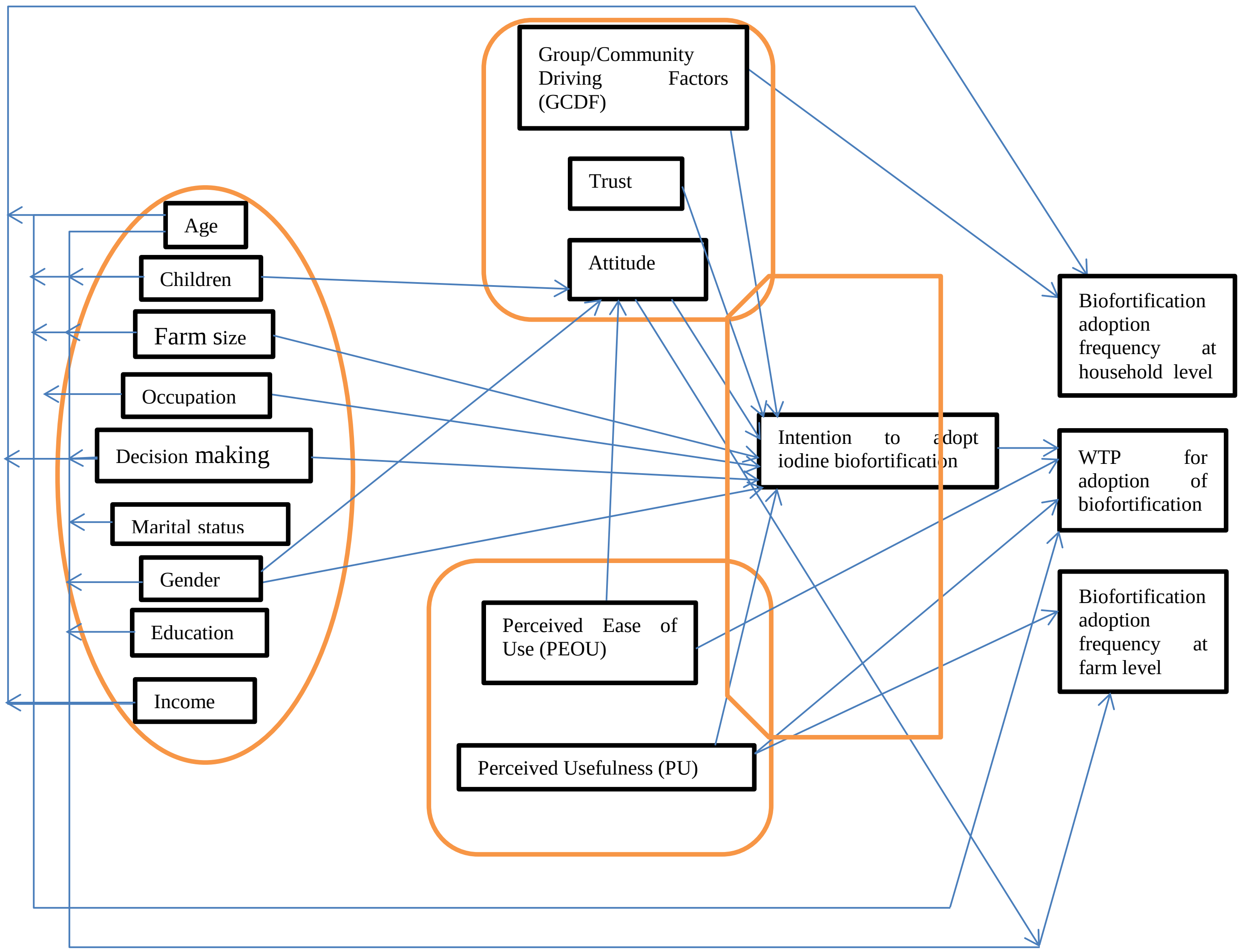
However, when resultant frequency of adopting biofortification at the household level was examined using the model, eight groups of elements were particularly important. Perceived usefulness, (0.37, $p<0.05$), attitude (0.34, $p<0.05$), age (0.03, $p<0.05$), education level (0.30, $p<0.05$), children (0.28, $p<0.05$), marital status (-0.54, $p<0.05$), farm size (0.14, $p<0.05$), and decision making at the household level *(*0.26, $p<0.05$), had a significant effect on the resultant frequency of adoption of biofortification. Further, when the model was used to examine the frequency of adoption at the farm level, four groups of elements were decisive, including: group and community driving factors (-0.57 $p<0.05$), age (0.02 $p<0.05$), income (0.31, $p<0.01$), and decision making (0.35, $p<0.01$). All other elements included in the model did not achieve significance and therefore the hypotheses attached to them were not confirmed.

Table 21 Tobit modelling for resultant willingness to adopt biofortification by smallholder farmers

Variables	y willingness-to-pay for adoption of biofortification, $\boldsymbol{\beta 1}\ (\boldsymbol{SD})$	y Resultant adoption frequency at HH level, $\boldsymbol{\beta 2}\ (\boldsymbol{SD})$	y resultant adoption frequency at farm level, $\boldsymbol{\beta 3}\ (\boldsymbol{SD})$
Intention	0.01 (0.44)*	0.02 (0.24)	-0.28 (0.22)
Perceived Ease Of Use	0.54 (0.39)*	0.15 (0.22)	0.27 (0.20)
Perceived Usefulness	-0.21(0.48)	0.37 (0.27)*	0.27 (0.24)
Trust	-2.51 (1.02)*	0.06 (0.57)	-0.38 (0.52)
Attitude	0.31 (0.34)	0.34 (0.19)*	-0.16 (0.17)
Group and Community Driving Factors	-0.21 (0.43)	0.19 (0.24)	-0.57 (0.22)*
Gender	-0.33 (0.47)	0.05 (0.26)	-0.02 (0.24)
Age	0.04 (0.02)*	0.03 (0.01)*	0.02 (0.01)*
Household size	-0.04 (0.15)	0.11 (0.08)	0.08 (0.08)
Education	0.01 (0.22)	0.26 (0.12)*	0.05 (0.11)
Children	0.36 (0.31)*	0.28 (0.17)*	0.23 (0.16)
Income	-0.09 (0.20)	0.04 (0.11)	0.31 (0.10)**
Occupation	0.23 (0.22)	-0.8 (0.13)	-0.06 (0.11)
Marital status	-0.04 (0.41)	-0.54 (0.23)*	0.11 (0.22)
Farm size	0.35 (0.19)*	0.14 (0.10)*	0.11 (0.09)
Decision making	0.04 (0.21)	0.30 (0.12)*	0.35 (0.11)**
Left-Censored	32	48	35
Level of Censoring	<=1	<=4	<=4
Uncensored	140	124	137
Right-Censored	0	0	0

*Notes:-*P<0.05; **P<0.01; and ***P<0.001*

The resultant model from the two analysis levels, Logistic and Tobit modelling, is presented in figure 15. The figures highlight the key linkages that determine the adoption of iodine biofortification by smallholder farmers in iodine endemic areas. The figures suggest that the elements influence the adoption of biofortification either directly or indirectly through a mediating effect.



Notes: -GCDF: group and community driving factors; WTP: willingness-to-pay; PU: perceived usefulness; PEOU: perceived ease of use

Figure 15 Resultant iodine biofortification acceptance model based on the TAM model for analysing adoption of iodine biofortification at the farm level

7.4 Discussion

Based on our analysis of the collected data, most of the hypotheses formulated were supported, as shown in figure 15. Thereby, the findings of this study demonstrate that a large group of elements under examination significantly influenced the adoption of iodine biofortification among smallholder farmers, albeit at different levels of presentation. These findings are threefold.

First, individual driving factors were active at both the higher and lower levels. The lower level is the level at which they influenced attitudes towards, and the intention to adopt, iodine biofortification; while the higher level is the level at which they influenced resultant adoption of biofortification. Although gender increased the intention to adopt biofortification, the occupation, farm size and decision making of the farmer significantly reduced farmers’ intention to adopt iodine biofortification.

These findings are consistent with previous research that shows gender as a decisive factor in behavioural intention, and men are greater risk takers than their female counterparts (Doss & Morris, 2001).

Additionally, engagement in other activities and occupations considerably reduced the favourable reactions towards the adoption of biofortification, which is consistent with earlier studies on uptake of innovations and technologies, including biofortification, at the farm level (Adrian et al., 2005; Rezaei-Moghaddam & Salehi, 2010). Further, the size of the farm is inversely proportional to the intention to adopt, meaning the smaller the farm size the less likely the farmers will intend to adopt biofortification, which is consistent with earlier studies (Coelho, Pinto, & da Silva, 2001; Vanclay & Lawrence, 1994). The results, however, contradict earlier research that shows a direct relationship between involvement in decision making of the farmer regarding the consumption and production of food at household level and the intention to adopt new strategies and farming practices at the household level (Adesina & Baidu-Forson, 1995; Atanu, Love, & Schwart, 1994; Doss, 2006). This could be attributed to the sensitive nature of the technology in question, with the decision maker remaining sceptical about the overall implications of adopting the technology.

Meanwhile, gender and the presence of young children reduced the attitude of the smallholder farmers towards iodine biofortification. Women were more likely to have a positive reaction towards biofortification than men. This can be traced to the strong attachment of the women in the household to the health and wellbeing of everybody in the household (Doss & Morris, 2001). This is consistent with previous research that has documented the influence of gender on innovations and technologies, particularly biofortification, by different stakeholders. However, the results contradict earlier studies that have shown a direct relationship between the presence of young children in the household and an increase in positive attitudes towards biofortification (H. De Steur, Gellynck, Feng, et al., 2012). This is possibly linked to the protective nature of parents, as they prefer not to try a new innovation and technology on their children, regardless of the fact that their children are young and susceptible to IDD.

Second, the higher level had three models for examining the resultant adoption process for biofortification among the smallholder farmers. We used tobit modelling to explore the resultant adoption of iodine biofortification, when presented in three different forms: a) as a willingness-to-pay for adoption of iodine biofortification; b) frequency to adopt at household level; and c) frequency to adopt at the farm level. The censoring was done at the lower level to ensure resultant adoption was either at zero or above zero for tobit modelling (Tobin, 1958). Six elements were particularly decisive in the resultant adoption, when presented as willingness-to-pay for adoption. Individual driving factors, including age, the presence of young children and farm size, as well as the TAM and moderating factors, including intention, perceived ease of use and trust in the information source and institutions, had a significant effect on the resultant adoption of biofortification when packaged as willingness-to-pay for adoption. Individual driving factors, age, the presence of young children in the household and the farm size increased the willingness of the farmer to pay for the adoption of biofortification. These findings are consistent with earlier research that has seen these elements positively influence the adoption of technologies and innovations (Feder & Umali, 1993; Kesseba, 1989), even in the case of adoption of biofortification by stakeholders (H. De Steur et al., 2015).

In addition, the intention to adopt biofortification and the perceived ease of using the technology at the farm level, increases the willingness of the farmers to adopt biofortification as a new strategy, (Anandajayasekeram, Puskur, & Zerfu, 2009; Sunding & Zilberman, 2001). This finding is consistent with previous findings that have shown the two elements significantly influence the adoption and acceptance of a technology, not only in the information technology industry (Chen et al., 2011; King & He, 2006; Li, 2010) but also in the agricultural sector (Feder & Umali, 1993; Kesseba, 1989) and in particular within developing countries (Feder et al., 1985). However, as expected, trust in the information sources about biofortification and trust towards institutions providing such information, often lowers the degree of willingness-to-pay for biofortification. This trend has also been reported in earlier studies (Maertens & Barrett, 2013), albeit more in the case of genetically biofortified food (Vanloqueren & Baret, 2009). Therefore, it is important to use highly trusted sources and institutions when launching iodine biofortification programs among SHF in these endemic areas.

When, resultant adoption was packaged as a frequency for the adoption of biofortification at the household level, eight groups of elements significantly predicted the resultant adoption of biofortification. Individual driving factors, including: age, education level of the farmer, the presence of young children in the household, marital status, the overall farm size and decision making, had a significant effect. These findings show that these socio-economic factors influence the adoption of innovations and technologies at the farm level. The older the farmer and the more educated they are the more likely this is to influence the frequency with which they will take up biofortification on the farm. This is consistent with earlier studies on the influence of age and education level on the frequency of adoption of these processes at the household level (Foster & Rosenzweig, 2010).

Further, the presence of young children also significantly increased the frequency of resultant adoption of biofortification. This has been demonstrated in earlier studies (Adesina & Zinnah, 1993; Doss & Morris, 2001). In addition, the farm size and the decision making role at the household level also significantly increased the frequency of resultant adoption. This trend has also been demonstrated with other innovations and strategies at the household level (Adesina & Zinnah, 1993; Feder et al., 1985; Foster & Rosenzweig, 2010). Meanwhile, the marital status of the household significantly reduced the frequency of resultant adoption. The status of having a stable married relationship will result in the likelihood of reducing the frequency of taking up biofortification. This contradicts other studies that report a direct correlation (Adesina & Zinnah, 1993; Doss & Morris, 2001; Feder et al., 1985). One explanation could be a commitment not to burden the other partner in the household, taking the view that frequently adopting biofortification at the household level would be expensive and could deprive the partner of support.

Consequently though, only two TAM and mediating factors had an effect on the frequency of adopting biofortification at the household level. Perceived usefulness and the attitude towards biofortification significantly increased the frequency of resultant adoption of biofortification. This is also consistent with earlier studies that show a greater trend towards adoption if a technology or innovation, in this case biofortification, is perceived to be more useful to the intended purpose (Anandajayasekeram et al., 2009; Feder et al., 1985; Feder & Umali, 1993; Kesseba, 1989). Equally, the increased attitude towards biofortification results in increased frequency of adoption. This finding, has been reported by numerous studies on the adoption of innovations and technologies (Adrian et al., 2005; Ajzen & Fishbein, 1980; King & He, 2006). This highlights the need to capture and communicate these elements, as well as targeting specific groups in the community, if the frequency of adopting biofortification at the household level is to succeed, for any iodine intervention program.

Nevertheless, when resultant adoption was presented as a frequency for adopting biofortification at the farm level over a period of time, group and community driving factors, as well as individual driving factors, had a significant effect on the resultant adoption of iodine biofortification at the farm level, with group/community driving factors significantly reducing the frequency of adopting biofortification. These elements point to the significant influence of peers with regard to adoption of biofortification by smallholder farmers in the community. Therefore, adoption is likely to vary with the diversity of other farmers in the community. These findings are consistent with studies which show that group and community driving factors negatively influence actual behaviour towards a new innovation and technology (Rezaei-Moghaddam & Salehi, 2010), for example biofortification. However, age, income of the household and the decision making of the farmer in relation to food production significantly increase the frequency of resultant adoption of biofortification at the farm level. The older the farmer is, the higher the frequency of adopting iodine biofortification and vice versa. This has also been demonstrated in other studies on the adoption of technologies and innovations.

Additionally, the higher the income of the SHF the more likely they are to adopt biofortification more frequently on their farm. This is shown in other studies that point to a direct relationship between income and uptake of technologies and innovations (Fernandez-Cornejo, Hendricks, & Mishra, 2005), including biofortification (Nwakor et al., 2011). Further, the more the SHF is involved in making decisions about the household the higher the frequency for adopting biofortification. This is also consistent with studies on the uptake of biofortification (H. De Steur et al., 2015; Feder et al., 1985;

Nwakor et al., 2011). Therefore, in designing iodine biofortification programs for endemic areas, these elements should be considered if the program is to succeed. Furthermore, increasing the frequency of adopting biofortification at the farm level significantly translates to greater production of iodine biofortified food. Consequently these practices will significantly improve the iodine intake, not only for the farmer but also for the most vulnerable groups in their community, such as young children.

The most visible inadequacy in our current study is the lack of information to discriminate between the different biofortification technologies available to the farmer, as well as the negative attributes that could be linked to these diverse processes, including GM technologies. The direct inclusion of these within the model specifications, as well as the level of risk perception exhibited by the farmers, would add significantly to the current findings about the resultant adoption of iodine biofortification or otherwise. The generalizability of the findings is also a concern as some variables that directly influence the overall behavioural action, for instance land availability was only skewed to about 50% of the smallholder farmers in the study which could have a bearing on the overall action. Nevertheless, the population size applied in this specific case could significantly ameliorate the representativeness of this data.

Nevertheless, despite this minor shortfall in our study, the results still give rich farm specifications for designing iodine intervention programs, based on biofortification, among the smallholder farmers over a relatively extensive time horizon. The findings and resultant model allow for decision making regarding the characteristics and condition of farm households that are appropriate for the adoption of iodine biofortification in endemic areas, particularly in developing countries. Another concern that can open the discussion is the purposive sampling of iodine deficiency endemic locations in the three countries, Why not other parts of the world, where the geochemistry of the rock affects the retention of iodine in crops? The sample size could be increased to capture this diversity by incorporating other areas as well as improving the accuracy of the findings.

7.5 Conclusions

This research creates various issues and the findings shed some light on the conditions under which iodine biofortification may be more effective in the design and implementation of iodine intervention programs and in producing more valuable biofortified products. The insights derived from this research highlight the significant potential for preventing IDD through agriculturally oriented approaches.

Firstly, the findings highlight the need for individual driving factors for the adoption of biofortification by farmers. Adoption of innovations and technologies is often driven by the characteristics inherent in the farmer and therefore intervention programs should capture these scenarios at the design level. An iodine biofortification program that captures the details on household size, farmer age, education level, income, marital status, the farm size and the involvement of the farmer in decision making regarding food production, not only at the household level but also at the community level, is likely to succeed on the adoption front. Meanwhile drawing on the gender and occupation of the farmer when designing these programs will be crucial at the mediation level, by influencing adoption through intentions and attitudes towards biofortification.

Secondly, biofortification programs targeted at smallholder farmers should package the technology as an easy to use strategy in order to boost perceptions about ease of applying iodine biofortification. This direction will subsequently increase their willingness-to-pay in order to adopt biofortification on their farms. Equally, the use of biofortification at the farm level should be clearly highlighted. This then boosts farmers' perceptions about the usefulness of the technology. This potentially improves the chances of frequently adopting and advocating biofortification in their farming practices and the community. In principle, these are main constructs that influence the overall acceptance and use of a technology such as biofortification (Davis, 1987). Therefore, program managers and implementers should work to remove any entry and technology adoption barriers. Measures should be put in place in the target region to improve both perceived ease of use and perceived usefulness of biofortification among the farmers. This could be achieved, for example, through field demonstrations, providing sufficient usefulness instructions and technical support, as well as inviting the farmers to participate in the actual design, and other activities in the program that need to be taken into consideration.

