Sensory evaluation and consumer acceptability of novel Fortified Blended Foods

by

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B.S., Chiang Mai University, Thailand, 2009
M.S., Kansas State University, 2015

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

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Abstract

Fortified blended foods (FBFs), which are the mixture of cereals and legumes fortified with micronutrients, have been widely used as supplementary foods for vulnerable populations such as infants and young children in developing countries around the world. The evaluation of current FBFs showed limited evidence on their effectiveness in treating childhood malnutrition, resulting the several recommendations on processing and formulation changes to improve their quality and ability to meet nutritional needs. Sensory properties are one of the important determinants for the success of the new FBFs. Therefore, sensory testing was conducted to determine the potential of novel FBFs to be used as supplementary food compared with FBF currently used in food aid programs. Descriptive sensory analysis was performed on novel FBFs along with the traditional FBF (Corn soy blend plus; CSB+) to determine sensory characteristics of each FBF. Results showed that novel FBFs had more pronounced toasted characteristics and higher sweetness than CSB+, due to the higher temperature during extrusion process and the addition of sugar in the novel formulation. In addition, novel FBFs that had higher amount of legumes (e.g. soybean, cowpea) in their formulations, especially for all sorghum cowpea blends, showed higher intensity in beany characteristics. Sensory shelf-life testing showed that novel FBFs could have shelf lives at least 2 years with no detection of off-note characteristics and these was comparable to the shelf life of the current FBF (CSB+). Sensory testing was also performed with target populations: children who eat the food and care givers who prepare it, during a 20-week field trial to determine the acceptability and preference of novel FBFs and current FBF. Results showed that all novel FBFs were highly preferred or accepted by children, even though, some of them might need longer time and more exposures to allow children to have more experience and be familiar with the food before being satisfied or preferred that food. In contrary, CSB+ that had bland flavor tended not to

be well accepted and highly preferred by children compared to novel FBFs. Moreover, giving children more opportunities to consumed food prepared from CSB+ did not help to improve its acceptability or preference. Data from household visits and interview sessions showed that porridges prepared from novel FBFs required less cooking time than CSB+ and no additional ingredients needed to be added compared to CSB+ where sugar and milk were common additions. Finding from this research indicated that novel FBFs have high potential to be used successfully as supplementary food with comparable shelf life, and higher acceptability and preference to FBF currently used in food aid programs. In addition, the simple cooking of novel FBFs make them valuable to caregivers who have limited time and access to energy sources and nutrient-rich ingredients.

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Chapter 1 - Literature Review

Food insecurity around the world is always increasing due to growing populations, natural disasters, poverty, conflicts, and many other causes (Ahmed and others 2007). Malnutrition or undernutrition is a major problem in many developing countries and adversely affects the health and growth of children under the age of 5 (Nyaruhucha and others 2007). Black and others (2008) indicated that undernutrition is a major risk factor for child mortality and is implicated in approximately 28% of deaths in children under the age of 5. Food aid can be used as an important tool in addressing food insecurity issues. In fiscal year 2015, the United States Agency for International to Development (USAID) provided 1.06 million metric ton (MT) of food at more than $1.4 billion to serve a total of over 32 million beneficiaries in 41 countries, 78 percent of this was for emergency response and 25 percent for non-emergency programming (USAID 2015). Food commodities provided by USAID include wheat or wheat products, whole grains, fortified blended food products, vegetable oils and pulse (Rowe and others 2008; USDA 2015). Most of the food aid are distributed in Africa and Asia (USAID 2015).

Fortified Blended Foods

Fortified blended foods (FBFs) are defined as a combination of cereal–legume–oil admixtures fortified with a range of vitamins and minerals, with the possible addition of a dairy based source of protein. The grains and legumes should be partially precooked in order to 2 enhance their digestibility, denature antinutritional factors, and reduce the cooking time required (Wood and others 2008). These foods need to be energy-dense and “rich in micronutrients”, easily digestible and palatable, and able to be prepared relatively quickly, i.e. with minimal cooking (IASC, 2009).

FBFs are used in a very large scale to feed populations in low income countries, especially malnourished individuals and vulnerable groups. FBFs were developed in the 1960s to serve as a protein-rich, micronutrient-dense food supplement for infants and young children (preschool-age children) in developing countries to improve child nutrition (Perez-Exposito and Klein 2009; Fleige and others 2010). The basic recipe consisted of cereal - Corn and wheat (75-80%) as the source of carbohydrates, and soy flour (20-25%) as protein source. Corn-Soy Milk (CSM) and Wheat-Soy Milk (WSM) were the first two original formulations of FBFs developed in 1967. Corn-Soy Blend (CSB) was developed in the 1980s to replace CSM and WSM because of the increasing cost and shortage of non-fat dry milk which was a main component of CSM and WSM (Perez-Exposito and Klein 2009; Fleige and others 2010; Webb and others 2011). There were some modifications which had been made to the FBFs in the early 1990s to reflect current thinking on recommended intakes and bioavailability of nutrients, but no significant work had been done since the 1960s to incorporate advances in food science and technology into new and improved products for food aid (Fleige and others 2010).

Corn soy blend (CSB) is now the most commonly used of FBFs. Wheat-Soy Blend (WSB) is another FBF that has been used but at a much lower volume than CSB. CSM and WSM are still available but they are rarely distributed due to the cost constrain (Fleige and others 2010). CSB, classified as ready-to-use supplementary foods, had changes in its macro and micronutrient profiles, proteins and energy density between 2005 and 2011 and was identified as CSB10, 11, 12, 13 & 14 and instant corn soy blend to reflect the changes. However, these various versions of CSB were considered ineffective in addressing moderate acute malnutrition due to inadequate composition such as micronutrients, energy density, lipids and dietary fibers (de Pee and Bloem 2009; Fleige and others 2010). CSB and its various formats is the FBF of choice for USAID implementing partners, including the World Food Program (WFP). FBFs produced in The United State have to meet the requirements from the United State Department of Agriculture (USDA), while the locally produced FBFs are controlled by organizations such as the WFP and UNICEF. The typical formulations of CSB distributed by USAID and WFP is shown in Table 1-1.