Finally, programs targeted at iodine deficiency endemic areas should attach great importance to boosting the attitude of smallholder farmers towards iodine biofortification, as well as using highly trusted information channels and institutions. These elements have a significant mediation effect towards the adoption of biofortification, both in terms of willingness-to-pay to adopt as well as frequency of adoption.

In principle, willingness, frequency and ability of farmers to adopt appropriate new technologies, is often considered an important component for effective farm management and production (Feder & Umali, 1993; Sunding & Zilberman, 2001). The model of iodine biofortification adoption developed in this study (figure 15) allows a judgement to be made regarding the structural household factors that affect the use of biofortification. Hypothetically, modelling the household and, in particular, farm factors that drive the adoption of biofortification enables understanding of the differences between research and program output on the one hand and different endemic areas, target groups and locations on the other. Therefore, it is hoped that this will, in turn, equip the decision makers, including policymakers, donors and implementers to design policies and programs that efficiently promote iodine biofortification and subsequently improve iodine intake particularly for vulnerable groups, from available food sources.

"Each of us has about 4 chances to accomplish their goals in life. I learned this through my PhD at Ghent University, because all students can expect 4 years to get great findings from their research, giving them just 4 chances to achieve their goals as leaders of tomorrow"— **Mogendi J.B.**

PART V RESEARCH DEDUCTIONS AND IMPLICATIONS

This part was established from:

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis. *International Journal of Food Sciences and Nutrition*. Volume 67, Issue 4 pp. 355-371.

De Steur, H., Mogendi, J. B., Wesana, J., Makokha, A., & Gellynck, X. (2015). Stakeholder reactions toward iodine biofortified foods. An application of protection motivation theory. *Appetite journal*. *Volume 92*, pp 295-302.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Experimental Auctions to Measure Willingness to Pay for iodine Biofortified Food: A Methodological and Empirical Approach. *Agribusiness: An International Journal, Under review*.

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Farmers' perceptions and willingness-to-adopt Biofortification: An Application of Technology Acceptance Modelling to Iodine Biofortification. *International Journal of Agricultural Sustainability, Submitted*..

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2015). Modelling protection behaviour towards micronutrient deficiencies: Case of iodine biofortified vegetable legumes as health intervention for school going children. *Nutrition Research and Practice.* Volume 10(1):pp 56-66

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Integration and Validation of an SMS-Based Bidding Procedure of eliciting Consumers' Willingness-To-Pay for Food. *British Food Journal*. **(In press)**

Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. (2016). A Novel Framework for Analysing Stakeholder's Reaction in Healthy Foods: A case-study on Iodine Biofortification. *Ecology of Food and Nutrition.* Volume 55, Issue 2 pp. 182-208.

Chapter 8 General conclusion

8.1 Summary of results and research questions answered

The principle aim of this thesis was to provide an explanation and answer to the question, "*What are the overall stakeholders' reactions toward biofortified foods, in particular iodine biofortified food? (RQ0)"*. To address this question, a total of 6 studies were conducted and either published (chapter 2-5), accepted or under review (chapter 6-7) in peer-reviewed journals. The fact that 70% of the studies conducted were accepted and published in peer reviewed journals point to significant degree of contribution to the existing literature, both methodologically and empirically, on stakeholders' reactions toward these foods. Stakeholders from the demand-side and the supply-side of the iodine biofortified food supply chain were investigated and various processes and innovative procedures were applied, including; the development and testing of conceptual framework for analysing stakeholders, a systematic review of the existing literature regarding the consumer evaluation of nutritious food, as well as a data collection protocol for each individual study conducted.

In principle, this information and the findings from these thesis is important in designing and implementation of nutrition intervention programs targeted at vulnerable groups, living in iodine endemic areas. In addition, it is a one-stop shop for building a policy framework and guidelines for improving the health and wellbeing of consumers, not only in resource poor settings but at the global level. Therefore, this thesis addresses nine specific research questions concerning stakeholders' reactions toward iodine biofortification, as identified in the conceptual framework developed and supported by the specific objectives of this dissertation (J. Mogendi et al., 2016).

What influences consumers' evaluation of food with nutritional benefits? (RQ 1)

The systematic review conducted yielded 38 primary studies with evidence that four groups of determinants influence consumer evaluation of food with nutritional benefits, such as iodine biofortified food(Joseph Birundu Mogendi, Hans De Steur, Xavier Gellynck, & Anselimo Makokha, 2016). The first group, encompassing nutritional knowledge, information and claims, are ranked among the top explanatory factors, further emphasizing the crucial role of knowledge and information provision in healthy food behaviour. It also lends support for implementing nudging towards healthy food behaviour. Second, the group of cognitive determinants (attitudes, beliefs and perceptions), and also lifestyle and dietary behaviour, seem to play an important role in consumers' decisions about functional foods and nutritious foods in particular. Together, both groups highlight the importance of integrating these elements within health promotion campaigns, school feeding programs and market promotion activities, in order to increase market share, and overall consumption, particularly in endemic areas or in at risk populations. This corresponds with the International Food Information Council (IFIC) (Washington:, 1999).

Third, price, product (e.g. sensory attributes) and process attributes (e.g. application of technologies) were also shown to influence acceptance and purchase intentions, while some consider them less important than the previous groups of determinants (Nancy M Childs, 1997; De Groote & Kimenju, 2008; H. De Steur, Gellynck, Feng, et al., 2012; Washington:, 1999), particularly for young people (H. De Steur, Gellynck, Feng, et al., 2012; Urala & Lähteenmäki, 2003). This group of internal and external product characteristics appears to be a precondition for acceptance. Consumers are, for example, affected by potential negative changes in taste, texture, flavour and colour (Chowdhury et al., 2011; Verbeke, 2006) or by the GM nature of foods (Annunziata & Vecchio, 2010; Colson et al., 2011; Hans De Steur et al., 2014; H. De Steur et al., 2010), regardless of their attitude towards the nutritional benefits. It is therefore crucial to note that it is often the (hypothetical) price perception, rather than the resultant price perception, that has been found to be a significant determinant (N. M. Childs, 1997; Menrad, 2003; Williams, 2005).

Finally, socio-demographic variables, which are often used to develop marketing strategies targeted towards specific population segments, four key variables are identified, namely gender, age, income and education, in line with consumer research on functional foods (Nancy M Childs, 1997; N. M. Childs, 1997; Washington:, 1999). Whereas women are significantly more favourable towards nutritious foods, age, income and education are generally positively related to acceptance of foods with nutritional benefits. The greater interest by older consumers with high income levels is particularly striking, as young, poor people are much more at risk of nutrient deficiencies, particularly in developing countries. Young people on a low income are the hardest hit and are considered to be a key target group for health interventions. This further underlines the challenges faced in alleviating the burden of malnutrition, as demonstrated in the Millennium Development Goals report (Blanchfield & Lawson, 2010), and now the sustainable development goals (Roehrl, 2012).

Regarding the conceptualization of acceptance, which was an extension of this objective, this study coined a clear and standardised terminology for describing foods with health benefits and enhanced nutrient levels in particular (e.g. nutraceuticals and biofortified foods). Therefore, one should correctly refer to the most appropriate term within the broad spectrum of functional foods in general, or food with nutritional benefits in particular, of which the latter could be coined as a standardized, easy-to-interpret generic term such as “nutritious food”. When, for example, referring to biofortified foods developed through GM technology as a subcategory, researchers and other stakeholders (e.g. policy makers, health planners, the media and consumers) should aim to adopt the same terminology, i.e. either GM biofortified food or transgenic biofortified food. From a marketing viewpoint, the pooled evidence in this review demonstrate that clearly communicating the nutritional benefits, and thus using the right term, can be expected to improve understanding and most likely the acceptance of such foods. While from a research viewpoint, correctly defining and using these terms will facilitate literature searches in future studies, especially in the case of systematic reviews.

However, the same accounts for the measurement of acceptance, the heterogeneity of which is expected to increase the risk of method bias in the studies, while hampering the external validity of the results. Studies dealing with acceptance refer to different terms, such as perceptions, beliefs, attitudes, preferences, choices, purchase intentions and even eating behaviour. The response to this question provided an avenue for identifying key elements for integration when building a conceptual framework for analysing stakeholders, as demonstrated in the response to the next question (RQ2)

Is a conceptual framework that integrates protection motivations and technology acceptance modelling, as well as economic valuation techniques valid to explain stakeholders' reactions toward biofortified food?(RQ2)

The aim of the current research was to replicate, extend and test an integrated model, bringing together protection motivations theory, the technology acceptance model and the contingent economic valuation technique, for use in analysing the stakeholders' reactions to and uptake of novel nutrition intervention strategies, such as biofortification. The amalgamated model is crucial in understanding stakeholders' reactions towards biofortified products in the biofortified food supply chain, for prevention of micronutrient malnutrition. To respond to this question, our findings provide a resultant integrated model, to be called PTAM, with two major aspects: a consumer-oriented part, based on the PMT constructs and a production-oriented part, based on the TAM constructs, and an interlinking portion, based on an economic valuation technique for assessing resultant behaviour, such as preference (willingness-to-pay).

Then a validation study was conducted to test the applicability of the conceptual framework developed, showing that the resulting construct can accurately and consistently describe both the behavioural intentions, as well as the resultant behaviour, of the stakeholders across the iodine-biofortified vegetable legumes supply chain. This integration is in tandem with previous research on the amalgamation of behavioural change models, incorporating new techniques that improve their applicability in different fields and settings (Dreibelbis et al., 2013; MacKenzie et al., 2011; Quinn et al., 2012). This integration is particularly important in describing the respective determinants and economic value attached to biofortification uptake by stakeholders in the food supply chain. This is a crucial element in designing and implementing nutrition interventions and campaigns for micronutrient malnutrition, which is a major public health challenge in the developing world (Harrison, 2010; Ramakrishnan, 2002; Tulchinsky, 2010).

To our knowledge, and in principle, this is the only integration and validation that provides an alternative for assessing protection motivations (behavioural intention) and behavioural action of stakeholders in relation to the consumption and production orientation of biofortified foods for the prevention of micronutrient malnutrition. The model is then applied to respond to the next questions in this doctoral research, which further acts to test the conceptual framework.

What are the stakeholders' reactions toward iodine biofortified food? (RQ3)

To respond to this research question, a PMT- based portion of the conceptual framework was applied to model parents' and school heads' reactions towards iodine biofortified food in Uganda. By applying this conceptual framework to the case of iodine-rich legumes in an at risk region of Uganda, the effect of both external and internal (coping, threat) PMT components on protection motivation (intention) is analysed. In general, the intention to adopt is high, a finding that is shared in previous research on nutritious products (Dannenberg, 2009; de Beer, 2012; J. L. Lusk et al., 2005) and biofortified foods (Hans De Steur et al., 2014; H. De Steur, Gellynck, Feng, et al., 2012; Gonzalez et al., 2009; J.L Lusk, 2003).

Therefore, this successfully answers the current research question (RQ3). Nevertheless, it seems that knowledge of the health problem is still crucial for enabling protection motivations. The positive effect of knowledge, or – from a policy viewpoint – information, is also found in previous research on Folate and Vitamin A enriched crops (H De Steur et al., 2013; Depositario et al., 2009). Furthermore, whereas self-efficacy turned out to be a strong determinant of motivation intention among parents, response cost, a component rarely included in PMT studies, has a clear negative effect on the behavioural intentions of school heads. In addition, socio-demographics such as age and gender also influence the likelihood of adopting a behavioural change towards biofortified food consumption. With respect to these findings, a child feeding intervention based on iodine biofortified foods should strive to increase awareness of iodine, its association with deficiency disorders and self-efficacy among stakeholders, while at the same time ensuring that the cost incurred by schools is not considered to be a barrier.

What elements predict protection motivations (behavioural intention) and resultant protection behaviour regarding the purchase and consumption of iodine biofortified food? (RQ4)

To answer this research question, a study was conducted to provide insights into how well factors exogenous and endogenous to the PMT model predict protection motivations (intention) and subsequent protection behaviours (willingness-to-pay a premium or discount) towards iodine biofortified food. The study presents the case of IBVL as an option for protecting households and their children from iodine deficiency disorders and improving children's school performance. Over the years, knowledge about nutrients and nutritious foods, such as biofortified foods, and their links to health has been insufficient (Axelson et al., 1985). Although attempts have been made to draw significant associations between nutritional knowledge and nutrient intakes on the one hand and actual behaviour towards purchase and consumption on the other, very few studies have demonstrated these links, and significance levels are far from being realized (David N. Cox & Bastiaans, 2007; David N Cox et al., 1998).

The findings of the current study are no different and strong evidence existed to support the line of research questioning presented (RQ4). Knowledge about iodine, its link to iodine deficiency disorders and poor school performance, as well as the available prevention strategies, such as salt iodization and biofortification was insufficient and lower in less educated than highly educated groups. The responses regarding a set of questions evaluating nutritional knowledge about micronutrients, iodine, iodine deficiency, salt iodization, and biofortification differed significantly between different groups. The nutritional knowledge of less educated household respondents was relatively low compared to more educated respondents at the school level. Figure 10 shows that knowledge about iodine, health threats arising from iodine deficiency, and the subsequent novel strategy of food biofortification is insufficient. Nevertheless, many previous studies have presented elements that largely account for the low influence of nutritional knowledge on dietary changes to increase nutrient intake for health and nutritional wellbeing (David N Cox et al., 1998; Wardle et al., 2000).

These findings not only answer the research question in this thesis but also demonstrate the likely importance of including nutritional knowledge when designing health education campaigns, particularly for the prevention of iodine deficiency disorders and poor school performance, through novel strategies such as biofortification. Knowledge about nutrient-related deficiency disorders and approaches for preventing these disorders are very important elements for consideration (H De Steur et al., 2013). Furthermore, for nutritional education campaigns to be successful, it is worth considering the types, sources, and modes of communicating nutritional messages such as nutrients, sources, health threats, and available prevention mechanisms (Kozup et al., 2003). To emphasize the role of these elements, figure 10 demonstrates also that the market, media, and professionals are the most effective avenues. Even though the media is effective in highly educated groups, such as school heads, use of professionals and markets are more effective in less educated groups such as households.

In addition, to predict protection motivations (intention) to consume biofortified foods (IBVL) as a means of preventing IDD and improving school performance in children, the study results provide some support for endogenous and exogenous elements in the PMT model. At the household level, in contrast to our hypothesis, only two exogenous elements, knowledge and occupation, and three endogenous elements, severity, fear, and self-efficacy, were able to directly and significantly predict protection motivations (intention). Accordingly, iodine status and the presence of young children (6-12 years old) indirectly predicted behavioural intention through ‘threat’ appraisal and ‘coping’ appraisal. Furthermore, at the school level, in contrast to our hypothesis, only two endogenous variables, vulnerability and self-efficacy, and one exogenous variable, country of origin, significantly predicted intention to consume IBVL.

Our findings are consistent with results from earlier studies predicting intention and interventions in health behaviour, particularly dietary behaviour (Milne et al., 2000). Self-efficacy, an endogenous element of the coping appraisal construct of PMT, was found to be the most important predictor of intention to consume biofortified foods at both the household and school levels. This is consistent with earlier studies predicting dietary behaviours in relation to nutritious foods that reported self-efficacy as a decisive factor in nutritional education campaigns for dietary changes (David N. Cox & Bastiaans, 2007; D. N. Cox et al., 2004; Otieno et al., 2013). However, severity, fear, and vulnerability from the PMT threat appraisal construct, as well as the exogenous elements of knowledge and occupation, had direct and significant effects on intentions towards biofortified foods. Nevertheless, other exogenous elements such as iodine intake status and the presence of young children aged 6-12 years had significant effects, albeit indirectly.

These findings point to a more pronounced effect of threat appraisal combined with exogenous elements, which differs from earlier studies that demonstrated 'coping' appraisal as having the most important effect on intention to consume nutritious foods (David N. Cox & Bastiaans, 2007; D. N. Cox et al., 2004). Therefore, it is a precarious undertaking to ignore 'threat' appraisal, as well as exogenous elements, in the prevention of micronutrient deficiencies through biofortified foods such as IBVL. The combined effect of these elements is highly significant and important, which contradicts the conclusion that self-efficacy is the most important factor in health and nutritional promotion. Therefore, to increase protection motivations (intention) to consume a healthy diet, or nutritious foods such as biofortified foods, communication of the 'threat' appraisal and exogenous elements is worthwhile. Programmes targeted at vulnerable groups, both at the household and school levels (school feeding programme), should include these elements in their nutritional promotion campaigns and in launching novel preventive strategies such as biofortification.

What factors influence consumers' willingness to pay a premium or discount for iodine biofortified food? (RQ5)

In addition to the description of the responses in RQ4, in support of this research question, path analysis modelling was conducted to assess elements that influence and predict protection motivations (intention) to consume nutritious foods, particularly biofortified foods(J. B. Mogendi, H. De Steur, X. Gellynck, & A. Makokha, 2016). Furthermore, two-limit Tobit modelling (Table) was used to evaluate the effect of endogenous and exogenous variables on the PMT model that influence protection behaviours or preferences for adopting biofortified foods (in this case IBVL). The preference was presented as a willingness-to-pay component when the biofortified product was offered at a premium or discount at both the school and household levels. An attempt was also made to examine the elements influencing preference for this product to be included in a school feeding programme.

In support of the research question, the findings show that households are willing to pay an average US $1.89 (premium, US $0.39) and US $1.72 (premium US $ 0.22) for an IBVL meal and inclusion of IBVL within a school feeding programme to protect their children. Consequently, school heads are willing to pay US $1.84 (premium US $0.34) L and US $1.67 (US $0.17) for IBVL and inclusion within a school feeding programme, respectively. However, when the product was offered at a discount, parents were willing to pay US $0.98 (discount, US $0.52) and US $0.67 (discount US $0.83) for IBVL and inclusion within a school feeding programme, respectively. These results demonstrate a willingness-to-pay a premium and acceptance by both the parent and school for accruing nutritional benefits. This is consistent with earlier studies examining willingness-to-pay for foods with health benefits, particularly nutritional benefits (David N Cox et al., 1998; De Groote et al., 2011; H. De Steur, Gellynck, Feng, et al., 2012; Gonzalez et al., 2009; J. Meenakshi et al., 2012). Respondents were willing to accept fewer discounts when the iodine biofortified product was offered at a discount due to the envisaged nutritional benefits, albeit more at school level than in households due to the attachment of children to their parents.

Table 11 shows results from the Tobit model. A total of two sets of Tobit models were developed. First, the model estimated exogenous and endogenous PMT variables influencing preference for IBVL when offered at a premium. Protection motivation (intention) was the most important factor that directly and significantly influenced willingness-to-pay for iodine biofortified foods at both the household and school levels. At the household level, other elements, such as severity, and gender were very significant. However, to include the product within school meals, response (product) efficacy and country of the household are important at the household level, whereas response cost was important at the school level. These results are in tandem with previous findings examining the link between protection motivations (intention) and resultant protection behaviour (preference as defined by willingness-to-pay) with regard to health intervention (in this case Biofortification) (Park et al., 2011; Prentice-Dunn & Rogers, 1986; R. W. Rogers, 1983).

Therefore, these elements should form part of health and nutritional promotion programmes for the prevention of micronutrient deficiencies, in this case IBVL for iodine deficiency and improved school performance. For instance, households are likely to pay a premium to protect their children from iodine deficiency disorders and to improve their school performance if nutritional campaigns communicate the severity of the threat and if mothers are more involved and their motivation towards the proposed product is high. In essence, schools are likely to pay more when convinced that the proposed behaviour will protect their children against iodine deficiencies and improve school performance. Second, the model evaluated exogenous and endogenous PMT variables influencing the preference for IBVL offered at a discount at both the household and school levels. Severity, fear, response efficacy, and iodine status were the most important and significant factors influencing preference for IBVL when offered at a discount to households. When the product was offered at a discount at the school level, vulnerability, fear, gender, and age were the most significant factors.

However, for inclusion of the product within the school feeding programme, households are likely to accept that it can be significantly influenced by vulnerability, response efficacy gender, age, the household decision maker, and the country in question. However, findings are consistent with earlier results that have examined willingness-to-pay for nutritious foods (in this case biofortified foods), particularly in resource poor countries (De Groote et al., 2011; Gonzalez et al., 2009; J. Meenakshi et al., 2012).

When nutritious products were offered at a discount, the protection behaviour (preference) was shown to be a function of the health threat and socioeconomic factors such as age, gender, and knowledge level. Consumers, at either the household or school level, were more likely to accept fewer discounts (pay more for the proposed prevention measure) if the health threat in question was more important to them and their children. Therefore, these elements should be incorporated into nutrition campaigns if they are to be successful. Although consumers are likely to pay for various discounts depending on the perceived value of the product and its health benefits, they are not likely to compromise taste for health (Verbeke, 2006). These points to the fact that households are more sensitive to health threat and are likely to accept a lower discount in order to protect their children.

In principle, our results extend earlier findings and contribute to the growing body of literature on the prevention of micronutrient deficiencies through biofortification. The findings point to the growing need to consider endogenous PMT variables, particularly 'threat' appraisal constructs, as well as exogenous elements such as age, gender, and knowledge, in decision-making and in designing nutritional intervention campaigns for micronutrient deficiencies. The preference (willingness-to-pay) and factors that influence this protection behaviour are very important in understanding the adoption of biofortification as a novel strategy for the prevention of micronutrient deficiencies (Birol et al., 2015; H De Steur et al., 2014). These elements point to enhanced policies for building local markets and subsequently the availability of iodine biofortified foods.

What is the validity of using short messaging service (SMS) as a bidding procedure for eliciting WTP through BDM auction? (RQ6)

Two concurrent studies and analyses were conducted in relation to this question. A procedure, method or test yielding high sensitivity (at least 80%) is considered good enough to validate its use (Kanchanaraksa, 2008). More often than not, positive willingness-to-pay i.e. the number of people willing to pay for the product above a stipulated market price, is the target when launching new products and services to the market (Kalish, 1985; Ordover & Willig, 1981). This is often because it is indicative of marginal profit, as consumers are willing to pay for a product when offered at a price higher than the market price (Jayson L Lusk et al., 2004). The study examined the SMS-based findings against the standard BDM. The findings of this comparison (validity in response to RQ6) are that the level of sensitivity is of particular importance in the elicitation of WTP for a new product and the high sensitivity values presented by SMS-based BDM support its applicability. Equally, a high specificity reduces the chances of a new product being launched in rural areas and to consumer segments who may not be willing to pay above the market price for it, as there is a risk of losses and low uptake (McAfee, 2008). The SMS-based BDM procedure also produced high levels of positive and negative predictive values. Predictive values gives the proportion of positive and negative results produced by the method under validation (Stojanović et al., 2014). High positive predictive value refers to the percentage of individuals found testing positive when they actually have the condition (true positive) i.e. the percentage of consumers willing to pay more for the product when offered it at a given market value when they are actually ready and willing to pay more for it. It also involves accuracy and precision in identifying the percentage of individuals with a positive preference for the product when they truly are willing to pay for the product.

This is an important element in experimental economics and in the market, as one can predict the consumers who are likely to pay a premium for the new product (Dobson & Kalish, 1993; Kalish, 1985; Ordover & Willig, 1981). On the other hand, negative predictive value is the percentage of people or consumers who actually have a low preference for the product and are only willing to pay below the market price. This is an important indicator, as it points to the actual proportion of a consumer segment that is only willing to pay less than the market price for the product. Again, this is important for pricing and in decisions to launch new products either at a discount, providing more incentives, or avoiding the segment altogether (Braouezec, 2012; Ordover & Willig, 1981).

The new procedure also had a high value for likelihood ratio (LR+ 2.587 to 3.256 and LR- 0.083 to 0.148). Likelihood ratio incorporates both sensitivity and specificity to estimate the extent to which the results of a procedure, method or test provide the evidence for the presence or absence of a condition/ behaviour or state i.e. the evidence that consumers are willing to pay more or less than the market price. The more the likelihood ratio deviates from 1 the stronger the evidence for the presence or absence of the state, i.e. for all the experimental auction scenarios, the likelihood values are further away from 1, which provides strong evidence on the proportion of consumers willing to pay more for the new product (LR+) and those only willing to pay less than the market price for the product (LR-) when using the SMS-BDM. This can significantly influence pricing decisions in the market and increases understanding of consumer segments (Braouezec, 2012; Ordover & Willig, 1981).

Furthermore, the post-test probability plots in figure 13, present the trend in the proportion of consumers who are truly willing to pay for the new product in all the five treatment rounds. It provides similar information with positive predictive values, apart from its inclination to the performance of the method towards individual participants/ consumers. The post-test plots demonstrate that the SMS-BDM accurately and consistently identify those truly willing to pay more for the product and those only willing to pay less for the product. The divergence from the market prices for both positive willingness-to-pay and negative willingness-to-pay is equally important when pricing and targeting new products in the market (Ordover & Willig, 1981).

What is the resultant preference (WTP) for iodine biofortified food? (RQ7)

In addition to the above validation (RQ6), further analysis based on the pooled data show that the consumers had a very high preference for biofortified food, which is important in designing nutrition intervention programs geared to preventing iodine deficiency disorders(Angermayr & Clar, 2004; Peterson, 2000; Michael B Zimmermann, 2014), particularly among the at risk population (ICCIDD, 2014), living in areas where iodine deficiency is endemic and salt iodization and supplementation is largely ineffective (François Delange et al., 2001; Fiore et al., 2014; Halim et al., 2015; Peterson, 2000; Michael B Zimmermann, 2014). Adoption of new strategies, such as biofortification in developing countries (Stein, 2014; Sully, 2014), is mainly influenced by the preference levels exhibited by the target vulnerable group (Birol et al., 2015; H. De Steur et al., 2015; Johnson et al., 2015). If the stakeholders' preference for these types of strategy is not well quantified and incorporated into the design of nutrition intervention programs, then biofortification as a potential strategy for preventing iodine deficiency will not succeed (Johnson et al., 2015; Waized et al., 2015).

Consequently, the procedures applied for this process need to be validated to ensure that the results are consistent and can be reproduced. The estimated trend in the value of WTP values when different conditions prevail in the target community is vital in launching iodine biofortification as an alternative nutrition intervention for iodine deficiency disorders among the vulnerable population not protected by salt iodization and supplementation (François Delange et al., 2001; Fiore et al., 2014; Halim et al., 2015). Uptake of this novel strategy by vulnerable groups, can make a substantial contribution to the fight against iodine deficiency and its devastating toll in terms of brain damage and consequent mental and neurological disorders, which is the primary motivation for the current global campaign (François Delange et al., 2001; Prado & Dewey, 2014; Redman et al., 2015).

When launching iodine biofortification amidst the presence of salt iodization in locations where consumers or vulnerable groups are well informed of the product with elevated levels of iodine, overall nutrition information regarding their iodine status, should be incorporated within nutrition campaigns as a means to increase their willingness-to-pay for the product. This is consistent with previous research that has shown the crucial role of communicating the nutrition status of the individuals when launching intervention programs, as demonstrated in scenario 1. However, when information about the nutrient (iodine) intake status is provided to the vulnerable groups other elements come into play, as shown by scenario 5.

In principle, the findings demonstrate that trends in willingness-to-pay for biofortified foods under different circumstances/scenarios vary significantly. When WTP is analysed for five different scenarios with the aim of establishing potential, the resultant kernel density plot (Figure 14) indicates that each market condition has a significant impact. The kernel density estimates reveal that all the treatment scenarios contribute significantly to the bidding behaviour, in the form of WTP, exhibited by the target group. And each of the treatments led to some WTP behaviour which is significantly distinct.

These findings are consistent with previous studies that have demonstrated the volatility of willingness-to-pay behaviour in the presence of different information treatments (Gifford & Bernard, 2011; Simonson & Drolet, 2004), including for food with additional nutrition benefits (H De Steur et al., 2013; Oparinde et al., 2014). Therefore, the five scenarios created, including: Product characteristics; health threat; product improvement (GM or conventional); and the iodine status of the target group, depict the characteristics of an ideal market that has the potential to impact on the uptake of biofortification (Stein, 2014).

What is the reaction and overall trend in the adoption of iodine biofortification by smallholder farmers? (RQ8)

In response to this line of questioning, the study shows that individual driving factors examined were active at both the higher level and the lower level. The lower level is the level at which they influenced the intention to adopt and attitudes towards iodine biofortification; while the higher level is the level at which they influence the resultant adoption of biofortification. Although gender increased the intention to adopt biofortification, the occupation, farm size and decision making by the firm significantly reduced farmers' intentions to adopt iodine biofortification.

These findings are consistent with previous research that shows gender as a decisive factor in behavioural intention, and males are greater risk takers than their female counterparts (Doss & Morris, 2001). Additionally, engagement with other activities and occupations considerably reduced the reactions to adopt biofortification, which is consistent with earlier studies on the uptake of innovations and technologies, including biofortification, at the farm level (Adrian et al., 2005; Rezaei-Moghaddam & Salehi, 2010). Furthermore, the size of the farm is indirectly proportional to the intention to adopt, meaning the smaller the farm size the less likely the farmers will intend to adopt biofortification, which is consistent with earlier studies (Coelho et al., 2001; Vanclay & Lawrence, 1994).

The results, however, contradict earlier research that shows a direct relationship between involvement in decision making by the farmer concerning the consumption and production of food at the household level and the intention to adopt new strategies and farming practices at the household level (Adesina & Baidu-Forson, 1995; Atanu et al., 1994; Doss, 2006), This could be attributed to the sensitive nature of the technology in question, biofortification, with the decision maker being sceptical about the overall implications of adopting the technology. Meanwhile, gender and the presence of young children reduced the attitude of the smallholder farmers towards iodine biofortification. Females are more likely to have a positive reaction towards biofortification than males. This can be traced to the women's high level of concern for the health and wellbeing of everybody in the household (Doss & Morris, 2001). This is consistent with previous research that has documented the influence of gender on innovations and technologies, particularly biofortification, by different stakeholders.

However, the results contradict earlier studies that have shown a direct relationship between the presence of young children in the household and an increase in positive attitudes towards biofortification (H. De Steur, Gellynck, Feng, et al., 2012). This can be explained as having a link with the protective nature of the parents, as they prefer not to consider trying a new innovation and technology on their children, regardless of the fact that the children are young and more susceptible to IDD.

What are the willingness, ability and frequency of adopting iodine biofortification by smallholder farmers in endemic areas? (RQ9)

In support of this research question, the exploration started in RQ8 above was further extended. The findings from this exploration show that, at the higher level, there are three models that can be used to examine the resultant adoption process of biofortification among the smallholder farmers, as presented in tobit modelling: a) as a willingness-to-pay for adoption of iodine biofortification; b) frequency of adoption at household level; and c) frequency of adoption at the farm level. The censoring was done at the lower level to ensure resultant adoption was either at zero or above zero for Tobit modelling (Tobin, 1958).

Six elements were particularly decisive in determining resultant adoption when presented as willingness-to-pay for adoption. Individual driving factors, including age, presence of young children and farm size, as well as the TAM and moderating factors, including intention, perceived ease of use and trust in the information source and institutions, had a significant effect on the resultant adoption of biofortification when packaged as a willingness-to-pay for adoption. Individual driving factors, age, the presence of young children in the household and the farm size increased the willingness of farmers to pay for the adoption of biofortification.

These findings are consistent with earlier research that has seen these elements positively influence the adoption of technologies and innovations (Feder & Umali, 1993; Kesseba, 1989), even in the case of adoption of biofortification by stakeholders for health value (H. De Steur et al., 2015). In addition, the intention to adopt biofortification and the perceived ease of use of the technology at the farm level, increases the willingness of farmers to adopt a new strategy such as biofortification (Anandajayasekeram et al., 2009; Sunding & Zilberman, 2001).

These findings are also in line with the findings that have seen these two elements influence the adoption and acceptance of new technology in the agricultural sector (Feder & Umali, 1993; Kesseba, 1989) even in developing countries (Feder et al., 1985). However, as expected, trust in the information sources for biofortification, as well as trust in institutions that provide such information, often increases willingness-to-pay for biofortification. This trend has also been reported in earlier studies (Maertens & Barrett, 2013), albeit more in the case of genetically biofortified food (Vanloqueren & Baret, 2009). Therefore, it is important to use highly trusted sources and institutions when launching iodine biofortification programs among SHF in these endemic areas.

When, resultant adoption was packaged as frequency for adoption of biofortification at the household level, eight groups of elements significantly predicted the resultant adoption of biofortification. Individual driving factors, including: age, education level of the farmer, presence of young children in the household, marital status, the overall farm size and decision making, had a significant effect. These findings point to existing evidence that these socio-economic factors influence the adoption of innovations and technologies at the farm level. The older and the more educated the farmer the more likely they are to take up biofortification on the farm. This is consistent with earlier studies on the influence of age and education level on the frequency of adoption of these processes at the household level (Foster & Rosenzweig, 2010). Furthermore, the presence of young children also significantly increased the frequency of resultant adoption of biofortification. This has been demonstrated in earlier studies (Adesina & Zinnah, 1993; Doss & Morris, 2001).

In addition, the farm size and the decision making role at the household level also significantly increased the frequency of resultant adoption. And this trend has also been demonstrated with other innovations and strategies at the household level (Adesina & Zinnah, 1993; Feder et al., 1985; Foster & Rosenzweig, 2010). Meanwhile, the marital status of the household significantly reduced the frequency of resultant adoption. Therefore, the status of having a stable married relationship will result in the likelihood that the frequency of taking up biofortification will be reduced. This contradicts other studies that report a direct correlation (Adesina & Zinnah, 1993; Doss & Morris, 2001; Feder et al., 1985). This can be explained as having to do with the commitment not to burden the other partner in the household with the view that adopting biofortification at the household level will be expensive and can deprive the partner of support.

Consequently though, only two TAM and mediating factors had an effect on the frequency of adopting biofortification at household level. Perceived usefulness and attitude toward biofortification significantly increase the frequency of resultant adoption of biofortification. This is also consistent with earlier studies that show a greater trend in adoption if a technology or innovation, in this case biofortification, is perceived to be more useful for the intended purpose (Anandajayasekeram et al., 2009; Feder et al., 1985; Feder & Umali, 1993; Kesseba, 1989). Equally, the increased attitude towards biofortification results in increased frequency of adoption. This finding has been reported by numerous studies on the adoption of innovations and technologies (Adrian et al., 2005; Ajzen & Fishbein, 1980; King & He, 2006).These points to the need to capture and communicate these elements, as well as targeting specific groups in the community if the frequency of adopting biofortification at the household level is to succeed, for any iodine intervention program.

Nevertheless, when participants were presented with resultant adoption as a frequency for adopting biofortification at the farm level, only the group and community driving factors, as well as individual driving factors, had a significant effect on resultant adoption frequency at the farm level. Group/community driving factors reduced the frequency of adopting biofortification at the farm level. This shows that the influence of peers in the community has a very significant impact on the adoption of biofortification and they are more likely to be influenced by other farmers in the community. The findings are consistent with studies that show that group and community driving factors negatively influence the actual behaviour towards a new innovation and technology (Rezaei-Moghaddam & Salehi, 2010), for example biofortification.

Further, age, income of the household and the decision making of the farmer with regard to food production significantly increase the frequency of resultant adoption of biofortification at the farm level. The older the farmer is, the higher the frequency of adopting iodine biofortification and vice versa. This has also been demonstrated in other studies on the adoption of some technologies and innovations. In addition, the higher the income of the SHF the more likely they are to adopt biofortification more frequently on their farm. This is shown in other studies that point to a direct relationship between income and uptake of technologies and innovations (Fernandez-Cornejo et al., 2005), including biofortification (Nwakor et al., 2011). Furthermore, the more the SHF is involved in making decisions about the household the higher the frequency of adopting biofortification. This is also consistent with studies on the uptake of biofortification (H. De Steur et al., 2015; Feder et al., 1985; Nwakor et al., 2011).

Therefore, in designing iodine biofortification programs for endemic areas, these elements should addressed if the program is to succeed. This is mainly because the frequency of adopting biofortification at the farm level significantly translates into greater production of iodine biofortified food. As a consequence, the iodine intake is improved, not only for the farmer but also for the most vulnerable groups in their community, i.e. young children.

8.2 Research outcomes and practical implications

Contribution to research and bridging the knowledge gap are crucial elements in the advancement of science (Aghion, David, & Foray, 2006; Elg-VINNOVA, 2014). The fact that 80% of the studies that were conducted, constituting the 5 out of the possible 6 main chapters of this thesis, have been published in peer reviewed journals significantly favour the contribution of this thesis to the existing literature, both at the methodological and empirical level. This is however considered sparingly because although the peer reviews journal could miss thoroughness of evaluating the contribution to literature.

This thesis presents three forms of contribution: 1) theoretical contribution (including new techniques, concepts, and analyses); 2) practical contribution, including system experiments, prototypes and new applications; and 3) societal contribution (including, policy direction, guidance for consumers and producers). Based on the perspective demonstrated by Whetten (1989), the theoretical contribution comprises four elements: 1) *what*, with regard to what concepts are identified and specified; *how*, regarding the relationships that exist between the concepts; *why*, in relation to the logically-argued explanations for these relationships and ; *who*, *where* and *when* , referring to the bounding contextual elements within which the contributed theory operates, or otherwise. As outlined earlier, this thesis comprises distinct chapters bundled together in a unique and coherent way. The diverse contributions are also captured within each of the chapters.