Table 1-1 Typical formulations of CSB distributed by USAID and WFP

Ingredient (%)	USAID CSB+	WFP CSB (Super cereal)
Maize	78.47	78.30
Whole soybean	20.00	20.0
Vitamin/Mineral	0.20	0.20
Dicalcium Phosphate Anhydrous		1.23
Tri-Calcium Phosphate	1.16	
Potassium Chloride	0.17	0.27

Source: USDA (2014); WFP (2015); CSB = Corn Soy Blend

The benefits of FBFs are in the fact that they are shown to promote growth very well since they contain adequate calories and protein. They are also fortified with essential vitamins and minerals which are important because these micronutrients cannot be obtained from a normal diet in many situations. The preparation of FBFs is flexible and easy. As they are pre-cooked, they require short cooking time and only limited amounts of fuel which is a constraint in low resource settings. FBFs are high on digestibility and easy for infants and young children to swallow. Additionally, the cost of FBFs is low when compared to their nutritional value and other micronutrient-rich commodities. The low cost of the foods maximizes coverage of the populations in low income countries and increases long-term sustainability (WFP 2002; de Pee and Bloem 2009).

Recommendations for Improvement of Fortified Blended Foods

There are several recommendations for FBFs in order to make this product meet the needs of multiple vulnerable groups. Extrusion cooking is one of the processes that has been recommended to use to produce FBFs. Cooked porridge from extruded FBFs will have lower consistency, so mothers do not have to dilute porridge for their children and children would get enough energy and nutrient density to support their growth. Moreover, FBFs manufactured with extrusion process require less cooking time and less need for fuel, which is frequently in short supply in relief situations (Fleige and others 2010). (Grillenberger and others 2003) recommended the addition of animal –source protein in addition to the protein from soy to improve the nutritional value and contributing to lean mass accretion. Replacing some of soy flour with a dairy ingredient would potentially improve absorption of micronutrients such as iron and zinc (Fleige and others 2010).This has led to the addition of milk powder or other dairy derivatives to FBFs. World Food Programme (WFP) has already upgraded specifications for FBFs by adding milk powder into the blends which is called "super cereal plus". Webb and others (2011) also suggested USDA to increase protein quantity in FBFs by adding whey protein concentrate (WPC). Increasing fat and energy content is another recommendation for FBFs. Increasing fat content of the food can increase the energy density of the diet, support neurodevelopment and increase the absorption of fat-soluble vitamins. Moreover, fat can also improve the texture, flavor, and aroma of the food (Fleige and others 2010).Therefore, the recommended FBFs should be prepared and consumed with fortified vegetable oil (FVO) at defined volumes (15 g oil per 50 g dry matter and in increment of that ratio) which results in higher fat and energy content (Webb and others 2011). Upgrading the micronutrient composition of FBFs is another major recommendation in order to improve the quality of FBFs. Overall, micronutrient levels should be set higher than in the past. It was further recommended by Webb and others (2011) that a flavor enhancer might be added to formulations of FBFs. The addition of a sweet additive can enhance taste and acceptability, which is important when we try to increase the consumption among sick and undernourished children. It is also suggested by the industry that toasting the corn germ would provide and enhanced sweet flavor. de Pee and Bloem (2009) suggested to use cornmeal derived from dehulled and degermed corn and soy flour derived from dehulled soy beans in order to decrease fiber content of FBFs. Infants and young children typically eat smaller amount of high-fiber bulky cereals, which reduces the intake amount of food and affects their nutritional status. There was a study reported that infants' intake of a cereal product decreased significantly from 42±23 g/d to 34±23 g/d ($p<0.01$) as the fiber in the cereals increased from 1.8% to 8%, respectively (Davidsson and others 1996; Webb and others 2011). Therefore, using dehulled and degermed corn and dehulled soy beans in FBFs formulations would increase children's consumption and their energy intake.

Additionally, the traditional cereals and legumes used in FBFs – corn, wheat and soybean were recommended in The Food Aid Quality Review (FAQR) to be replaced by other cereals and legumes, such as sorghum, millet and rice (Webb and others 2011). Sorghum is looked at as a potential alternative because of a number of advantages over corn and wheat. Sorghum is mostly a non-Genetically Modified Organisms (GMO) crop which allows it to be used in many countries around the world that have banned the use of GMO products. It is priced competitively with other food aid grains. Moreover, when it is processed properly, it contains a level of carbohydrates similar to CSB and also has a higher level of protein, fat and some micronutrients (Dicko and others 2006). The study of extruded fortified sorghum soy blend (SSB) by Padmanabhan (2013) showed that sorghum can be used as a viable corn-substitute in FBFs. The extruded SSB has a high energy density (410 kcal/100g) with a consistency comparable to the new recommendation for fortifications in Tufts report to USAID. Cowpea also considered as alternative legume that can be used in FBFs because of the high levels of protein, energy and other nutrients (Uzogara and Ofuya 1992). Sorghum and cowpea are cultivated and consumed as a part of human foods in many parts of developing countries (Uzogara and Ofuya 1992; Anglani 1998), thus populations in that areas should be familiar with the tastes of sorghum and cowpea and that make them a good candidate for being used in FBFs.