Nevertheless, this is clearly communicated in seven different ways: first, clearly demonstrating the originality of the contribution; second, arguing the impact that the contribution will have both in research and practical spheres; third, providing compelling logical, as well as empirical, evidence for each new explanation; fourth, having a vigorous scholarly outline and execution; fifth, following a clear protocol of scientific writing and reporting; sixth, timeliness of the contribution and offering up-to-date dimensions in research; and finally, indicating, albeit broadly, the overall impact of the contribution to the scientific community, policy and society.

In the first instance, the methodological rigour, exhibited by conducting a systematic review to understand consumer evaluation of food with nutritional benefits and conceptualisation of food with nutritional benefits as well as terminologies thereof (chapter 2), demonstrate that the contribution to this domain is consistent from the outset of this thesis. Extrapolating a procedure commonly applied in the medical and epidemiological fields to conduct the review, is in itself a major contribution to consumer research and backs the conduct of future reviews in consumer research, food and nutrition science, as well as improving the quality of primary studies. The review not only provides the key determinants of acceptance, but also offers criteria for analysing the quality of the primary studies included, through the quality appraisal tool generated. This is often not common consumer research, but is currently gaining ground as a necessity to evaluate the quality of primary studies included in a review (LJ Frewer et al., 2014; L. J. Frewer et al., 2013). Also, by conceptualizing acceptance, it clearly provides an alternative to building a typology that differentiates this concept and helps to streamline research in this dimension. Thereby the findings are timely not only for the researchers and other players in the industry but also the consumers themselves as they allow informed healthy food choices.

Second, integration of behavioural change models and economic valuation techniques to build a resultant conceptual framework applied in analysing stakeholders throughout a biofortified food supply chain is a unique approach and a major contribution to science and the conduct of research in consumer science, agricultural, food and nutrition science (J. Mogendi et al., 2016). The resultant model is also subject to validation and this is one aspect not often demonstrated in previous integrations. Again, the fact that the integration and the findings from the testing of the resultant model using a specific case of iodine biofortification, point to the potential of applying the model to providing snap shot details about the stakeholders that often influences adoption of these new strategies and technologies. This framework is the first of its kind that seeks to examine different stakeholders across the entire food supply chain.

Third, investigating consumers' reactions towards biofortified foods, i.e. iodine biofortified food, offers insights into the actual application of the conceptual framework developed in chapter 3. The unique multistage cluster sampling employed and the convenient recruitment based on the underlying trends in the distribution of malnutrition, build on the need to link research with actual field conditions and to engage the beneficiaries in designing research and intervention programs. Additionally, this is the first attempt to highlight the element of behaviour, as outlined in the protection motivation theory in the resultant conceptual framework among consumers who influence the adoption of novel strategies for preventing micronutrient malnutrition, such as biofortification. It is the first approach to analyse the specific influences of iodine biofortified food adoption, as well as considering the most vulnerable locations in the developing world.

Fourth, application of the resultant conceptual framework, the PMTAM model (chapter 3) (J. Mogendi et al., 2016), that also integrates economic valuation methods, such as contingent valuation, provide explanation as to the willingness-to-pay values exhibited by stakeholders. For instance, the findings show that when iodine biofortified food is offered at a premium or a discount, the consumers located in iodine deficiency endemic areas, are willing to pay more for these product and are also likely to accept less discount. This finding is particularly important in launching nutritional intervention programs for preventing iodine deficiency at both the school and household level. Besides, they stands to bridge the knowledge gap regarding the application of these WTP values, as well as provide new approaches for conducting consumer research. Also, the findings from this part offer two directions in the market for iodine biofortified food. The willingness-to-pay a premium provides an explanation for the new demand market for biofortified food among the target community, which is crucial to the smallholder farmers venturing into this technology. Equally, it explains how much the government, investors; donors and implementers of programs need to invest in micronutrient intervention. The more consumers are willing to pay a premium, the lower the investment, and vice versa. This is an important breakthrough not only for society but also for policymakers to develop policy guidelines and for implementers to design the most appropriate nutrition intervention based on iodine biofortification.

Fifth, in conducting an experimental auction, an explanation is sought regarding the actual amount consumers susceptible to iodine deficiency disorder would be willing to pay for iodine biofortified food. This is a unique approach to involve the affected consumers in understanding their willingness-to-pay for a health product to protect them. Besides, this is the first attempt to quantify the value of iodine biofortification, particularly in these resource-poor and highly vulnerable locations. This builds directly on existing knowledge about biofortification and also provides insights into the most appropriate pricing mechanism when designing iodine intervention programs for these groups.

Furthermore, although a well-established experimental auction procedure, Becker-Degroot-Marschak (BDM), was used for this analysis (Becker et al., 1964), attempts were made to integrate a short messaging service (SMS) into the BDM procedure to improve its effectiveness and coverage in line with the benefits of a technological systems that are much faster, cheaper, technologically sound and safer way. SMS, commonly known as 'text messaging' (Gayomali, 2012; Kew, 2010; Trosby et al., 2010), is gaining support for its application in behavioural and economic research (Kew, 2010; Reimers & Stewart, 2009). According to the world bank, this is one of the innovative pro-poor systems widely adopted in the developing world (Kew, 2010; Manji et al., 2015; World_Bank, 2014).

To our knowledge, this is the first such attempt to apply and validate this procedure for elicitation of willingness-to-pay in experimental auctions. Again, a unique standard protocol commonly used in the validation of medical diagnostic tests (Budczies & Kosztyla, 2012; Mayasari & Lestariana, 2014; ten Bosch & Angmar-Mansson, 2000), was used to validate the integration of the SMS system into the standard BDM procedure. Thereby, the contribution at the two levels is enormous and seeks to revitalise the conduct of consumer research. In essence, this is crucial for understanding the demand for new food products, such as biofortified food, and services, as well as in designing food policies, often because the demand estimates for computing cost benefits, pricing and profits are not readily available (Maria Lus Loureiro & McCluskey, 2000; Mørkbak et al., 2011; Voelckner, 2006).

Sixth, previous research shows that the adoption of innovations and technologies within the food supply chain is stakeholder driven (H. De Steur et al., 2015; Doss, 2006; Feder & Umali, 1993). Research regarding the adoption of biofortification and biofortified products has largely been conducted on consumers', even in the case of iodine biofortification (H. De Steur et al., 2015).

Therefore, to our knowledge, this thesis provides the first attempt that aims to explore and provide an explanation for the trend in the adoption of biofortification by stakeholders on the supply-side (producers), e.g. farmers, particularly in areas where iodine deficiency is endemic. Nonetheless, the benefits accruing from biofortification are largely perceived to be inclined towards consumers. This misconception masks the potential of biofortification as an avenue for creating demand-driven niche markets that have benefits, not only for consumer accessibility, but also for smallholder farmers and their households, in terms of an increased market for their produce as a result of willingness-to-pay a premium and the ability to adopt biofortified food at a lower discount.

Moreover, the application of the conceptual framework for analysing stakeholders' uptake of biofortified food production strategies (J. Mogendi et al., 2016), which was developed, validated and published as part of this thesis, is a significant contribution to the advancement of science and society in this direction. Furthermore, the explanation about the determinants for the overall willingness to adopt iodine biofortification, as well as the choice of the participants from the most vulnerable locations in the south, presents another unique and significant dimension for streamlining consumer research and a foundation for future contributions.

In conclusion, the implications of this thesis are threefold:

Firstly, at the scientific level, the findings from each study conducted present both a methodological and empirical contribution which present a significant bearing to the performance of consumer research. For instance, the systematic review is a crucial element that not only streamlines how the impact of different studies can be summarised for ease of applicability, but also the overall conduct of primary studies based on the quality appraisal criteria presented. Furthermore, the resultant conceptual framework developed and tested, could guide the conduct of consumer research and provide basis for understanding stakeholders throughout food supply chain, particularly when launching new healthy products such as iodine biofortified food.

Besides, integration and validation of the short messaging service (SMS) is a unique way of conducting experimental auctions in line with benefits of a technological system including faster, safer, more accurate and attractive way. This is important in pricing and decision making regarding the marketing of biofortified foods or, for that matter, new health food products. On the scientific front, the overall data generated about the adoption of new strategies, for example, is important in designing new products, as well as in identifying the most appropriate conditions for acceptability and uptake in this case.

Secondly, at the policy level, this thesis provides insights for both health and agricultural interventions. Whereas, in terms of health interventions, the findings could form a basis, not only for designing policy framework for guiding nutrition interventions in the fight against iodine deficiency among vulnerable groups, but also inform the intervention geared to improving micronutrient intakes and overall mental and neurological development, which is considered a major public health challenge. In terms of agricultural or farm interventions these findings provide an opportunity, not only to guide the policy framework for the production of biofortified foods, but also guiding smallholder farmers in tapping into the niche demand-driven market for biofortified foods. In principle, this improves their livelihoods as well as protection of their households against nutrition related health problems, such as those associated with iodine deficiency.

Thirdly, at the society level, the findings from this thesis have the potential to improve the overall health of vulnerable groups with regard to iodine deficiency disorders, improve mental and neurological development and subsequently improve school performance, which is often a prerequisite for socio-economic development. In addition, the demand market created, improves the livelihoods and overall socioeconomic status of rural smallholder farmers. These are, in essence, the pillars of development, not only in the target location but also in the entire region. This is a significant element in sustainable development goals (SDG).

Consequently, at the dissemination and implementation level different approaches and stakeholders are inevitable: a) to ensure adoption of iodine biofortified food, it is important to understand the role of different players who often fuel the process of adoption including: the investors, donor agencies, and governments. The fact that findings of this thesis point to elevated level of WTP and accept fewer discounts for iodine biofortified food by consumers could be an entry line for these players. First, the investors are key players to ensuring increased production of the new products and subsequent delivery to the consumers. These players will likely consider the findings a positive indication of a potential demand market hence increased investment in the production and distribution of iodine biofortified foods. This will not only affect the actual production at the farm level including investment for the production of related inputs such as seeds, the fortified fertilizer and sprays for biofortification, but also investment in the distribution and retail market ensure the product is readily available to consumers. These investments are likely to inject more resources to the entire food supply chain that in essence increases the availability to the biofortified food to consumers as well as likely reduction in the prices for the product in the long run.

Regarding the donors and governments, the behavioural action exhibited by stakeholders, willing to pay more for the product, has the potential of reducing the donor and government contribution to programs that have high ownership levels owing to the expected nutritional benefits. This is likely to contribute more to the expansion of the programs to cover more vulnerable groups with limited resources or donor funding. For instance, the fact that consumers, parents and schools heads, show willingness to pay more to include the iodine biofortified product in school feeding programs owing to perceived benefits to their children, in itself increases their contribution thereby saving the government and donors from having to contribute significantly to sustain the programs. Again the fact that produce view this demand market as a potential source of livelihood increase their participation and willingness to adopt even with limited or no government subsidy. This potentially reduces investment from donors and governments thereby leading the local market to thrive based on the market forces.

8.3 Limitations and future research

Whilst the findings of this thesis could be applied in most instances under similar conditions, there are some important exceptions which identify several key areas for further research. These areas are not only suggested by the results but are important avenues to address the limitations inherent in the whole doctoral research. Therefore, in highlighting the exceptions for this thesis we also identify the criteria to address them, as well as the future direction for research. In the first instance, the purposive selection of the study location is a direct limitation in itself. However, the specific nature of the stakeholders being analysed dictates the appropriate location of the most vulnerable groups. Hence, the decision to settle on the East African region was a balance between both practical and technical factors. Although this limitation could be addressed by considering other target locations with similar settings, it is important to consider the diversity in food production, culture and socioeconomics of other locations in lieu of any replication.

Nevertheless, besides the general view of close-cutting exceptions to this thesis, all other limitations and major considerations for future research are drawn from the six individual papers, which have been bundled together to constitute the doctoral dissertation, thereby informing our presentation of the key expectations and future research directions arising from each of the six research studies.

First, the systematic review conducted presents one of the key innovative approaches in consumer research. However, the depth of the review is limited in making appropriately strong conclusions about consumer acceptance of food with nutritional benefits, mainly because the concept of acceptance is not clearly conceptualised within consumer research which was, again, one of the key objectives of this review. To address this exception regarding the conceptualization of acceptance, researchers should strive to develop a clear terminology in relation to foods with health benefits and enhanced nutrient levels, in particular, (e.g. nutraceuticals, biofortified foods …). Therefore, one should correctly refer to the most appropriate term within the broad spectrum of functional foods, in general, or food with nutritional benefits in particular, of which the latter could be coined as a standardized, easy-to-interpret generic term such as “nutritious food”. When, for example, referring to biofortified foods developed through GM technology as a subcategory, researchers, and other stakeholders (e.g. policy makers, health planners, media and consumers), should aim to adopt the same terminology, i.e. either GM biofortified food or transgenic biofortified food.

From a marketing viewpoint, the pooled evidence in this review demonstrates that clearly communicating the nutritional benefits, and thus, applying the correct term, is expected to improve understanding and, most likely, the acceptance of such foods. While from a research viewpoint, correctly defining and using these terms will facilitate literature searches in future studies, especially in the case of systematic reviews. However, the same accounts for the measurement of acceptance, the heterogeneity of which in the studies is expected to increase the risk of method bias, while hampering the external validity of the results. Studies dealing with acceptance refer to different terms, such as perceptions, beliefs, attitudes, preferences, choices, purchase intentions and even eating behaviour.

Therefore, future research could further evaluate the impacts of how acceptance of foods with nutritional benefits is measured (e.g., by comparing different survey questions), a standardized approach to define and measure food acceptance is inevitable for improving consumer food research and to clearly address the limitations of this review. Although none of the studies gave a clear definition of acceptance, we propose the following generic definition “acceptance depicts if and/or to what extent a consumer is favourable to a food product.” This covers, and can be measured through cognitive concepts (perceptions, beliefs and attitudes) or economic valuation concepts (purchase intentions, preferences or choices, consumption patterns). These concepts are, respectively, grounded in (health) behavioural theory and behavioural economics theory.

Regarding the outcome indicators for each of these concepts, more research is needed to map and identify the most appropriate data collection method (e.g. survey versus experiment) and operationalization of acceptance (e.g. Likert-scale versus stated preference). Even though we point out the need to cope with the variation in measuring and defining acceptance, as well as defining nutritious foods, this heterogeneity is the most important limitation of this literature review. Therefore, the methodological differences between the incorporated studies did not allow us to conduct a reliable meta-analysis. Nevertheless, by following the guidelines of the Cochrane Handbook (Higgins & Green, 2005) and incorporating a quality appraisal, this review provides an important overview of consumer studies on foods with nutritional benefits.

In line with the need to include quality appraisal, as addressed by previous consumer reviews on food (Dannenberg, 2009; de Beer, 2012; J. L. Lusk et al., 2005), more research is required into consumers’ reactions to food with nutritional benefits, through streamlined description and measurement methods for acceptance. It is also necessary to further explore other potential determinants of acceptance and other factors with similar constructs, for example preference, willingness-to-pay and purchase intention. In addition, greater focus is needed on improving the quality of primary studies and designing effective and consistent methods for quantifying acceptance.

In principle, this review, which constitutes chapter 2 of this thesis, provides a platform for supporting the orientation and marketing of food with nutritional benefits and further understanding the key determinants of consumer decision-making with regard to nutritious food. Also, it hopes to further assist researchers and professionals in this field and beyond, through a standardized identification, definition and measurement of consumer acceptance.

Second, we have integrated two behavioural change models and an economic valuation technique to build a conceptual framework for analysing stakeholders. This conceptual framework has been applied in this thesis to explore the consumers and producers within the biofortified food supply chain. Whilst there is evidence that integration of behavioural models has been done before, to our knowledge, this was the first attempt to incorporate an economic valuation technique as an indicator of the resultant behaviour. Therefore, care should be taken to streamline the applicability of this model, more so because there are different procedures for economic valuations and their interaction with the behaviour model constructs is not supported in the literature and could be a key exception in its applicability in the current thesis. Future research should attempt to examine the relationship between behaviour model constructs and the different economic valuation procedures and their outcome. Also, a distinction should be drawn to strongly support the willingness-to-pay values obtained as either behaviour intention or resultant behaviour.

However, to minimise the impact of this limitation, a validation case study was conducted. The case study outlined in this thesis attempts to explain the applicability of the consumer-oriented part of the model to the analysis of behavioural intention (protection motivations), as well as the actual behaviour (economic valuation) of households towards iodine biofortified vegetable legumes. However, this too presents a new dilemma. For instance, the use of questionnaires that focus on a hypothetical situation could be associated with hypothetical bias of the respondents (Jayson L Lusk & Norwood, 2006). It is also worth noting that the use of the contingent valuation technique to assess preferences for biofortified foods may also be prone to hypothetical bias, where respondents may possibly overstate their true values which could have translated into overvaluation of the biofortified food. This phenomenon has been demonstrated in previous studies and can be managed by adopting specific approaches (Mohammed, 2012).

Vis-à-vis our specific payment card procedure, there is a challenge that the respondent could have limited their answer to only those values on the card, ignoring the extreme levels on either side. However, we have controlled for this bias by ensuring that the dollar values are not truncated from above, but included in the analysis, which is consistent with earlier research findings on addressing payment card biases (R. D. Rowe et al., 1996). Another challenge is the use of self-reported data, which may affect the results. This is often associated with social desirability bias, as participants tend to answer questions in a way that is most favourable in the eyes of other people, particularly the interviewer (Jayson L Lusk & Norwood, 2006). Furthermore, we carefully selected our exogenous variables based on relevant empirical studies, but some other determinants could also have influenced the model, including environmental factors, advances in technology, traditional beliefs and practices, as well as market variability.

More importantly, five major attempts have been made to minimize the risk and impact of biases in the current study. Firstly, the randomisation of participants and the unmatched techniques reduces the risk of order biases and ensures truthful responses. It also allows us to control for the effect of study settings, model constructs and other determinants. Secondly we have developed the questionnaire in such a way that neutrality of questioning is emphasized so as not to appraise participants during the interview. Thirdly, a cheap talk script was incorporated into the current study to minimize, not only the social desirability bias, but also hypothetical bias and to ensure honest responses and appropriate determination of preferences. There is also abundant evidence that the use of cheap talk can control for attitude towards such food products and eliminate social desirability, as well as hypothetical biases (Bosworth & Taylor, 2012; Di Pasquale et al., 2011). This procedure binds and motivates the participants to be truthful during the interview. Fourthly, using closely matching product concepts ensures that the hypothetical product presented mimics the actual product, since using non-commercialized products has ethical restrictions and could affect the responses. Finally, using a combination of techniques, including models, instruments, standardised interviews and statistical calibrations was intended to mitigate various biases and reduce the impact of other study limitations (He & van de Vijver, 2012).