Uses of Fortified Blended Foods

FBFs, that are currently used, are partially pre-cooked foods. They are designed to be cooked, fried or baked to complete their digestibility. WFP (2002) suggested that the cooking time for FBFs should vary from 2 to 15 minutes depending on the kind of preparation required. Vegetables, seasoning and other additives are used in order to improve the palatability and to increase the nutritive value of the final product. Rowe and others (2009) reported that African people added sugar and vegetable oil to their meal. Cinnamon, herbs, or banana were often added to the Guatemalan recipes.

Thin or thick porridges are the most common dishes prepared from cereal-based products (Rowe and others 2008; Moussa and others 2011; Chanadang and others 2016). The difference between thick and thin porridge is the concentration of the flour used in the preparation. The thick porridges, known by different name such as tô, tuwo, aseda, ugali, muddle, are solid-like and consumed as a starchy staple food at meal. On the other hand, thin porridges are fluid-like or semi-fluid, consumed in the morning as breakfast or served to lactating mothers and young children. For thin porridges preparation, flavoring or other food items such as milk, fruits or spices are often added to improve the taste of the porridge (Anglani 1998; Moussa and others 2011). Although there are widespread uses of FBFs for making porridge, the cooking methods varied from household to household. Rowe and others (2008) reported that beneficiaries in Uganda and Guatemala prepare porridges with concentration ranges of 10% to 31% (wt/wt) in water and cook them from 5 to 53 minutes, with a mean of 26 minutes. Beside porridges, there are many dishes that can be prepared from FBFs. Tortillas and beverages are other common dishes observed in Guatemala (Rowe and others 2008). WFP (2002) listed the recipes which can be prepared from FBFs. These recipes include porridges, beverages, simple breads or cakes, roasted products, flitters, and other preparations such as steamed dumplings, banana leaf rolls, vegetable stew, and cookies.

Sensory and Consumer Testing with Children

Many foods and beverages products are developed specifically for children (Guinard 2000), and they must be well accepted by children to be successful in the market. Most of the research on food for children is carried out on adults (Leon and others 1999), probably because of their ability to understand instructions and task, and also readily express their choices and perhaps even the reasons behind them (Levin and Hart 2003). However, using adult responses for product development direction are not enough to predict success in a child market (Chen and others 1996; Levin and Hart 2003). Several differences between children and adults are observed. Adults and children are different in sensory perception, as well as different in how they interpret questions that they are asked and in how they use the intensity scales (Popper and Kroll 2005). Studies comparing responses from adults and children also indicated significant differences in their definition of an optimal product (Moskowitz 1994). Thus, children’s products should be tested by children to obtain the logical direction for product development. However, sensory testing for children have to perform with care and must take into account the range of sensory and cognitive abilities of children (Guinard 2000).

Learning Abilities of Children

ASTM's Committee 18 on sensory testing methods has been developed guidelines for sensory testing with children and also complied children's cognitive skills as a function of age as shown in Table 1-2.

Children can be classifies into Piaget's stages of cognitive and linguistic development (Guinard 2000; Popper and Kroll 2005). Children between the ages of 2-6 are classified in 'pre-operational' stage, which means they are limited in their logical thinking more likely to focus on a single aspect of stimulus. The older children between the ages of 7-12 are classified in 'concrete-operational' stage, where children have ability to perceived multidimensional stimuli (Popper and Kroll 2005).

When young children have to do food sensory testing, they often making their decision based on only one attributes of food rather than taking all sensory attributes into consideration. Other limitations in the cognitive skills of children related to sensory evaluation include limited verbal skills, short attention span, and difficulties in task understanding (Resurreccion 1998; Guinard 2000), thus special attention to be given to the phrasing of the questions and vocabulary used is required. Kroll (1990) also indicated that personal interviews are required for children aged 5-7 years because they are either preliterate or may have just basic reading skills, and that are more time consuming and expensive than traditional sensory test with adults.

To deal with the potential understanding problems, Guinard (2000) recommended to take the children the test protocol using visual stimili before having them taste that actual foods. Birch and Sullivan (1991) also recommended using individual training sessions or a group demonstration on the procedure before starting the actual session, in order to ensure children's understanding of the tasks.

Sensory testing methodology for children

Newborns - 3 years

Conducting sensory and consumer researches with children in this age group is a challenge because of their limited ability to communicate verbally (Guinard 2000; Levin and Hart 2003). Therefore, measuring taste or olfactory responses of children in this age group are based mostly on non-verbal cues such as face expressions, body movement, heart rate, and different ingestion and sucking patterns (Guinard 2000). In a study on the acceptability of porridge from fortified blended foods among toddlers by Bovell-Benjamin and others (1999), caregivers were asked to interpret the behavior of their child as they tasted the food and rated their acceptance on a traditional hedonic scale. In this study, caregivers also tasted and rated that samples as well. The results showed that toddlers' acceptability scores that was interpreted from their behavior were different from the scores rated directly from caregivers. Thus, measuring children's responses by indirect approach that has parent interpret the behavior of the child is highly recommended in order to obtain a good representative data for children's opinion. Toddlers with the ages between 2-3 years could also reliably perform paired preference tests (express their preference between two choices), but the more complex tests such as hedonic scales or ranking are beyond their ability (Kimmel and Guinard 1994; Guinard 2000).

Table 1-2 Cognitive abilities of children from infancy to teen age (from ASTM's Committee 18 on Sensory Evaluation) (Source: Guinard 2000)

Skill/behavior	Infant Birth-18 months	Toddler 18 months-3 years	Pre-school 3-5 years	Early readers 5-8 years	Pre-teen 8-12 years	Teenage 12-15 years
Language—Verbal, reading/written language vocabulary	Pre-verbal. Rely on facial expressions. Cannot read. Cannot write. Uses sounds, very few words.	Beginning to vocalize, adult interpretation still required. Cannot read. Cannot write. Early word usage developing.	Early language development. Can observe facial expressions, respond to questions and pictures. Generally, reading and writing skills are just beginning, if present.	Moderately developed verbal and vocabulary skills; understanding increases. Early reading and writing skills, may still require adult assistance for some tasks.	Very verbal—able to express themselves adequately. Reading and written language skills increase rapidly and are sufficient for most self-administered tasks	Strong language and vocabulary skills. Reading and written language skills continue to increase. Adult level in most respects.
Attention span	Gauged by eye contact	Gauged by eye contact or involvement with task, bodily movement.	Limited, but increasing. Bright colors, movement are effective.	Limited by understanding of task and interest level, challenge.	Potential attention span is increasing, but holding interest is critical.	Similar to adults, involvement and interest subject to peer pressure.
Reasoning	Limited to pain and pleasure.	Limited, but concept of 'no' becoming a factor.	Limited, but beginning to be able to know what is liked and what is not.	Developing with increased learning, cause/effect concepts	Full ability for understanding and reasoning, capable of decision making	Reasoning skills are fully developed and similar to adults.
Decision making	Does not make complex decisions	Does not make complex decisions, but 'yes'/'no' can be decisive	Limited, but concepts of what is liked and what is not strengthen. Able to choose one thing over another.	Ability to decide is increasing, but influence of adult approval is evident.	Capable of complex decisions, peer influences a factor	Fully capable of adult decision processes, subject to peer influences
Understanding scale	Does not understand scales	Does not understand scales	Understanding of simple scales beginning, sorting or identification tasks more effective	Scale understanding increasing, simple is best.	Capable of understanding scaling concepts with adequate instruction	Similar to adults

Motor skills	Possesses some gross motor skills, no fine motor skills	Rapid gains in gross motor skills, fine motor skills still limited.	Development of both gross and fine motor skills increasing	Gross motor skills developed, fine skills becoming more refined	Hand to eye and other fine motor skills developed.	Similar to adults
Recommended evaluation techniques	Behavioral observations. Diaries. Consumption or duration measurements	Behavioral observations. Diaries. Consumption or duration measurements	Previous, plus: Paired comparison. Sorting and matching. Limited preference. Ranking. One-on-one interviews	Previous, plus: Simple attribute ratings. Liking scales—pictorial or simple word scales. Group discussions. Concept testing	Previous, plus more abstract reasoning tasks. Hedonic scales. Discrimination tasks. Attribute scaling and ratings.	Capable of all adult evaluation techniques.
Adult involvement	Primary caregiver. Trained observer. Experimenter	Primary caregiver. Trained observer. Experimenter	Primary caregiver. Trained observer. Experimenter	Previous, plus: Self-administered	Previous, plus: Self - administered	Adult participation not required, unless appropriate to evaluation technique.

Children 3-12 years

The testing of children the age of 3 and above allows for more direct methods. Table 1-3 is a compilation of sensory testing protocol that could be used with children from preschoolers (3-5 years) to pre-teens (8-12 years).

A study by Kimmel and Guinard (1994) indicated that children as young as 4 years old could evaluate product by using a 7-point hedonic scale with descriptive categories of 1 = super bad and 7 = super good. Chen and others (1996) found that children 3 – 6 years of age were able to express their degree of liking of food samples using 3-, 5-, and 7-point hedonic scales anchored with the word 'super bad' and 'super good' respectively. Guinard (2000) had summarized published studies regarding children's ability to perform sensory testing methods at different ages. This review showed that children aged 4-5 are capable to do some discrimination tests such as paired comparison and ranking product in term of preference and rating products on hedonic scales. Children from 5-6 years are able to do more complex tasks such as scaling intensity and duo-trio or triangle tests. By the age of 8, children are capable of performing all standard sensory tests and also able to do the test by themselves with occasional help from experimenters.

Table 1-3 Appropriateness of sensory testing methods for use with children 2-10 years old (adapted from Guinard 2000)

Sensory test	**Age group (years)**			
	2-3	**4-5**	**6-7**	**8-10**
Discrimination				
Paired comparison	No	Yes	Yes	Yes
Duo-trio	No	No	Yes	Yes
Same-different	-[1]	Yes	Yes	Yes
Intensity ranking	No	Yes	Yes	Yes
Intensity scaling	-	-	Yes	Yes
Hedonic/Preference				
Paired preference	Yes	Yes	Yes	Yes
Preference ranking	-	Yes	Yes	Yes
Hedonic scales				
3-point	-	Yes	-	-
5-point	-	Yes	Yes	Yes
7-point	No	Yes	Yes	Yes
9-point	-	Yes	Yes	Yes

[1]No information for the test

Hedonic testing with children

Hedonic testing seems to be one of the most popular sensory test that used to determine level of children's acceptability of a product. Several forms of hedonic scales for children have been proposed, some using pictures, some using words, and some using a combination of pictures and words (Popper and Kroll 2007; ASTM 2003). Three examples of pictorial scales (often faces) are shown in Figure 1-1.