To further test this model in future research, it should be applied to multiple domains, in various settings, particularly resource poor and rural regions, and it should target different stakeholders. While we expect that empirical studies on the producer side will further underpin the applicability of this integration in the uptake of nutrition intervention strategies, such as biofortification, across the entire biofortified food supply chain, our application to iodine biofortification in Eastern Africa, lends support to the inclusion of the consumption-oriented portion of the model and, thus, demonstrates its potential use in evaluating (future) micronutrient interventions in developing regions.

Third, to assess the reaction of stakeholders towards iodine biofortified food, this thesis applied the conceptual framework developed to measure stakeholders on the demand-side. This was subject to the limitations presented in the case study (see second limitation). Future research could consider deploying different research designs, e.g. experimental auctions, as the indicator elements, or improved data collection methods to address the limitations outlined above. Furthermore, one of the key challenges in this study is the use of self-reported data. Self-reporting is often associated with social desirability bias. We cannot rule out its presence in our study with a tendency of the participants to answer study questions in a way viewed favourable by others, which would have affected the interpretation of the results.

However, we have attempted to minimise the risk of these potential biases in four major ways: first, we have formulated the questions in a very neutral manner, so as not to appraise the respondents. Secondly, in certain questions we used forced choice questions where two or a limited number of options were equated for their desirability. Thirdly we incorporated a cheap talk script, which has been found to blind and motivate the respondent to tell the truth during the interview, and fourthly, we used randomisation of responses and unmatched techniques which have been found to promote honest answers during this type of interview.

Another challenge was the small sample size for school heads producing results with low precision, hence limiting possible inferences made to certain settings outside the current context. The diversity in the same area means that the data collection and feeding practices may also vary and, as such, may affect iodine intake levels, both at household and school level. It is also difficult to conclude that the dietary intake of a child is influenced at only two levels. An additional challenge is that one needs to carefully interpret these findings when developing future nutrition campaigns, after a certain period, as the dietary and food production practises are likely to change over time, mainly due to a number of elements including: acculturation, population growth and nutrition transition.

Nevertheless, future studies need to consider analysing protection motivations for different elements and to assess the influence of overall nutrition status towards adopting coping strategies, such as biofortification. Furthermore, the design and the multi-stage sampling and multi-stage data selection could be extended to cover other groups of children not attending primary schools in the location. It will also be important to assess the same variables in the whole population or use a bigger sample. In other words, one needs to further evaluate its external validity and the appropriateness of the model. Nevertheless, different factors have shown a considerable effect on the intention and preference to adopt biofortified foods in rural regions, further supporting the use of PMT models to evaluate reactions towards nutritious foods.

Fourth, a study was conducted to analyse how well factors exogenous and endogenous to the PMT model predict protection behaviours towards iodine biofortified food. The resultant protection behaviour was ascertained by examining how much premium or discount they are willing to pay, using a contingent valuation technique. The fact that the study focused more on the resultant behaviour than on the intended behaviour and not at all for other external influences, such as attitude and trust, which are often a crucial element in consumption, is by itself an exception. Again, the procedure applied the stated preference method, contingent valuation, which only reflects consumer opinion rather than action. Nonetheless, the use of a premium card to collect their responses is a clear step to minimise the impact of this limitation. However, future research could consider more inclusive research designs, as well as the use of experimental auctions, which enable recording of resultant behaviour of the stakeholders by eliciting their actions rather than opinions towards iodine biofortified food. The findings from these future dimensions could further test the results on resultant protection behaviour and could therefore describe the effects of stakeholder reactions in more detail.

Fifth section of this doctoral research analyses the preference or consumers' resultant willingness-to-pay for iodine biofortified food using the Becker-Degroot-Marschak (BDM) method. An attempt is also made to validate the use of the short messaging service (SMS), a technology based system, in BDM auctions. A longitudinal auction was conducted with a sample of 180 participants from open-air markets in 3 different locations in East Africa. One of the notable limitations here is the small sample size used for such crucial data. For this reason, the generalisation of this finding to the broader community should be considered with caution. Therefore, there is an inevitable need to amplify these findings with additional research data through improved methodologies and more conditions and drivers that affect the market for iodine biofortified food and which directly impact on the overall WTP recorded. Besides, even though SMS-based bidding is shown to be an accurate, but also convenient and attractive, bidding procedure, which is in line with novel ways of purchasing food, further validation is required to determine its reliability in different contexts and its most effective use.

Finally, in assess the potential adoption of iodine biofortification by smallholder farmers; we employed the conceptual framework to explore the stakeholders' uptake of innovations and technologies. The most visible inadequacy in this study was the lack of information that discriminates between different biofortification technologies available to the farmer, as well as the negative attributes that could be linked to these diverse processes, including GM technologies. The direct inclusion of these in the model specifications, as well as the level of risk perception exhibited by the farmer, would add significantly to the current findings about the resultant adoption of iodine biofortification, or otherwise. Nevertheless, despite this minor shortfall in the research, the results still give rich farm specifications for designing iodine intervention programs, based on biofortification, among the smallholder farmers over a relatively extensive time horizon.

The findings and resultant model allow for decision making regarding the characteristics and conditions of farm households that are appropriate for the adoption of iodine biofortification in endemic areas, particularly in developing countries. Another concern that can open the discussion is the purposive sampling of locations in the three countries where iodine deficiency is endemic. Why not other parts of the world? Could the geochemistry of the rock in the areas influence the retention of iodine by crops? The sample size could be increased to capture the diversity by incorporating those from other areas, as well as improving the accuracy of the findings.

Therefore, future research should be tailored to address this concern through a more elaborate and inclusive research design and a more representative sample which is large enough to improve on the conclusions drawn from the current study.

Overall, the research in this direction and the tools applied in this thesis, as well as the consequences and pre-requisites of handling biofortified food as an alternate intervention for micronutrient deficiencies, is only in the early stages of development. The findings in this research, and indeed future research, provide insights into the impact the biofortification revolution in the biofortified food supply chain will have with regard to the fight against micronutrient deficiency. Although the findings highlight which key reactions the stakeholders will exhibit toward iodine biofortified food in particular, studies across various other fronts, or their application in vulnerable communities, need to add more value to the potential of policy direction and program design and implementation to provide an ideal combination for success.

Although, this thesis covered key focus areas and provided insights, many questions still need to be addressed for the full addition of iodine biofortification to the already successful biofortification campaigns. Therefore, the understanding provided in this doctoral research and the new line of questioning stimulated herein will inspire other researchers to further explore this interesting phenomenon of a stakeholder-driven biofortified food supply chain in the light of the emergence of many biofortified foods, particularly iodine biofortified foods.

SYNOPSIS

Synopsis (*English*)

This doctoral dissertation investigates stakeholders' reactions toward iodine biofortified foods. Iodine deficiency alone affects over 2 billion people worldwide, and is particularly prevalent in developing countries. Iodine is an essential trace element found in seafood and iodized salt, as well as certain vegetables and is important for growth and development throughout the body, as well as cognitive development. Given the critical role of iodine in human nutrition, various strategies have been implemented to reduce iodine deficiency and Iodine Deficiency Disorders (IDD). However, despite considerable progress through iodine fortification, the goal is still far from being achieved.

Therefore, there is a need to explore the potential of new approaches, such as iodine biofortification. Biofortification is a strategy to enhance micronutrient concentrations in staple crops, either through conventional or transgenic breeding techniques. Given its status as an agriculture-based, micronutrient strategy, a thorough insight into stakeholder reactions is necessary, examining stakeholders from both the demand-side (consumers) and the supply-side (farmers). A conceptual framework bringing together behavioural change models, technology acceptance modelling and an economic valuation technique was developed and tested for use in stakeholder analysis. Six distinct studies were conducted, targeting locations drawn from three East African countries: Kenya; Uganda; and Tanzania, which have high levels of iodine deficiency disorders (IDD) as well as retarded mental and neurological development coupled with poor school performance. These locations meet the criteria for iodine deficiency endemic areas with a large at risk population that seldom benefits from the existing intervention programs.

All model constructs in the framework are decisive in determining the uptake of iodine biofortification. Consistent with evaluation of food with nutritional benefits, stakeholders on both the demand (parents and school heads) and supply-side (small-scale farmers) had favourable reactions towards iodine biofortified food, the uptake of which could drastically change the trend in iodine intake in iodine deficiency endemic areas. These findings present a niche opportunity for producers to tap into the demand market created. In principle, the findings could shape the policy terrain for addressing iodine deficiency, as well as ameliorating the nutrition intervention campaign through agricultural-based interventions, such as biofortification.

Samenvatting (*Dutch*)

Dit proefschrift onderzoekt de reacties van stakeholders tegenover met jodium verrijkte (biofortificatie) voedingsmiddelen. Jodiumtekort alleen treft meer dan 2 miljard mensen over de hele wereld, vooral voor in ontwikkelingslanden. Jodium is een essentieel element voor de groei en ontwikkeling van het lichaam en de cognitieve ontwikkeling. Het is voornamelijk aanwezig in vis, verrijkt zout en bepaalde groenten. Gezien de cruciale rol van jodium in het voedingspatroon, zijn er verschillende strategieën geïmplementeerd om jodiumtekort en de bijhorende stoornissen te reduceren. Ondanks de aanzienlijke vooruitgang door jodium biofortificatie, is het doel echter nog niet bereikt.

Dit onderschrijft de nood aan het onderzoeken van het potentieel van nieuwe benaderingen, zoals jodium biofortificatie. Biofortificatie is een strategie om concentraties van micronutriënten in basisvoedselgewassen te verhogen, hetzij door conventionele of transgene technieken. Gezien het een op landbouw gebaseerde gezondheidsstrategie betreft, is een grondig inzicht in de reacties van belanghebbenden, zowel aan vraagzijde (consumenten) als aan aanbodzijde (landbouwers), cruciaal. In dit onderzoek is de stakeholderanalyse gebaseerd op modellen voor gedragsverandering en technologie acceptatie, gecombineerd met economische valuatietechnieken. Zes verschillende studies werden uitgevoerd in drie Oost-Afrikaanse landen: Kenia, Oeganda en Tanzania. Deze landen vertonen een hoge mate van jodiumtekort, wat zich kenmerkt in een achterstand in psychische en neurologische ontwikkeling en lage schoolprestaties. De specifieke gebieden liggen in een risicozone waar velen zelden gebruik (kunnen) maken van bestaande interventieprogramma's.

Alle gebruikte modellen bevestigen hun nut om de omgelijke opname van jodium biofortificatie te voorspellen. Net zoals bij de evaluatie van andere gewassen met nutritionele voordelen, staan stakeholders aan vraag- (ouders en schoolleiders) maar ook aan aanbodzijde (kleinschalige boeren) positief tegenover jodium biofortificatie gewassen. De bevindingen vormen een kans voor producenten om gebruik te maken van de marktinzichten, terwijl de bevindingen ook vorm kunnen geven aan het beleid ter verbetering van (jodium) biofortificatie strategieën.

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APPENDIX 1: List of search terms used in retrieving the primary studies for the systematic review

(Chapter 2)-October 26, 2012

ALL

('Consumer') **AND**
'GM' OR ('genetically modified') OR ('Genetic modification') OR ('Transgenic') OR
OR ('Biofortification') OR ('Biofortified') OR ('Nutrition') OR ('Micronutrient') OR
('Food') OR ('Foods') OR ('Crop') and ('Product') OR

Valuations

('Preferences') OR ('valuations') OR ('values') OR ('purchase intention') OR
('WTP') OR ('Willingness-to-pay') OR
('WTA') OR ('Willingness-to-accept') OR

OR ('auction) OR ('auctions') OR ('Contingent valuation') OR ('Choice experiment') OR ('Conjoint analysis') OR

Acceptance

('Acceptance') OR ('Segmentation') OR ('Resistance') OR ('Acceptability') OR ('Attitude') OR ('Perception') OR ('Behaviour')

PRODUCT

GM (O)
Genetically modified
Genetic modification
Transgenic
Conventional
Non-GM
Hybrid
Food
Crop
Product
Biofortification (fortification)
(Biofortified/fortified)
Nutrition
Enriched/enrichment
Health benefits
2nd generation
Farmer benefits
1st generation
Acceptance
Consumer

MEASURE

WTP
WTA
Willingness-to-pay
Willingness-to-accept
Purchase intention
Preferences
Acceptance
Segmentation
Resistance - Reluctance
Acceptability
Attitude
Perception
Behaviour

METHOD

Consumer valuation
Economic valuations
Experimental auction
Contingent valuation
Choice experiment
Conjoint analysis
(Hypothetical non-hypothetical)

APPENDIX 2: Systematic review protocol

Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis

Background

Poor quality of diets in developing countries is a major cause of micronutrient malnutrition which causes suffering to millions of people. Globally, more than 2 billion people are affected (Micronutrient Initiative, 2009) which underlines the need to explore new approaches to manage this problem (Martinez-Poveda, Molla-Bauza, Campo Gomis, & Martinez-Carrasco Martinez, 2009). Again according to "*The state of food insecurity 2012"*[1], with its 7 billion people, the world is about 11% hungry (FAO, 2012). Thus, although most common approaches that have been advocated traditionally focused more on the farmer benefits, the increasing consumer awareness and health concerns has shifted the focus to include not only farmer but also consumer benefits. Evidently even though many current methodologies provide consumer benefits through increased supply, improved food quality and lower food prices, of most concern in the consumer benefit sphere is health and well-being particularly nutrition. Hence the need for foods of increased nutritional value to improve the nutritional well-being of the consumers mainly through the staple foods. A process called biofortification (Figure 1). In essence, though there is no single strategy to eliminate micronutrient malnutrition, this process is emerging as one of the potential solutions that can radically change the trend if accepted, adopted and exploited in different populations (Horton *et al.,* 2008; Mayer *et al.,* 2008). Biofortification involves both conventional and transgenic development of crops with enhanced nutrition values (Genc Y *et al.,* 2005).

The process of biofortification should not be mixed-up with genetic modification, whereas the terms are used together not all biofortified foods are GM foods and vice versa. Moreover, not only is the distinction between different categories of crop improvement necessary but the economic valuation and choices (acceptance and purchasing behaviour) of these foods is equally important. Despite a plethora of consumer studies focusing on the consumer demand for GM foods and other biofortified foods, there are no studies that give the estimated effect size of economic valuations and acceptance of foods with farmer and consumer benefits. Even a meta-analysis examining the value estimate for GM verses non-GM food (Dannenberg, 2009; J. L. Lusk et al., 2005) did not discern foods of added consumer benefits via biofortification as a gateway to improved nutrition nor the effect size of WTP for such foods. In addition the most of other systematic reviews and met analyses have not assessed the quality and biases of primary studies used. Thus this review will try to examine the extent of valuation of different categories of foods with farmer and consumer benefits (GM biofortified and conventional biofortified) and the choices of these foods in different markets. Quality and bias of primary studies will assess appropriately. In addition to an extensive literature search to capture all the relevant studies and weed out other studies. Efforts will be made to identify and enlisting research gaps to inform future studies in this area.

Objectives of this review

The main objective of this review is to analyse available evidence regarding the consumer evaluation of food with nutritional benefits as expressed in a surfeit of primary studies.

The review will assess the determinants of the consumer evaluation of these food, conceptualisation acceptance of these food as well as the conceptualisation of terminologies that clearly describe foods with nutritional benefits. This will allow testing the extent to which consumers' choice is influenced by the envisaged benefits by comparing GM and conventional food of improved nutrition value (Biofortified) and with farmer benefits against non GM, non-conventional and non-biofortified.

Further evaluation, integration and comparison of WTP/WTA of biofortified foods (GM and conventional biofortified) are carried out through a meta-analysis of relevant primary studies.

Effort is also made to pool the results of all previous reviews together through and overview of reviews as defined by the Cochrane reviews

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[1] ***The State of Food Insecurity in the World*** *is a global series report released regularly which raises awareness about global hunger issues, discusses underlying causes of hunger and malnutrition and monitors progress towards hunger reduction targets established at the 1996 World Food Summit and the Millennium Summit. The publication is targeted at a wide audience, including policy-makers, international organizations, academic institutions and the general public with a general interest in linkages between food security, and human and economic development. It's published jointly by the Food and Agriculture Organization of the United Nations, the International Fund for Agricultural Development and the World Food Programme.*

Methods

Review design

The review will largely follow the procedure outlined in Cochrane[2] for systematic reviews, meta-analysis and overview of reviews in addition to the reviews by Lusk *et al.* (2005), C. Lachat *et al.* (2011) and Verstraeten *et al.* (2012). This will allow the determination of the primary studies to be included in the study, quality and bias assessment and eventual meta-analysis of applicable studies.

Nevertheless this review will derive from mythological approach normally applied medical and epidemiological studies for use in consumer studies and with thorough quality and bias assessment.

Criteria for selection of primary studies

The following schematic diagram represents the selection of studies to be included in this study. From the diagram consumer studies focusing on GM, conventional, non GM and non-conventional food will be included in the study. A systematic review will first be carried out followed by a meta-analysis on specific primary studies with appropriate data and finally an overview of reviews in this area. Studies focusing on other consumer and farmer benefits will be the main focus and all other studies including studies on indigenous foods will be excluded from the review.

Search methods for identification of studies

A combined systematic review[3], meta-analysis[4] of primary studies and an overview-of-reviews[5] will be carried out. First comprehensive search of electronic and manual databases will be done to obtain the primary studies and respective reviews using clearly defined search terms and inclusion-exclusion criteria. Existing studies in EBSCO, EconLit, Agricola, AgEcon, Greenfile, compendex, Web of science databases will be searched and summary of each study recorded and managed using Endnote X5 (The Thomson Corporation , NY). A generic search strategy will be developed and adapted for all the databases. The search will then be extended to Google scholar platform, National Agricultural Library Digital Repository (NALDR), relevant company and institutional journals and websites documenting target consumer studies. Additionally direct contact with line researcher will be used to capture their recent work or work in progress. All the retrieved studies will then be pooled into one database using Endnote X5 and saved ready for use.

The primary studies reporting on the following will be targeted to provide the required information. WTP and WTP for GM biofortified, conventional biofortified, GM non biofortified, conventional non biofortified. Studies reporting on acceptance and studies only reporting on farmer benefits, studies in languages other than English, French and Spanish along with studies focusing on animal products will be excluded. Further, Selection of paper fulfilling the set inclusion criterion will be carried out by two independent researchers working alternately and blinded from the findings of each other. The two researchers will then work together to identify the discrepancies in the two lists obtained and makes the final inclusion and exclusion. In all the target databases the following search terms will be used to obtain the relevant primary studies:- "willingness-to-pay" or "willingness to accept" or "acceptance" or "consumer choice" or "consumer valuation" or "consumer attitude" or " willingness to adopt" AND "GM food" or "GMOs" or "genetically modified foods" or "biofortified food" or " or "improved varieties".