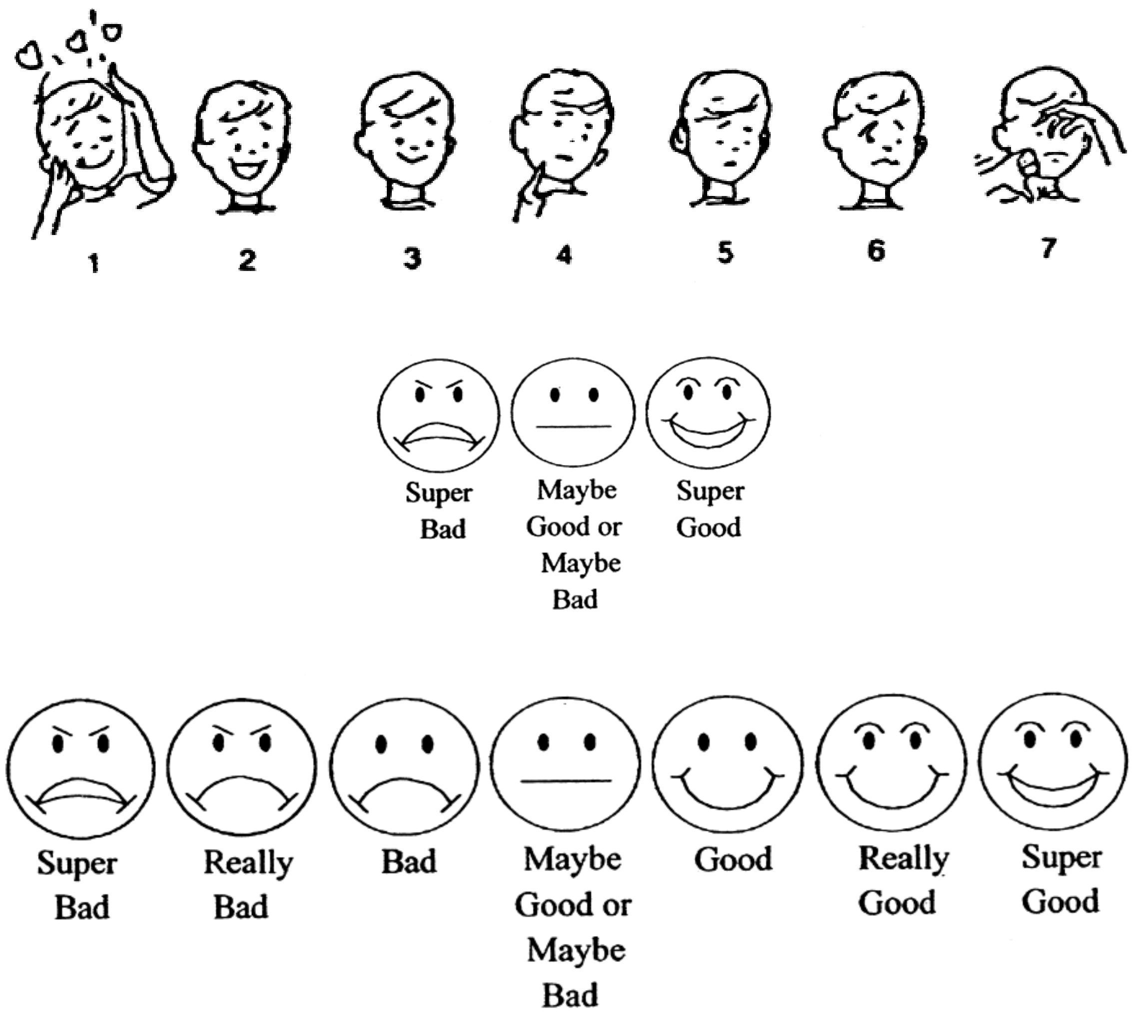

Figure 1-1 Examples of pictorial hedonic scales used for hedonic rating with children (Source: Guinard 2000)

Face scales are often used when conducting acceptability test with preliterate children because children at this level cannot read and may not fully understand complex words but may understand more about facial expression (Popper and Kroll 2005). However, Popper and Kroll (2007) indicated that the face that represent a degree of ‘dislike’ can be interpreted by children as ‘anger’, and the face that used to represent ‘liking’ can be interpreted by children as ‘happiness’. Therefore, children may choose the happy face because they like it better, rather than because it represents their opinion about the food that they taste (Popper and Kroll 2007). Cooper (2002) also indicated that eyes and mouth are important to the interpretation of facial expression and can lead to misinterpretations of the scales. In addition, there are cultural differences regard to the interpretation of facial expression. Curtain expressions may be appropriate in some cultures, but not in others (Cooper 2002).

Kroll (1990) developed a verbal liking scale for testing children, which has become known as the Peryam & Kroll (P&K) or the super good/super bad scale (Table 1-4). The scale is similar to the traditional 9-point hedonic scale, except the words at anchors. Verbal anchors for P&K are more child-friendly. The term ‘like extremely’ is replaced by ‘super good’, and the term ‘dislike extremely’ is replaced by ‘super bad’. Kroll also compared the effectiveness of several hedonic scale variations with children 5-10 years, and the results showed that a 9-point super good/super bad scale actually discriminate the products better than a 9-point face scale. This indicated that children do not uses face scale better than purely verbal scales.

Table 1-4 The traditional 9-point hedonic scale and P&K hedonic scale for children (Source: Popper and Kroll 2007)

Traditional 9-point hedonic scale	P&K hedonic scale for children
Like extremely	Super good
Like very much	Really good
Like moderately	Good
Like slightly	Just a little good
Neither like nor dislike	Maybe good or maybe bad
Dislike slightly	Just a little bad
Dislike moderately	Bad
Dislike very much	Really bad
Dislike extremely	Super bad

Sensory Analysis of Fortified Blended Foods

Descriptive Analysis

There are few studies on descriptive analysis of FBFs. Recently, Chanadang and others (2016) studied the tolerance of sorghum based fortified blended food by using sensory characteristics as an indication. In this study, the blend was made into porridge with variations in ingredients and cooking procedures. Thirty five sensory attributes (e.g. overall grain, toasted, lumpy, oily mouthfeel) were developed and used to describe the sensory properties of porridge from each variation. Results showed that sensory properties of sorghum based fortified blended food had high tolerance to variation in cooking procedures, and this was a good aspect for product use and development. Padmanabhan (2013) also did research on sensory characteristics of cooked porridge prepared from sorghum based fortified blended food Sorghum-soy blend (SSB), corn-soy blend (CSB) and whole-corn soy blend (WCSB), which were developed by extrusion process. This study aimed to evaluate fortified blended foods (FBFs) when prepared with an increased solids amount (from 11.75% to 20% solids), as recommended by Webb and others (2011) to increase energy density of the products. All blends were prepared as porridges at 11.75% and 20% solids content and evaluated by a highly trained panel on aroma, flavor, and texture characteristics. The scale used was an intensity scale with 0.5 increments from 0=none to 15=extremely high. The greatest differences between the 11.75% and the 20% solids were found in the texture of porridges. Thickness, particle amount, and lump size attributes fortified blended foods were all increased in the 20% solids porridges. Moreover, porridges at 20% solids content typically had an increase in starch and toasted flavor, and reduced sorghum or corn flavor compared to the products at 11.75% solids (Padmanabhan 2013).

Kehlet and others (2011) chose Quantitative Descriptive Analysis (QDA) to identify and quantify sensory properties of porridges prepared from original CSB and CSB with either skim milk powder (SMP) or whey protein concentrate (WPC). A trained panel developed a descriptive language and divided the sensory attributes into groups of odor, color, texture, flavor and taste. The original CSB was perceived as grayer in color, and more mealy/dry than CSB with milk proteins. The addition of milk protein increased the sweetness the CSB, which could be positive in terms of acceptability in children.

The flavor profile analysis technique was chosen to evaluate sensory properties of products prepared from CSB that had been extruded at different temperatures (155 and 171ºC). A highly train panel was used to describe the aroma, flavor and aftertaste associated with each product. The higher temperature of extrusion resulted in higher aroma and flavor amplitudes of the products

(Maga and Lorenz 1978). Deliza and others (1990) conducted a descriptive analysis on a new weaning food based on sweet corn dehydrated pulp by using 10 mothers as panelists because the products were to be used in infant feeding. The panelists developed 5 sensory attributes to describe the products including appearance, fresh corn flavor, off-flavor, consistency, and global impression. The scale used was a nine-point scale. The results of sensory evaluation shown that all 3 formulated products developed in this study were similar in most of sensory attributes except consistency. The product with higher content of dehydrated sweet corn pulp was found to be higher in consistency.

Consumer Studies

Rowe and others (2008) conducted a field study in Uganda, Malawi, and Guatemala to obtain data on preparation, and usage of fortified blended foods provided by the US Agency for International Development. The observational and interview data were collected from more than 100 households in 32 different villages spread across different regions of the three countries. Thin or thick porridges appeared to be the most common dishes prepared from cereal-based products, with a wide range of concentration from 10% to 31% (wt/wt) in water. Sugar, vegetable oil, and other seasoning were commonly added to the meals. Cooking times for porridges ranged from 5 to 53 minutes. Moreover, many private voluntary organizations that often implement child feeding program might provide recipes that vary in cooking procedures.

Wang and others (2013) conducted the study on the acceptability soy ready-to-use supplement food (RUSF) and a fortified corn-soy blend (CSB++) among children 6-59 months in Malawi. The acceptability level of each product was based on the frequency that children refused to eat the food. The higher frequency of refusal, the lower acceptability of the product. In overall, 27% of caregivers reported that their child “always” or “sometimes” refuse to eat the food and no significant difference in children’s acceptability between two supplementary product types were found.

Hedonic testing was used by Owusu-Kwarteng (2010) to determine consumers’ acceptability of Ghanaian fermented porridge (*Hausa koko*). The fermented porridges with variation in soybeans level were served to 20 untrained panelists, who are familiar with *Hausa koko*. They were asked to evaluate sensory qualities (taste, odor, color, texture, and overall acceptability) using a 9-point hedonic scale. Results showed that taste, odor and overall acceptability of porridges were significantly and negatively affected by the higher soybean content. Color significantly improved upon addition of soybeans whereas texture was not noticeably affected.

Amegovu and others (2014) conducted a study to determine acceptability of sorghum peanut blend (SPB) and corn soy blend plus (CSB+) among children 12-59 months in Uganda. In this study, caregivers were instructed to cook porridge from both products, tasted and fed their child at study location. A 5-point hedonic scale was used to evaluate the caretakers’ sensory preferences for the two supplementary diets. For children’s acceptability of prepared porridges, mother were ask to observe their child’s behavior while they were eating porridges and then ranked the children’s degree of liking based on their perception. The mother’s overall acceptability scores of the two products were very similar to children’s acceptability scores (based on mother’s perception), and porridge made from CSB+ appeared to have higher score than SPB.

Another example of consumer study related to FBFs was conducted in Burkina Faso to determine the acceptability of new formulations of corn soy blends (CSB) and lipid-based nutrient supplements (LNS) (Iuel-Brockdorf and others 2016). Children were randomized to one of the 12 different supplements. After one month of supplementation, caretakers were asked to report the acceptability of the supplements according to the child's reaction as perceived by the caretaker and caretaker's own perception, based on a 5-point hedonic scale. The results showed that LNS products were likely to be more acceptable by caretakers and children, probably due to the sweetness of the product and the perceived ease of use. Additionally, the quantity of left-over of each product was also use as indicator of product acceptability in this study. Caretakers of children who received CSB were more likely to report leftovers by the end of the day, compared to caretakers of children who received LNS, and this supported the acceptability resulted collected from hedonic testing.

Research objectives

Novel extruded FBFs were developed based on FQAR recommendations to improve their effectiveness on improving nutritional outcomes, and sensory properties are one of the important determinants for the success of the new FBFs. Therefore, the objective of this study was to use sensory analysis to determine the potential of novel FBFs to be used as supplementary food compared with FBF currently used in food aid programs.