The final records obtained after merging all the articles from the literature into one database will first be subject to thorough screening to weed out any double records as identified. The topic and abstract of the obtained records after eliminating the double records will then be screened based on the defined objective of the study and all the records not meeting the criteria removed. Further screening full-text article done and all the articles not meeting the criteria defined at this stage eliminated. An explanation for each elimination of the article (s) will be given and record of full-text articles screened and retained subject to quality and bias assessment (see quality and bias assessment below).

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[2] *The Cochrane reviews are defined as "systematic reviews of primary research in human health care and health policy, and are internationally recognized as the highest standard in evidence based health care. They investigate the effects of interventions for prevention, treatment and rehabilitation. They also assess the accuracy of a diagnostic test for a given condition in a specific patient group and setting". They are usually available online at http://www.cochrane.org/cochrane-reviews/about-cochrane-library"*

[3] *According to P .W66 of Liberati et al., (2009) explains that a systematic review has the following key attributes: ''(a) a clearly stated set of objectives with an explicit, reproducible methodology; (b) a systematic search that attempts to identify all studies that would meet the eligibility criteria; (c) an assessment of the validity of the findings of the included studies, for example through the assessment of risk of bias; and (d) systematic, presentation, and synthesis, of the characteristics and findings of the included studies''*

[4] *Although the first meta-analysis was performed by Karl Pearson in 1904 in an attempt to overcome the problem of reduced statistical power in studies with small sample sizes, Glass GV crafted the first defines Meta-analysis as "analysis of analysis. Meaning the statistical analysis of large collection of data from individual studies for the purpose of integrating the findings" a definition that has been adopted by many reviewers (Educ Res, 1976)*

After the quality assessment of all full-text articles the records of articles meeting all the inclusion and quality criteria will then be maintained and used for this review. List of articles meeting the criteria for a further analysis will then be subject to meta-analysis to integrate their finding and give the effect size of the target parameter i.e. WTP, WTA or acceptance (see analysis section).

Overview of reviews

This is a new approach usually employed in Cochrane reviews and common with medical and epidemiological studies. Overviews of reviews bring different review on a particular topic to state a direction on that topic and it's usually subject to change as new reviews are done or any of the reviews is updated. In this study recent reviews obtained from an extensive literature search will be pooled together to obtain an overview of reviews and presented in this study.

Quality assessment of the articles

It is generally recommended that for any successful review quality assessment of the primary studies is carried out to detect any latent flaws in their overall methodological quality that may bias their findings. Borrowing from Cochrane[6], methodological quality trepidation here relates to three domains: internal validity, external validity and statistical validity of the data at the primary level. In this regard clear definition of key components constituting the three forms of validity will be guided by the criteria used in a recent article by (de Beer, 2012) According to these criteria internal validity will be defined by the characteristics of the target population and location while the external validity will be edged around actual data collection methodologies and the third validity –statistical validity will revolve around the sampling criteria used, the statistical estimates and measure of variability presentation and proper calculation of respective parameters. See the review low diagram (Figure 4)

Data extraction and analysis

Data on willingness-to-pay, willingness to accept, acceptance, characteristic food, methodology used in data collection, summary findings, location and the accruing benefits (farmer or consumer benefits) will be extracted from each of the selected full-text articles. Extracted data will be used for critical review and further data with comparable parameters on WTP/WTA and acceptance will be subject to meta-analysis[7] in order to combine these parameters to a pooled estimate. I.e. a pooled WTP/WTA for biofortified foods (GM versus conventional), versus foods with farmer benefits (GM versus conventional)

Time frame

Activity	**Duration**						
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**
State of the art exposé and Protocol development and agreement	■	■					
Pre-testing the methodology		■	■				
Literature review-Systematic review /Meta-analysis				■	■		
Write-up and submission					■	■	■

DRAFT 1-syntax

("willingness-to-pay" or "willingness to accept" or "consumer valuation" or "consumer attitude" or "acceptance" or "purchase intention" or "consumer trade-offs" or "willingness-to-pay premiums") and TITLE-ABSTR-KEY("food" or "GM food" or "genetically modified food" or "gmos" or "non-gm food" or "conventional food") AND LIMIT-TO(content type, "1,2","Journal") AND LIMIT-TO(topics, "functional food, food acceptance, genetically modified, food, consumer acceptance, consumer attitude, food product, novel food, consumer, organic food, new food, purchase intention")

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[6] *The Cochrane handbook, although focusing more on medical studies, gives direction as to the treatment of 'bias' and 'methodological quality' of primary studies for any successful review. Nevertheless the two should be distinguished as they are assessed differently and their effect on the final results is significant.*
From the handbook the details as to the different tools applicable and the methodology of assessing the two are clearly outlined (http://www.cochrane-handbook.org/-ch 8.1

[7] *Borrowing the explanation from a review by Hans de beer "Meta-analysis is a statistical technique for combining the effect estimates from independent studies. The estimate from each study is weighted by the precision of the estimate. A fixed-effect meta-analysis provides a result that may be viewed as a 'typical intervention effect' from the studies included in the analysis. In order to calculate a confidence interval for a fixed-effect meta-analysis the assumption is made that the true effect of intervention (in both magnitude and direction) is the same value in every study (that is, fixed across studies). A random-effects meta-analysis model involves an assumption that the effects being estimated in the different studies are not identical, but follow some distribution". Source:* http://www.cochrane-handbook.org

APPENDIX 3: Phase 1 Questionnaire for the study on the reactions of the stakeholders on the demand-side (consumers) - Household study

SECTION A: KNOWLEDGE ABOUT IODINE AND IODINE DEFICIENCY DISORDERS

Explain each item before proceeding Giving a small definition each time.

1. **Do you have heard about the following items? Please indicate to what extent you are familiar and understand.**

Instructions: *From this piece of information, kindly help us understand your reaction using the following scale:* ***1****=Not at all familiar/understand,* ***2****=Slightly understand/familiar,****3****=Somewhat familiar/understand* ***4****=Moderately familiar,* ***5****=Extremely familiar*

Items	1	2	3	4	5	Instruction
Micronutrient (vitamin/mineral)						*Explain and proceed*
Iodine						*Explain and proceed*
Iodine deficiency disorders (IDD)						*Explain and proceed*
Salt iodization						*Explain and proceed*
Biofortification						*Explain and proceed*

2. **How did you get the information about each of the above items?**

Instructions: *From this piece of information, kindly help us understand your reaction using the following scale:* **1**=Media: TV, newspaper, radio, Internet **2**=Market: food industry, Supermarket , , Biotechnological industry **3**=Relatives: Family, friends, neighbours **4**=Professionals: Teachers, consumers organization, scientists, Doctors, medical experts **5**=Other: Government , Environmental group , Consumer organization

Item	1	2	3	4	5
Micronutrients					
Iodine					
Iodine deficiency disorders					
Salt iodization					
Biofortification					

3. **Has any of your family members suffered from any IDD?**

Item	1	2	3	4	5
Goitre					
Cretinism					
Hyperglycaemia					
Hypoglycaemia					

4. **Do you have had that people living in mountainous areas and landlocked areas are susceptible to IDD due to low iodine in their food.** Yes ☐ No ☐ Do not know ☐

5. **Are you aware that iodine is associated with mental development and subsequently poor school performance?** ☐ Not at all aware ☐ Slightly aware ☐Somewhat aware ☐ Moderate aware ☐ Extremely

6. **Are you aware iodine intake improves mental development and school performance?**
☐ Not at all aware ☐ Slightly aware ☐ Somewhat aware ☐ Moderate aware ☐ Extremely aware

7. **Which food do you think gives your child iodine?**
Fruits/vegetables ☐ Meat ☐ Fish and sea food ☐ Salt ☐ Cereals ☐ Legumes ☐

8. **Are you convinced that children diet provides enough iodine?**
Yes ☐ No ☐ Do not know ☐

9. **What type of salt do you use at home?**
Traditional ☐ Industrial iodized salt ☐ Both ☐

10. **Why don't you use iodized salt?**
Expensive ☐ All salt contains iodine ☐ Bad taste ☐ Not safe ☐ Other ☐

11. **Which kind of biofortification have you heard of?**
GM biofortified ☐ Conventional biofortified ☐ Do not know ☐

Explain the differences

SECTION B: OWN IODINE INTAKE AND CONSUMPTION OF VEGETABLE LEGUMES

1. How do you obtain food consumed in the household? ☐ Own farm ☐ Market ☐ Donation

Now I would like to ask you about the types of foods and frequency that your child eats.

Instruction*: indicate all the foods mentioned while scoring 1 to 7 as shown in the scale:* Never (1 day), Rarely, in 10% of the chance when they could have (2days), Occassionally, in 30% of the chance when they could have (3 days), sometimes in 50% of the chance when they could have (4 days), Frequently, in 70% of the chance when they could have (5 days), Usually, in 90% of the chance when they could have (6 days) Every time (7days)

2. How often does your child consume the following types of food

Food groups	**Examples**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cereals and tubers	Maize (Ugali/Posho), sorghum, wheat, rice, millet, matooke, potatoes, cassava							
Vegetable legumes, nuts and seeds	Beans, peas, lentils, nuts, seeds or foods made from these							
Fish and seafood	Fresh fish, dried fish, Omena, sea vegetables							
Meat, offal, organ, blood, eggs	Beef, pork, lamb, goat, rabbit, wild game, chicken, duck, or other birds							
Egg and egg products	Boiled or fried egg							
Milk and milk products (dairy products)	milk, cheese, yogurt or other milk products							
Oils and fats	Oil, fats or butter added to food or used for cooking							
Fruits and Vegetables	Mangoes, oranges, papaya, apples, green/leafy vegetables, including wild ones.							
Sugar and sugary foods	sugar, honey, sweetened soda, sweetened juice or sugary foods such as chocolates, candies, cookies and cakes							
Salt (Condiments)	common or traditional salt							
	Iodized salt							

Dairy product	Less than 1 cup-serving ☐ 1-2 cups ☐ More than 2 cups ☐
Sea food and Fish	Less than 1 fillet (100g) ☐ 100- 250 gm (1 fish) ☐ More than 250 gm (> I fish) ☐
Egg	Less than 1 egg ☐ 2 egg ☐ more than 2 egg ☐
Green legume and leafy vegetables	Less than (250g) ☐ 250-500 g ☐ More than 500 g ☐
Iodized salt	Less than 1teaspoon ☐ 1-2tea spoon ☐ More that 2 teaspoon ☐

3. Each time your child consume the above foods, how much do they consume?

Let the respondent explain the foods consumed --Indicate in quantity or per serving

4. In how many times do you use vegetable legumes e.g. lentils, beans, cowpeas, kunde in your diet?

☐Never ☐ Almost never (once) ☐Occasionally (twice) ☐ Almost every time (thrice) ☐ Every time (Four time)

SECTION C: INFORMATION

Information script

Iodine is a mineral found in soil that is needed by our body for many things. Mainly, it is an essential component of the thyroid hormones involved in regulating the body's metabolic processes. Too little intake of this nutrient results in iodine deficiency disorders. Iodine deficiency disorders include mental retardation, hypothyroidism, goitre, cretinism, and varying degrees of other growth and developmental abnormalities. Poor mental development results in low IQ and school performance. But, Iodine deficiency is the most preventable cause of mental retardation in the world. Iodized salt and seafood are the major dietary sources of iodine. However, people leaving away from sea and eating low amount of sea food, those leaving far and interior places where its lost in salt and mountainous areas where soil iodine is depleted and food and foods are deficient are likely to get this problem. The diversification of diets and enhancing the iodine content of food are other measure to prevent this problem. The concept of iodine biofortification where local staple foods are modified to increase the iodine content is a new strategy being explored to prevent this problem. It is either GM biofortified or through conventional methods of adding certain stable iodine in fertilizer to produce crops rich in iodine or through cross breeding.

1. Have you heard this information before?

Yes ☐ No ☐ Do not know ☐

2. How did you get the information about each of the above items?

Instructions: *From this piece of information, kindly help us understand your reaction using the following scale:* ***a) Media: 1****=TV,* ***2****=newspaper,* ***3****=radio,* ***4****=Internet* ***b) Market: 1****=food industry,* ***2****= Supermarket ,* ***3****= Biotechnological industry* ***c)Relatives and neighbors: 1****=Family,* ***2****= friends,* ***3****=neighbours* ***d)Professionals****:* ***1****=Teachers* ***2****= scientists,* ***2****=Doctors and medical experts* ***e) Other: 1****=Government ,* ***2****=Environmental group ,* ***3****=Consumer organization*

Item	**1**	**2**	**3**	**4**	**5**
Media					
Market					
Relatives and neighbors					
Professionals					
Other					

SECTION D: PROTECTION MOTIVATION THEORY

PMT components						
Instructions: *From this piece of information, kindly help us understand your reaction using the following scale:* ***1*** *strongly disagree* ***2*** *disagree* ***3*** *Neither agree or disagree* ***4*** *Agree* ***5*** *strongly agree*						
Perceived severity		**1**	**2**	**3**	**4**	**5**
1	IDD frightens you as a very serious health problem					
2	I know people who have suffered from IDD					
3	It is probably that your children perform poorly at school because of Iodine deficiency					
From this piece of information, kindly help us understand your reaction using the following scale: ***1=*** *extremely unlikely* ***2=*** *unlikely* ***3=****Neutral* ***4=****Likely* ***5=****Extremely likely*						
Perceived Vulnerability						
1	I feel my children are vulnerable to suffer from IDD if they do not eat iodine rich foods					
3	My children are likely to perform poorly at school due to iodine deficiency					
4	Protecting my children from the risk of IDD by opting for foods rich in iodine is important					
Perceived fear						
1	Thoughts about IDD affect my mood?					
2	Has school performance of your children affected your mood					
Instructions: *From this piece of information, kindly help us understand your reaction using the following scale:* ***1*** *strongly disagree* ***2*** *disagree* ***3*** *Neither agree or disagree* ***4*** *Agree* ***5*** *strongly agree*						
Response Efficacy Instructions		**1**	**2**	**3**	**4**	**5**
1	Consuming iodine biofortified food will reduce the risk of IDD					
2	Iodine biofortified legumes will help improve school performance of my children					
Self-efficacy						
1	It is possible for your children to eat iodine biofortified legumes at school					
2	I would be in agreement to include if iodine biofortified legumes are introduced in schools meals?					
Response cost						
1	I doubt the effectiveness of biofortified legumes					

Cheap talk

Imagine for the next questions you could use iodine biofortified food to increase school performance of your children and protect them from iodine deficiency disorders. Your household could need to consider paying a fee to include the food in the children's diet at home or to be included biofortified food in school feeding program. We are going to ask you some questions about your households' willingness to pay for this type of food. However, many studies have shown that people say they are willing to pay more for an enhanced food product than they actually will pay when the product is presented to them. Therefore, in the next questions about biofortified foods please imagine your household is actually paying them.

Protection motivation (intention) Instructions: *From this piece of information, kindly help us understand your reaction using the following scale:* ***1*** *Extremely unlikely* ***2*** *unlikely* ***3*** *Neutral* ***4*** *likely* ***5*** *Extremely likely*

		1	**2**	**3**	**4**	**5**
1	How likely are you to accept iodine biofortified vegetable legumes as a source of iodine for your children?					
2	How likely is it that you will include iodine biofortified lentils in the household menu for the children?					
3	Are you likely to buy iodine biofortified vegetables for the household?					
4	I will consider advocating for inclusion of iodine biofortified vegetable legumes in school meals?					

Willingness-to-pay (WTP) **Instructions:** *From this piece of information, kindly help us understand your reaction*	***Instructions***
Considering biofortified vegetable legumes cost $1.5 which of the following would you select for your children? ☐ Conventional Biofortified ☐ GM biofortified ☐ Indifferent ☐ Neither	*onvert into local currency and make sure they don't state the price but how much value they attach to the product than the basic price.*
If normal vegetable legumes cost $1.5 (put in local currency) and biofortified vegetable legumes $1.75~2.25, how much are you willing to pay for iodine biofortified vegetable legumes without viewing them expensive? Biofortified vegetable legumes ………………$	
Considering the normal school meal cost $1/day (put in local currency), and biofortified $1.5~2, how much more are you willing to pay for inclusion of iodine biofortified vegetable legumes in school meal. Iodine biofortified vegetable legume in school meal…………….$	
If normal vegetable legumes cost $1.5 (put in local currency) and biofortified vegetable legumes $0.75~1.25, how much are you willing to pay for iodine biofortified vegetable legumes? Biofortified vegetable legumes this time………………$	
Considering the normal school meal cost $1/day (put in local currency), and biofortified $0.5~.75 how much more are you willing to pay for inclusion of iodine biofortified vegetable legumes in school meal. Iodine biofortified vegetable legume in school meal this time…………….$	

APPENDIX 4: Study protocol

PHASE/STUDY 1 AND SURVEY DETAILS

Phase 1: Assessment of stakeholders influencing consumption of biofortified food by the children i.e. Parent and school authority (PMT model)

INTRODUCTION

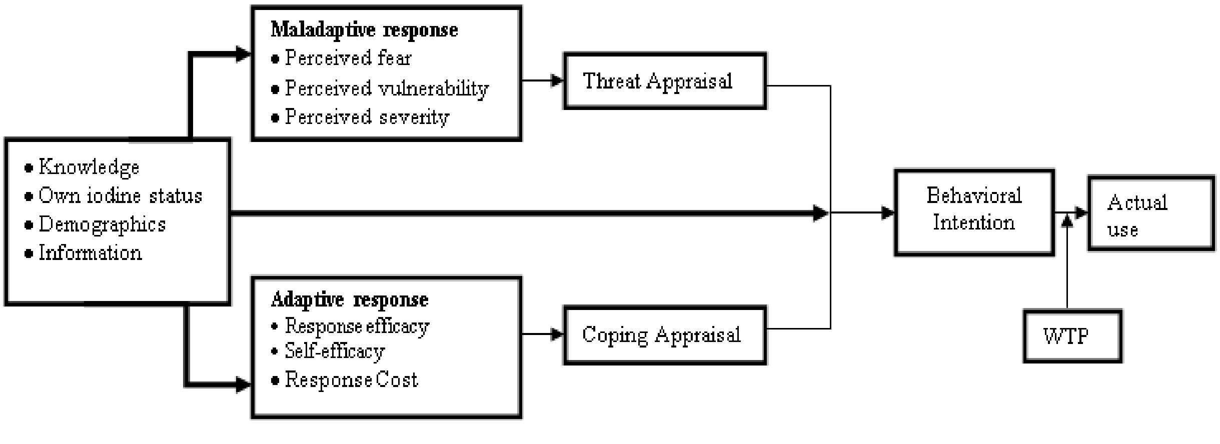
In the current study, protection motivation theory(Ronald W. Rogers, 1975) will be applied and combined with economic valuation research (Lusk) with a focus on primary stakeholders (parents and school authority) of iodine biofortified crop consumption. Iodine is a mineral found in soil that is needed by human body for many functions(Bleichrodt et al., 1996). Mainly, it is an essential component of the thyroid hormones involved in regulating the body's metabolic processes. Too little intake of this nutrient results in iodine deficiency disorders including: mental retardation, hypothyroidism, goitre, cretinism, and varying degrees of other growth and developmental abnormalities (Bleichrodt & Born, 1996). Poor mental development results in low IQ and directly impact on school performance of children (Al-Mekhlafi et al., 2011; Qian et al., 2005; van den Briel et al., 2000). But, Iodine deficiency is the most preventable cause of mental retardation in the world. Iodized salt and seafood are the major dietary sources of iodine. However, people leaving away from sea and eating low amount of sea food, those leaving far and interior places where its lost in salt and mountainous areas where soil iodine is depleted and food and foods are deficient are likely to get this problem(Bleichrodt et al., 1996).