Descriptive sensory analysis was conducted to estimate shelf life of novel FBFs. Acceptance and paired preference tests were conducted to determine children's acceptability and preference of novel FBFs. Moreover, one-on-one interview with caregivers who prepared the food for their child and household visits were performed in order to understand household level behaviors (i.e. cooking techniques, storage practices) of novel FBFs.

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Chapter 2 - Determination of Sensory Characteristics of Traditional and Novel Fortified Blended Foods Used in Supplementary Feeding Programs

Abstract

Despite the wide use of traditional non-extruded fortified blended food (corn soy blend plus; CSB+) in supplementary feeding programs, there is limited evidence of its effectiveness on improving nutritional outcomes. Fifteen novel extruded FBFs have been developed with the variations of processing techniques and ingredients in order to improve the quality of food aid products based on the Food Aid Quality Review (FAQR) recommendations. Descriptive sensory analysis had been performed to determine the effects of processing parameters and ingredients on sensory properties of FBFs. The extrusion process was the only processing parameter that affected aroma and flavor of tested products. FBFs from the extrusion process had more pronounced toasted characteristics due to the higher temperature during extrusion. Compositions of FBFs showed a significant impact on sensory properties of the products. The addition of sugar in novel FBFs could lead to a significant increase in sweetness. Levels of lipids in binary blends were mainly responsible for bitterness of the product. In addition, legumes, which were the primary ingredient, contributed to beany characteristics of the products. The higher amount of legume used in the formulations led to beany characteristics that could be perceived from the products.

Introduction

Food insecurity around the world is always increasing due to many causes, including growing population, poverty, and natural disaster (Hill and others 2007). The State of Food Insecurity in the world 2015 reported that approximately 795 million people in the world were undernourished in 2014-2016 (FAO 2015). Fortified blended foods (FBFs) were developed in the 1960s by the United States Agency for International Development (USAID) to provide a supplement to young children who suffered from moderate acute malnutrition in many developing countries around the world (Perez-Exposito and Klein 2009; de Pee and Bloem 2009). The most commonly distributed cereal based FBF by USAID is a Corn-Soy blend (CSB) which consisted of corn (75-80%) as a source of carbohydrate and soy (20-25%) as a source of protein. Although FBFs form an important part of the food aid ration, there is limited evidence of their abilities in treating young children with malnutrition (Perez-Exposito and Klein 2009; de Pee and Bloem 2009; Fleige and others 2010).

The Food Aid Quality Review (FAQR) in 2011 by Webb and others (2011) has recommended changing formulation of existing FBFs in order to improve their nutritional quality. These recommendations include adding animal-source protein to promote linear growth of children, increasing fat content through the addition of vegetable oil, adding a flavor enhancer to formulations to improve the acceptability of FBFs, and upgrading micronutrient compositions in FBFs. In addition, decortication of cereals and legumes used in FBFs is recommended in order to reduce fiber content and eliminate phenolic compounds that can reduce the energy intake, lower protein digestibility and mineral absorption (Fleige and others 2010).

Another recommendation from Webb and others (2011) was to increase the solids content of FBFs to 20% to increase nutrient content. However, porridge prepared from the current FBFs at this concentration is too viscous for consumption by infants and young children (Black and others 2009). Mothers normally add more water into porridge to make it more drinkable before feeding to their child, which results in a low nutritional value and energy density (Fleige and others 2010). Extrusion cooking of starchy ingredients for FBFs can result in less viscous cooked porridge, making them more ideal for delivering higher density energy meals at lower viscosities for infants and young children (Ozcan and Jackson 2005). Extruded products also require short cooking time and less fuel (Fleige and others 2010), which makes them more valuable for people with limited time and energy sources.

Webb and others (2011) also encouraged to explore new grains or legumes that could be used beyond the traditional FBFs – CSB and Wheat-Soy blend (WSB). Corn has been used as the main staple for current FBF because it is a good source of starch, plant-based protein, dietary fiber, B vitamins, and is available in bulk for the food aid program (USAID, 2015; Hoppe and others 2008). However, the high demand of corn for may uses especially for fuel production makes the prices increase (Tenenbaum 2008) and that directly affects food aid commodities. Heat-treated soy in full fat form or defatted flour is primarily used as a source of protein in FBFs. However, soy may contain high levels of anti-nutritional factors such as phytate and phytoestrogen with unknown long-tern health effects (Hoppe and others 2008).

Sorghum was looked at as a potential alternative ingredient in FBFs with a number of advantages over corn, including higher level of protein, fat, and some micronutrients when processed properly (Dicko and others 2006; Mahasukhonthachat and others 2010). Cowpea is also considered as an alternative legume that can be used in FBFs because of the high levels of protein, energy and other nutrients (Uzogara and Ofuya 1992). Sorghum and cowpea are cultivated and consumed as part of human foods in many parts of developing countries (Uzogara and Ofuya 1992;

Anglani 1998). Therefore, populations in those areas should be familiar with the flavor of sorghum and cowpea and that makes these good candidate for being used in FBFs. Moreover, both sorghum and cowpea are mostly non-genetically modified organism (GMO) crops, which allows them to be used in many countries that have banned the use of GMO products.

Based on the recommendations of FQAR, fifteen newly formulated, extruded FBFs varied in processing techniques and ingredients were developed. The objective of this study was to determine the effects of processing techniques (extrusion vs non-extrusion and milling types) and ingredients on sensory properties of the traditional and novel FBFs.

Materials and Methods

Sample

Fifteen novel extruded FBFs and one current-non extruded FBF were used in this study.

Novel extruded fortified blended foods

Fifteen possible extruded FBFs varied in milling types and ingredients were shown in Table 2-1.