Although there are previous strategies to manage iodine deficiency and subsequent school performance like supplementation, fortification of food and dietary diversification. Biofortification of food with iodine is a new potential strategy that can provide a breakthrough in preventing micronutrient deficiency, poor mental development and poor school performance if accepted and consumed by the local group not covered or largely where other strategies have failed. The concept of iodine biofortification where local staple foods are modified to increase the iodine content is a new strategy being explored to prevent this problem. The most common strategies of developing the crop include GM technology or conventional methods. The later has widely been explored including cross breeding and addition of certain forms of iodine to fertiliser used by local farmers which has been found to successfully retain adequate iodine in crops. Like other strategies, the success of the new strategy requires understanding of the reactions of stakeholders that influence the consumption of this food particularly by young children. By analysing the reaction of parents and school authority the intake of iodine biofortified foods both at the household level and through school feeding program can be leveraged. It is the objective of the current study to access the parameters external to protection motivation theory that influence the intention to consume this food. The study will also examine the most significant PMT variable that influences the uptake of iodine biofortified food. In addition we aim to assess economic value attached to such food by both the parents and the school authority through analysing their willingness-to-pay. PMT has two components threat appraisal and coping appraisal. Besides, previous studies point to parameters including knowledge, own health status, information and socio demographic are among the key determinants influencing the consumption health promoting foods. The influence of these factors will be examined.

Conceptual framework:

The study will apply the PMT portion of the model combined with economic valuation component to ascertain the monetary value the participants are willing to pay for the iodine biofortified food.

Two component comprising external parameters and economic valuation component are introduced into the original PMT model.



Survey design:

Due budget and resources available for this study, prevalence of the problem, the size of the population in question and timeliness of the survey results, a census survey is not feasible and we intend use a **sample Survey design.**

Target group:

The target group include the parents and school authority who are the gate keepers for the children dietary intake.

Selection of a survey frame

Survey frame provides means of identifying and contacting the units of the survey population. After considering different survey frames following frames were the most appropriate for the target sample populations. The two populations for the current survey include: parents and school heads which will have distinct survey frames:

School heads: The head of each school will be selected from a physical list of schools. The list of schools will be obtained from the department of education also providing the details of the head teacher or immediate person in charge of the school. This is called conceptual list frame

Parents: A geographical list will be used. In this case parents from households within the vicinity of selected school will be selected. This is commonly referred as Area because there is not conceptual list of the units and therefore the parents will be selected from the area around the participating school. The two survey frame used are based on our target survey populations, method of data collection, sample selection and estimation and logistics in terms of costs and time , as well as the quality of its output (expected output)

Study area description

The study will be conducted in three East African Countries; Tanzania, Uganda and Kenya. Due to the nature of the research, emphasis will be put in regions within these countries that are hardest hit by iodine deficiency based on previous urinary iodine and total goitre prevalence data. The northern region of Tanzania, Eastern region of Uganda and western region of Kenya will be included (WHO, 2006). Arusha district in Tanzania, Kisoro district in Uganda and Busia/Kisii district in Kenya will be included in the study. These areas are mostly located in mountainous areas that experience leaching of iodine from the soils and also comprise of very remote villages with limited coverage by salt iodization program (Micronutrient Initiative 2009, WHO 2006).

Determination of sample size and design:

The Rural landlocked regions of East Africa at high risk of iodine deficiency which is associated with poor mental development and growth in children are part of the study. The prevalent rates of iodine deficiency are used to define the location of the study in each of the target countries. Taking Kisoro (Uganda) as an example, the sample size will be 296 households. Considering the design effect of 1.1 and 10 % non-response rate, the sample size becomes 360 households. The school authority interview will involve the selection of 40 schools. A Multi-stage Cluster sampling method will be used in the study. In each country an IDD endemic region will be identified. From a region, one district will be conveniently selected based on iodine deficiency prevalence and accessibility (first stage). Within the selected district, 40 clusters (schools) will be systematically selected based on Probability Proportion to Size (second stage). A random walk will be used to select 9 households (parent-child pair) with school age children (6 -12 years) within a predetermined radius from each school in order to get a representative sample of the study population (third stage).

Questionnaire Design;

Components of the questionnaire: Two questionnaires targeting sample population of parents and school authority were developed (Attachment). The questionnaires are structured into six sections: a) demographics b) nutrition knowledge with reference to iodide, IDD, biofortification and school performance c) iodine intake reflecting own iodine intake status c) information script d) PMT variables e) the economic valuation. In particular, demographic section for one questionnaire will collect social demographic data including age, gender, income, education and household status, while questionnaire for the school will collect data about the school, the status of the feeding program and income supporting the program and composition. A questionnaire with six sections is developed: Demographics; Knowledge; Own iodine intake; Information; PMT and Economic valuation

Data collection

Instrument for data collection

Two Structured pre-tested questionnaires (see appendix) will be administered by a trained interviewer to parents and school heads. Questionnaire one has four sections including questions on; socio-demographic characteristics of parents, 24-hour recall with emphasis on iodine nutrition, parent's knowledge about iodine and Iodine Deficiency Disorders, and PMT components. The second questionnaire is designed for school heads had has three section including; socio-demographic characteristics, knowledge about Iodine and Iodine Deficiency Disorders and PMT components.

Individual Dietary Diversity (with emphasis on iodine)

Data will be collected from school aged children in the sampled households with assistance of parents because Individual Dietary Diversity based on the proportion of individuals consuming iodine rich foods is the appropriate indicator of iodine nutrient adequacy (FAO, 2011). This Information will be collected using the previous 24-hours as a reference period (24-hour recall). Unlike other prolonged recall period, the 24 hour reduces memory bias and is less demanding for the respondent. The interviewer will first determine whether the previous 24 hour period is a "usual" or "normal" day. If it will be a special occasion, such as a birthday or feast, another day will be selected for the interview. Data will be collected by asking the parent the food groups the child consumed using nine predetermined food groups and scoring accordingly but with special interest in iodine rich food sources (appendix) (FAO, 2011).

Protection Motivation Theory

PMT constructs as elucidated in the conceptual framework (Figure 1) will be assessed using varying points of a Likert scale suitably designed to give the best response to a given question. As shown in the questionnaires, perceived severity will be assessed with three items, perceived vulnerability with four items, perceived fear with one item, response efficacy with two items, self-efficacy with two item, response cost with one item and protection motivation with two items.

Data analysis

Data collected will be entered using the EpiData platform. This will allow for pre-screening and cross checking all the entries from the primary questionnaires. The correct database will then be exposited to Stata software for subsequent analysis. Descriptive statistics will be used to explain socio-demographics, knowledge variables and own iodine status. Where necessary comparison tests will also be used to assess if there are significant differences between various variables. Regression analysis will be employed to determine how much variance in the intention to adopt bio-fortification is explained by the PMT components.

Ethical consideration

Ethical clearance to carry out the study will be obtained from authorities in the target locations of data collection. Informed written or verbal consent will be obtained from each respondent before any interview is conducted and confidentiality will be highly guaranteed.

Limitation of the study

The coverage of the region and the sample size present some of the possible challenges however efforts will be put to ensure we cover as much households and schools as possible to obtain a representative sample. For consumer research unless a census is carried out there any sample is possibly not enough and we strive to get a bigger sample to make meaningful conclusions.

Time frame

	Location	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
Protocol, conceptual frame and Tools	UGent										
Ethical clearance	KE, UG and TZ										
Sampling	KE, UG and TZ										
Data collection	KE, UG and TZ										
Data entry and pre-screening	KE and UG										
Data Analysis											
Write Up and submission											

APPENDIX 5: Phase 2 Questionnaire for the study on the reactions of the stakeholders on the demand-side (consumers): Experimental auction

SECTION A

Product characteristics: Vegetable legumes

a. Do you have heard about the following items commonly consumed in this area? Please indicate to what extent you are you familiar and understand?

Instructions: *From this piece of information, kindly help us understand your reaction using the following scale:* ***1****=Not at all familiar/understand,* ***2****=Slightly understand/familiar,****3****=Somewhat familiar/understand* ***4****=Moderately familiar,* ***5****=Extremely familiar*

Provided in small bags of 500g each

Items						**uction**
Common bean (including pinto bean, kidney bean, Pea, Chickpea, Lima bean and others)						*Explain and proceed*
Lentils						*Explain and proceed*
Runner bean						*Explain and proceed*
Velvet bean						*Explain and proceed*
Other legumes: Specify ……………………………..						*Explain and proceed*

b. What is the current market price of each of the products in the prevailing market value

Items **Vegetable legumes**	**Market price**
Common bean (including pinto bean, kidney bean, Pea, Chickpea, Lima bean and others)	
Lentils	
Runner bean	
Velvet bean	
Other legumes: Specify ……………………………..	

Section B: Iodine Biofortification Auction

Cheap talk script

Imagine for the next questions you could use iodine biofortified food to increase school performance of your children and protect them from iodine deficiency disorders. Your household could need to consider paying a fee to include the food in the children's diet at home or to be included biofortified food in school feeding program. We are going to ask you some questions about your household's willingness-to-pay for this type of food. However, many studies have shown that people say they are willing to pay more for an enhanced food product than they actually will pay when the product is presented to them. Therefore, in the next questions about biofortified foods please imagine your household is actually paying them.

Product improvement and Knowledge level

Auction Round 1: Information about iodine in vegetable legume

Information round: *Iodine is a mineral found in soil that is needed by our body for many things. Mainly, it is an essential component of the thyroid hormones involved in regulating the body's metabolic processes. Too little intake of this nutrient results in iodine deficiency disorders. Iodine deficiency disorders include mental retardation, hypothyroidism, goitre, cretinism, and varying degrees of other growth and developmental abnormalities. Poor mental development results in low IQ and school performance. But, Iodine deficiency is the most preventable cause of mental retardation in the world.*

Information on Health benefits regarding nutrition (iodine deficiency disorders) provided twice through SMS as well as in the auction designated area

Bid 1: How much are you willing to pay for vegetable legume with iodine?

Information provision/// own Read or through SMS*

† Bid converted to USD

Auction round 2: **Health threat (iodine deficiency disorders)** ***Information round:*** *Iodized salt and seafood are the major dietary sources of iodine. However, people leaving away from sea and eating low amount of sea food, those leaving far and interior places where its lost in salt and mountainous areas where soil iodine is depleted and food and foods are deficient are likely to get this problem (Give example of the current location). The diversification of diets and enhancing the iodine content of food are other measure to prevent this problem.* *Information on Health benefits regarding nutrition (iodine deficiency disorders) provided twice through SMS as well as in the auction designated area* Bid 2: How much are you willing to pay for the product avert iodine deficiency?	**Information provision///** own Read or through SMS* † Bid converted to USD

Product improvement: GM versus conventional ***Information round: Genetic Modification*** *involves new methods that make it possible for scientists to create new plants and animals by taking part of genes of one plant or animal and inserting them into the cells of another plant or animal. This is sometimes referred to as genetic engineering or biotechnology.* ***Genetically modified food*** *is food of which the genetic material has been modified in order to taste better, last longer, or be resistant to certain pesticides. Genetic modification can also be used to alter plants in a manner that results in increased crop yields, increased nutritional value or improved health effects.* ***Conventional production:*** *involves local procedure of developing vegetable legume products* **You are provided with the above product (s) for your household. How much are you willing to pay for each of these products**	**Information provision///** own Read or through SMS* † Prices converted to USD

Product	
Genetically modified Vegetable legumes	
Conventional vegetable legumes	

Auction round 3: **Product improvement :** GM biofortified vegetable legumes ***Information round:*** *The concept of iodine biofortification where local staple foods are modified to increase the iodine content is a new strategy being explored to prevent this problem. It is either GM biofortified or through conventional methods of adding certain stable iodine in fertilizer to produce crops rich in iodine or through cross breeding. Iodine GM biofortified vegetable legumes is made using genetic modification in order to increase the amount of iodine and health benefits.* Bid 3: How much are you willing to pay GM biofortified vegetable legume product?	Information provision///own Read or through SMS* † Bid converted to USD

Auction round 4: Conventional biofortified ***Information round:*** *Conventionally Iodine biofortified vegetable legumes involve local procedures that have been found to increase the level of iodine in vegetable legumes, such as crop breeding, fertilizations with high iodine fertilizers (fortified), Spray with high iodine content sprays, irrigation with high iodine content water etc.* Information provision///own Read or through SMS* Bid 4: How much are you willing to pay for conventionally iodine biofortified vegetable legume product?	Information provision///own Read or through SMS* † Bid converted to USD

Auction round 5: Iodine intake status ***Information round:*** *Given your calculated iodine intake of …………………. (Calculated from intake data) is considered (low), (moderate) (adequate) and (high). Iodine intake status from available sources if paramount in endemic areas. If your access to these sources is limiting and the intake is low the susceptibility to iodine deficiency is increased.* ***Bid 5: How much are you willing to pay for iodine biofortified food given your current level of iodine intake?***	Information provision///own Read or through SMS* † Bid converted to USD

APPENDIX 6: Study Protocol and introduction to auction

Key objective: To assess the WTP for iodine biofortified vegetable legumes in EA using an integrated BDM-SMS-Cheap talk bidding system

Sample

The sample will be selected from open air market in three locations in Kenya Uganda and Tanzania.

Experimental design
This will be a cross sectional study and simple random sampling will be used to select the participant. An introduction statement read about the auction and the researcher (cheap talk script developed). Participants will be recruited a few days prior to the auction and there basic information recorded including the contact mobile. Those without mobile will be request to provide alternative means of reach. 12 auctions will be conducted in each of the 3 locations with anywhere between 5-10 participants, giving a total of between 180 and 360 responses (sample size to be discussed). Questionnaires developed and pretested, inevitable since the order of questioning affect WTP responses! (questionnaires to be pretested to provide a standard order of items).

Procedure: - BDM procedure, integrated with a cheap talk script and SMS platform for bidding (literature reviewed! Practically possible)

Sampling frame:- Participants from an open air market in three locations in East Africa

Welcome & introduction to the auction

Dear All,
Good morning/afternoon*, my name is Joseph Mogendi from Kenya and a student at the University of Ghent, Belgium. I would like to thank you all for willing to participate in this food auction study on iodine biofortified vegetable legumes in East Africa. I would like to remind you that all the information you provide, either through bidding or filling in the questionnaire, is confidential and will be treated anonymously as guided by the ethical clearance provided by the authorities in EAC. Therefore, it is in our best interest that you answer honestly, whatever the answer might be.

If you allow me, I first explain briefly all about food auction. A food auction is a market experiment with several consumers, where each participant decides for herself what the value is of an alternative product(s), compared to an initial, conventional product. In our case, we would like to know how much you value a particular vegetable legume product(s), compared to conventional legume product. You will inform us of the true value you attach to this alternative product(s) by stating the highest amount you are prepared to pay for these products in comparison with conventional product provided. The highest exchange price you are prepared to pay is what we call your 'bid' in our auction. In this vegetable legumes auction, you will have the opportunity to bid to pay for an alternative vegetable legume product in comparison with a conventional vegetable legume product, based on the information we will provide you. As there will be different bidding rounds in our action, we will provide you each time with new information in this room for the first stages of the auction and through an SMS to your Phone for subsequent auction rounds.

The initial stages of the study will last approximately 30 min, depending on the time you need to fill in the questionnaire, and the duration of the bidding rounds. We kindly ask you not to talk with each other or not to show your answers/SMS to other participants during the session unless told otherwise. If you would have any question, feel free to ask one of the organizers now or later on during the market experiment. You are about to make part of a market experiment on vegetable legume. In particular you will be a participant in a Vegetable legume auction. An experiment or an auction might sound weird to you, but you should not be afraid at all. Your experience as a household consumer and buyer of vegetable legumes is enough to participate. I will shortly introduce what will happen in the coming hour.

Basically, there will be two main stages in this food auction. In the first stage we will explain to you how the auction works so that everybody understands. Then we provide show you a basket of local vegetable legumes that we have collected from the local market. After which we provide you with 3 different vegetable legume products labelled 1-3 for use in the auction rounds. At the end of this stage, we will ask you to fill in the Section A of the question and return it to us. The stage helps you to understand the different procedures in this auction and familiarize yourself with the local vegetable legume market.

In the second stage, we will run our real auction rounds. During this auction you will not be allowed to talk or communicate with other participants or to show your bids to others. We will run 4 different auction rounds, where each time you will have to decide how much you are willing to pay for the 500g of vegetable legume product, initially given to you, based on the information you will receive. During the first two rounds you will be provided with short information extracts from the main questionnaire which you can fill in your bid, while we are collecting the bids and preparing the next round. It might be confusing for you right now, but it will become clear to you once we start our training session.

At the end, you will receive your full participant fee in form of MPESA or Credit top-up however for the auction the participant with the highest bid of that round is obliged to pay for the vegetable legume product. At the initial stage everybody participating will be some money equivalent to 1 USD which will constitute, the participant fee and the potential bidding budget. As this auction has to be considered as a real auction, we will charge for every product you have to buy, which means your take-home income will consist of your participant fee and the potential bidding budget (given as 1 USD) minus the price you had to pay for the vegetable legume product.

Thank you again for your willingness to participate

APPENDIX 7: Phase 3 Questionnaire for the study on the reactions of the stakeholders on the supply-side (smallholder farmers): Adoption based on TAM segment of the PMTAM model (chapter 7) - Based on the literature review (Model paper-EFN) and TAM model

SECTION A: INDIVIDUAL DRIVING FACTORS

Variable Group	Measures	Scale and measurement elements
Individual driving factors and socio-demographics: Age , Gender, Source of income, occupation, How they obtain household food and Decision maker in the household and level of education	Gender of the farmer?	☐ Male
		☐ Female
	Age of the farmers?	☐ < 20 years
		☐ 21-30 years
		☐ 31-40 years
		☐ 41-50 years
		☐ 51-60 years
		☐ > 50 years
	Household size: How many members live with you in the household?	☐
	Children (Vulnerable children) How many children (6-12years) live with you in the household?	☐
	Education level of the farmer?	☐ College Degree
		☐ Some college education/diploma
		☐ High School/Secondary Education
		☐ Elementary
		☐ No formal education
	Income of the Farmer Per Annum?	<100 ☐
		<100-250 ☐
		250-400 ☐
		400-650 ☐
		>650 ☐
	Occupation- other occupation of the farmer Respondent`s other occupation that direct impact on farming?	None (Unemployed) ☐
		Casual worker ☐
		Self-employed-none farm ☐
		Government worker ☐
	Marital Status?	Single ☐ Married ☐ Widowed ☐ Divorced ☐

	Farm size: What is the size of the farm that you are cultivating?	<0.5Ha ☐ 1ha ☐ 2ha ☐ 3ha ☐ 4ha ☐ >5ha ☐
	Decision Making: In the farm, how often are you involved in deciding the food production for the household?	☐ 1 day ☐ 2 days ☐ 3days ☐ 4days ☐ 5 days ☐ 6 days ☐ 7days

SECTION B: GROUP/COMMUNITY DRIVING FACTORS

< ***Instructions:*** *From this piece of information, kindly help us understand your reaction using the following scale:* ***1*** *– Strongly disagree;* ***2*** *– Disagree;* ***3*** *– Somewhat disagree;* ***4*** *– Neither agree or disagree;* ***5*** *– Somewhat agree; 6 – Agree; and* ***7*** *– Strongly agree* >

Group/Community driving factors	Constructs/ characteristics	1	2	3	4	5	6	7
	Participants in my community who have influence (relatives) my behaviour think that I should use biofortification.							
	Participants in demonstration who are important to me (non- relatives) think that I should use biofortification							
	In general, the community encourages to use new technologies and share the information as much as can							
	I have necessary resources to use biofortification							
	I have necessary knowledge to use biofortification							
	Biofortification is not the only technology deals with during increasing micronutrient levels and nutritive value of my produce							
	I do not need assistance to deal with biofortification as a technology.							

SECTION C: TECHNOLOGY ACCEPTANCE FACTORS AND MODERATING VARIABLES

– **Farmer`s Attitudes towards biofortification**

< ***Instructions:*** *From this piece of information, kindly help us understand your reaction using the following scale:* ***1*** *– Strongly disagree;* ***2*** *– Disagree;* ***3*** *– Somewhat disagree;* ***4*** *– Neither agree or disagree;* ***5*** *– Somewhat agree; 6 – Agree; and* ***7*** *– Strongly agree* >

Attitude statements	**1**	**2**	**3**	**4**	**5**	**6**	**7**	Attitude toward the new type of food using food neophobia scale (Pliner & Hobden, 1992),
I think using biofortification to improve nutritional value of crops is a good idea								
Using biofortification is a good idea for my produce								
I think the use of biofortification is a wise idea to protect my children and my community								
I am constantly applying new and different innovations an technologies in my farm								
I don't trust new technologies								
If I don't know what is in biofortification, I won't try it								
I like different technologies which increase production and confers additional health benefits								
Biofortification of food looks too weird to adopt in my farm								
At home I and my community will try a new technology such as biofortification								
I am afraid to adopt technologies and innovation I have never had before								
I am very particular about the technologies and innovation I will adopt in my farm								
I will adopt almost anything								
I like to try technologies and innovation that can improve my health and those related me								

TAM Factors: Perceived Usefulness, (PU), Perceived Ease Of Use (PEOU), Intention to Adopt (IA), and Resultant Adoption (RA)

Construct	Line of questioning	1	2	3	4	5	6	7	Instructions
Perceived usefulness	*From this piece of information, kindly help us understand your reaction using the following scale: **1** – Strongly disagree ; **2** – Disagree ; **3** – Somewhat disagree ; **4** – Neither agree or disagree ; **5** – Somewhat agree ;**6** – Agree; and **7** – Strongly agree >*								
	I would find biofortification useful in order to improve the nutritional composition of my produce.								
	Through biofortification I can improve the nutrition value of crops and hence acceptability by consumers								
	I think the nutrition status of my children will improve through using biofortification at the farm level.								
	I think the advantages of using biofortification outweigh the cost and other disadvantages of the process.								
	On overall using biofortification is advantageous to our community								
Perceived Ease Of Use	I do not need so much time to learn how to use biofortification in my farm								
	It would be easy to know how to apply biofortification in my farming practice.								
	I would find biofortification easy to apply, flexible and no restrictions to use in our farm.								
	I think using biofortification is clear and understandable								
	I think it is easy to apply biofortification without expert help								
	I think it is easy to apply biofortification to improve our nutrition and health								
Intention to use biofortification as a novel technology	I will work on publishing demonstration news on biofortification								
	I will continue to publish demonstration events without stop								
	It is probable that I will use or continue using biofortification in my farm								
	I intend to begin or continue using biofortification								
	I will frequently use biofortification in the future								
	I will recommend biofortification to others in this community and beyond								
Resultant adoption	Scale: 1 – Never ; 2 – Rarely, in less than 10% of the chances when I could have ; 3 – Occasionally, in about 30% of the chances when I could have ; 4 – Sometimes, in about 50% of the chances when I could have ; 5 – Frequently, in about 70% of the chances when I could have ; 6 – Usually, in about 90% of the chances I could have.; and 7 – Every time								
	On average how often will you use biofortified food in your household								
	How frequent are you likely to apply biofortification and biofortified food in your household								
	On average, If normal farming adoption cost $120 per acre, how much more are you to pay to implement biofortification in your firm	<$5	$10	$15	$20	$25	$30	>$35	Amount in dollars

Scientific curriculum vitae

PERSONAL INFORMATION

First name	Joseph Birundu
Last name	Mogendi
Address	P.O Box 62000-000200, Nairobi, Kenya.
DoB	September 21, 1982
Place of birth	Kisii Central
Nationality	Kenyan
Sex	Male
Marital status	Married
GSM	M+254-725-355682/+254723041143-Kenya; M+32472730439-Belgium
E-Mails	Josephbirundu.mogendi@ugent.be; snjomobi@yahoo.com; snjomobi@gmail.com
Passport holder:	B144869
Identity card number	22602171

EDUCATION

Year	Institution (Date from - Date to)	Degree(s) or Diploma(s) obtained:
2012-2016	University of Ghent, Belgium	Degree: PhD Applied Biological Science (ABS) A Novel Framework for Analysing Stakeholder's Interest in Healthy Foods. A Case-Study on Iodine Biofortification
2015-Ongoing	University of Nairobi	Degree: MA Public Administration **Grade/Status: Ongoing**
2010-2012	University of Ghent, Belgium	Degree: Msc. Nutrition and Rural Development, Human Nutrition Major: Public Health Nutrition Grade: **Distinction**
2002-2006	Jomo Kenyatta University of Agriculture and Technology, Kenya	Degree: Bsc. Food Science and Nutrition Grade: BSc (Hons) **Status: Completed**
1997-2000	Sameta Boys high school	Kenya Certificate of Secondary Education Grade: B+ Status: **Completed**

ADDITIONAL TRAINING (Technical and professional training)		
Year (Date from - Date to)	**Institution**	**Course**
2013	University of Ghent, Belgium	Theory and Methods of research: By, Dr. Rolfe A Leary (United States Forest Service)
2014	University of Ghent, Belgium	Opportunity recognition for food security and livelihood
2015	KU Leuven	Project management and Quantitative research methods:- Systematic reviews and Meta-analysis
2014	Mt Kenya University	University Level Pedagogy Training Examination Setting and processing training

WORK EXPERIENCE		
Year	**Institution**	**Duties**
2016	**Jomo Kenyatta University of Agriculture and Technology**	**Lecturer, Department of Food Science and Technology/Nutrition** **Teaching & Research**
2012 -2016	**University of Ghent -Belgium**	**Doctoral Researcher:** Faculty of Biosciences Engineering- Novel Framework for Analysing Stakeholder's Interest in Healthy Foods. A Case-Study on Iodine Biofortification in East Africa
2013-2015	**Jomo Kenyatta University of Agriculture and Technology (JKUAT)**	**Part-time Lecturer:** Faculty of Agriculture, Department of Food Science and Technology **Key areas:** Nutrition Epidemiology, Nutrition interventions, Human Nutrition, Food and Nutrition surveillance; community Nutrition and health; Nutrition in Emergencies
2008-2014	**Mt Kenya University (MKU)**	**Assistant Lecturer** School of Health Sciences and School of Applied Science, Departments: Nutrition and Dietetics; Food Science and Technology
2014	**Thika Level5 Hospital and Mount Kenya University**	**Clinical Instructor**- Nutrition and Dietetics
2006-2008	**Thika Institute of Technology (TIT)And KNEC-Examiner**	**Consultant Lecturer:** Faculty of Health Sciences **Kenya National Examination Council**: Diploma in Dietetics Management
2007-2012	**Thika School of Medical and Health Sciences (TSMHS)**	**Consultant Lecturer:** Faculty of Applied Sciences, Department of Nutrition
2007-2008	**Bidco Oil Refineries**	Production Technical Supervisor/Operator
2006-2007	**Delmonte Kenya limited**	Production and quality control departments

CONSULTANCY EXPERIENCE

Year	Organisation	Duties
2014	**UNICEF-Somalia**	**Lead consultant** Countrywide Training Consultant Nutrition in Emergencies, Based on the Harmonized Training Package for Nutrition In Emergencies: Global Nutrition Cluster
2012	**Global Alliance for Improved Nutrition (GAIN)**	A UN unit established in Geneva to reduce micronutrient malnutrition in developing countries. **Large scale fortification Advisor:** East Africa
2004-2015	**Government of Kenya (Ministry of Health-Division of Nutrition-MoH)**	Involved in the development of national strategic/policy documents: Most Recently: Development of National Micronutrient Strategic Plan for the Ministry of health-Kenya: - Funded by Micronutrient Initiative (MI). National Food and Nutrition Security Strategic Plan; Kenya National Nutrition and HIV-Guidelines.
2008- 2014:	**Kenya Institute of Education (Kenya Institute of Curriculum Development)**	**Consultant and Curriculum Review Panellist:** Developing the curricula for training nutrition professionals in Technical Institutions and Universities with invitation by Kenya Institute of Education (KIE) **Cluster:** Nutrition and dietetics Food science and processing technology

LANGUAGE SKILLS (Language competence on a scale of 1 to 5 (5 - excellent; 1 - basic)

Language	Reading	Speaking	Writing
English	5	5	5
Swahili	5	5	5
French	2	1	1
Dutch	5	3	3

MEMBERSHIP OF PROFESSIONAL BODIES	
2008	Kenya Institute of Nutritionists and Dieticians (KNDI)-Registered Nutritionist
2012	Belgium nutrition Society-Registered Member (BNS)-Revolving

SPECIFIC EXPERIENCE IN THE REGION

Year	Country
2005	Kenya
2010-2016	Belgium
2012-2016	Uganda
2012-2016	Tanzania
2011-2015	Ethiopia
2008-2011	Rwanda
2014	Somalia

COMPUTER SKILLS:

2002	**Ms Office:** Excel, Word, Outlook, Publisher, PowerPoint
2007-date	**Statistical packages** STATA; SPSS; GenStat; S+; and R Endnote, Refman EpiData HLM

AWARDS AND FELLOWSHIPS

2012-2016	BOF International Scholarship University of Ghent /Belgium: PhD Research
2010-2012	VLIR-UOS International Scholarship Belgium Government-Msc
2011	VLIR-UOS International South-South Research grant in together with Prof. H. Vasantakalam Kigali University of Science and Technology (KIST-Rwanda)
2002-2006	Government of Kenya

Articles published in international peer-reviewed journals referenced in PubMed/ISI Web of Science (A1 publication)**	
2016	**Mogendi, J. B.,** De Steur, H., Makokha, A., & Gellynck, X (2016). Integration and Validation of an SMS-Based Bidding Procedure of eliciting Consumers' Willingness-To-Pay for Food. *British Food Journal* ***(in press)***
2016	**Mogendi, J. B.,** De Steur, H., Makokha, A., & Gellynck, X. (2016). Consumer Evaluation of Food with Nutritional Benefits: A Systematic Review and Narrative Synthesis. *International Journal of Food Sciences and Nutrition*. Volume 67, Issue 4 pp. 355-371.
2016	**Mogendi, J.B.,** De Steur, H., Makokha A.O., Gellynck, X. (2016). A Novel Framework for Analyzing Stakeholder's Interest in Healthy Foods: A case-study on Iodine Biofortified Food in Africa. *Ecology of Food and Nutrition Journal.* Volume 55, Issue 2 pp. 182-208
2015	**Mogendi J.B,** De Steur H, Gellynck X, Saeed HA, Makokha A (2015). Modelling protection behaviour towards micronutrient deficiencies: The case of iodine biofortified vegetable legumes as a health intervention for school going children. *Nutrition research and practice.* Volume 10(1):pp 56-66
2015	Hans De Steur[a*], **Joseph Birundu Mogendi[a,b]**, Joshua Wesana[a], Xavier Gellynck[a] , Anselimo O. Makokha (2015). Stakeholder Reactions Towards Iodine Biofortified Foods: An Application of Protection Motivation Theory. *Journal of Appetite.* Volume 92, pp 295-302.
2015[8]*	Kinyuru, J.N., **Mogendi, J B**., Riwa, CA., Nancy W (2015). *Edible insects—a novel source of essential nutrients for human diet: Learning from traditional knowledge.* Animal Frontiers, 2015. Volume 5(2): pp 14-19. https://dl.sciencesocieties.org/publications/af/abstracts/5/2/14
2014[8]*	**Mogendi JB,** De Steur H, Gellynck X, Saeed HA, Makokha A (2014). Efficacy of mid-upper arm circumference in identification, follow-up and discharge of malnourished children during nutrition rehabilitation. *Nutrition Research and Practice.* Volume 9: pp16. http://e-nrp.org/search.php?where=aview&id=10.4162/nrp.2015.9.e16 &code=0161NRP &vmode=AONLY

***5 Articles related to 5 chapters of this thesis*
[8] not related to the current PhD thesis*

Articles under review in international peer-reviewed journals referenced in PubMed/ISI Web of Science (A1 publication)	
2016	Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Experimental Auctions to Measure Willingness to Pay for iodine Biofortified Food: A Methodological and Empirical Approach. *Agribusiness: An International Journal*, ***Under review.***
2016	Mogendi, J. B., De Steur, H., Makokha, A., & Gellynck, X. Farmers' perceptions and willingness-to-adopt Biofortification: An Application of Technology Acceptance Modelling to Iodine Biofortification. *International Journal of Agricultural Sustainability*, ***Submitted.***

Articles published in international peer-reviewed journals not referenced in one of the Web of Science databanks (A2 publication)	
2015	Saeed H. A, **Mogendi J. B,** Akparibo R, Kolsteren P. *Reliability of Mid-Upper Arm Circumference Measurements Taken by Community Health Nurses.* Curr Res Nutr Food Sci 2015;3(1).http:// www.foodandnutritionjournal. org/?p=1392

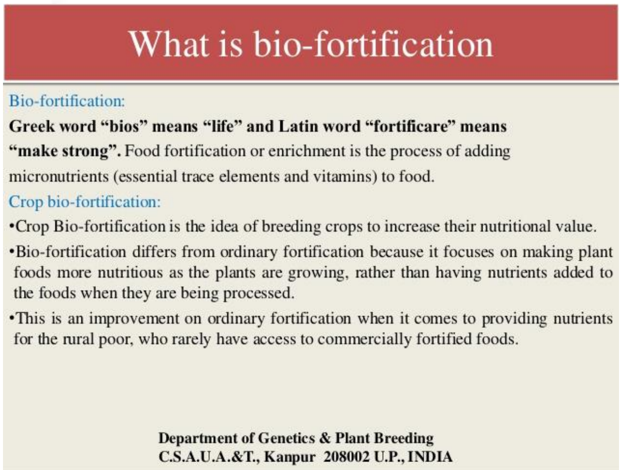
Books as author or co-author (B1 publication)	
2014	De Steur, H., **Mogendi, Birundu J**., Wesana, J. and X. Gellynck. *Analysis of Stakeholder Reactions towards the Use of Biofortified Foods in School Feeding Programs. An Application of the Protection Motivation Theory to Iodine Enriched Legumes in Uganda.* Contributed paper prepared for oral presentation at the IFAMA 24th Annual World Symposium "People Feed the World: The Talent Factor", June 16-17, 2014, Cape Town, South Africa.
2013	**Mogendi, B. J**., De Steur, H., Makokha A., and X. Gellynck 2013: *An integrated model for analysing stakeholders' adoption of innovative products and technologies in the food sector: The case of iodine biofortification. Conference theme: towards achieving knowledge economy through research and innovation.*
2014	**Mogendi, Birundu J**., De Steur, H., Makokha A., and X. Gellynck: *Potential of Biofortification as a Means to Prevent Micronutrient Deficiencies: An Overview of Stakeholders Acceptance and Adoption of Crop Biofortification, Chuka International conference*

B2 publication and book chapter: (B1 publication)	
2014	De Steur, H., **Mogendi, J. B.,** Blancquaert, D., Lambert, W., Van Der Straeten, D., & Gellynck, X. (2014). *Genetically Modified Rice with Health Benefits as a Means to Reduce Micronutrient Malnutrition: Global Status, Consumer Preferences, and Potential Health Impacts of Rice Biofortification.* In R. R. Watson, V. R. Preedy & S. Zibadi (Eds.)
2009	**Mogendi J.B**., (2009): *Essentials of clinical and community Nutrition in the developing world. 1st Edn.*

Theses	
2016*	**Mogendi JB,** De Steur H, Gellynck X, Makokha A (2016): *Stakeholders' reactions toward iodine biofortified foods: an application of protection motivation theory and technology acceptance model*
2012	**Mogendi J. B.**[a,b], Kolsteren (2012): *Validity of Mid-Upper Arm Circumference as a predictor of recovery for malnourished children*. Thesis (**MSc, Completed**)

Master thesis supervised	
2014	Wesana J., Mogendi J.B., De Steur H., Gellynck X (2014) *Analysis of the parents' and school authorities' reactions towards the use of bio-fortified foods in School Feeding Programs. The case of Iodine Deficiency in East Africa.* Ghent University, Belgium.

*Current thesis under consideration



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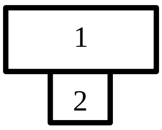

@1: World distribution of the intelligence of the indigenous people in relation to iodine intakes

@2: Highlight of biofortification as an alternative to increasing the nutrient intakes through staple food