The whole grains– sorghum variety V1 (Fontanelle 4525), V2 (738Y), V3 (217X Burgundy) (Nu Life Market, Scott City, KS, USA), and corn (Agronomy Foundation Seed, Kansas State University, Manhattan, KS, USA) were used for pilot milling at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA) to obtain whole and decorticated flours. Soybeans (Kansas River Valley Experiment Field, Kansas State University, Manhattan, KS, USA) and cowpea grains (LPD Enterprises LLC, Olathe, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA). Commercially milled whole and decorticated sorghum flour variety V1 were obtained from Nu Life Market, Scott City, KS, USA. Commercially milled degermed corn flour and whole corn flour were purchased from Agricor, Marion, Indiana, USA. Defatted soy flour was purchased from American Natural Soy, Cherokee, IA, USA.

The cereal/legume flours were blended. For sorghum-cowpea blends (n=7), three sorghum varieties flour, whole or decorticated, were mixed with cowpea flour. For sorghum-soy blends (n=5), sorghum variety V1, whole or decorticated, were mixed with low fat (1.85%) or medium fat (6.94%) or full fat (16.93%) soybean flour. For corn-soy blends (n=3), whole or degermed corn flour with medium fat and full fat soybean flour were used. All binary blends were extruded on a single screw extruder X-20 (Wenger Manufacturing Inc., Sabetha, KS, USA) at screw speed ranged from 500-550 rpm with 18-24% process moisture. The extrudates were cut at the die exit with face-mounted five blade rotary knife, and dried in Wenger double pass Dryer/Cooler (Series 4800, Wenger Manufacturing Inc., Sabetha, KS, USA) at 104°C for 10 minutes.

The dried extrudates were ground using a Schutte Buffalo Hammer mill (Buffalo, NY, USA). The ground binary blends were then mixed with sugar (Domino Foods, Inc., Yonkers, NY, USA), whey protein concentrate -WPC80 (Davisco Foods International, Inc., Eden Prarie, MN, USA), antioxidant (BHA, butylated hydroxyanisole and BHT, butylated hydroxytoluene), vitamins and minerals (Research Products Company, Salina, KS, USA) and non-gmo soybean oil (Zeeland Farm Services, Inc., Zeeland, MI, USA). The composition of all blends is shown in Table 2-2.

Table 2-1 List of processing and ingredients used for each extruded FBFs

Treatment	Product code[1]	Cereal			Legume
		Cereal type	**Variety**	**Milling type**	
1	SCB-V1 com	Sorghum - Decorticated	White-Fontanelle 4525	Commercial	Cowpea
2	SCB-V1	Sorghum - Decorticated	White-Fontanelle 4525	Pilot	Cowpea
3	SCB-V2	Sorghum - Decorticated	White-738Y	Pilot	Cowpea
4	SCB-V3	Sorghum - Decorticated	Red-217X Burgundy	Pilot	Cowpea
5	WSCB-V1	Sorghum - Whole	White-Fontanelle 4525	Pilot	Cowpea
6	WSCB-V2	Sorghum - Whole	White-738Y	Pilot	Cowpea
7	WSCB-V3	Sorghum - Whole	Red-217X Burgundy	Pilot	Cowpea
8	SS'B-V1 com	Sorghum - Decorticated	White-Fontanelle 4525	Commercial	Soybean – High Fat
9	WSSB-V1	Sorghum - Whole	White-Fontanelle 4525	Pilot	Soybean – Low Fat
10	WSS'B-V1 com	Sorghum - Whole	White-Fontanelle 4525	Commercial	Soybean – High Fat
11	WSS'B-V1 com (pre-anti)	Sorghum - Whole	White-Fontanelle 4525	Commercial	Soybean – High Fat
12	WSS"B-V1	Sorghum - Whole	White-Fontanelle 4525	Pilot	Soybean – Full Fat
13	CS'B com	Corn - Degermed		Commercial	Soybean – High Fat
14	WCS'B com	Corn - Whole		Commercial	Soybean – High Fat
15	WCS"B	Corn - Whole		Pilot	Soybean – Full Fat

[1] W=Whole, 1st S = Sorghum flour, 1st C = Degermed corn flour, 2st S = Low-fat soy flour; S' = Medium-fat soy flour; S" = Full-fat soy flour, 2st C = Cowpea flour, V1&V2 = White variety of sorghum, V3 = Red variety of sorghum, com = Commercial milling, (pre-anti) = Antioxidant had been added to the binary blend before extrusion process

Table 2-2 Composition of extruded FBFs and non-extruded FBFs.

Ingredients (%)	Extruded FBFs[1]			Non-extruded FBF
	Sorghum-Cowpea blends (SCB; n=7)	Sorghum-Soy blends (SSB; n=5)	Corn-Soy blends (CSB; n=3)	Corn soy blend plus (CSB+)
Sorghum flour	24.7	47.6		
Cowpea flour	38.6			
Corn flour			48.1	
Corn (White or Yellow)				78.5
Whole soybeans				20.0
Soy flour		15.7	15.2	
Sugar	15.0	15.0	15.0	
Whey Protein Concentrate (WPC80)	9.5	9.5	9.5	
Soybean oil	9.0	9.0	9.0	
Vitamin & Mineral Premix	3.2	3.2	3.2	
Vitamin/Mineral				0.2
Tri-Calcium Phosphate				1.2
Potassium Chloride				0.2

[1] For extruded FBFs, SSB and CSB with full-fat soy, WPC80 was increase from 9.5% to 13.0% and soybean oil was decreased from 9% to 5.5%.

Current non-extruded fortified blended food

Corn soy blend plus (CSB+) was produced by Bunge Milling (St. Louis, MO, USA) according to the USDA commodity requirements (USDA 2014) (Table 2-2).

Sample preparation

All products were prepared into porridges which are the most common dishes prepared from cereal-based commodities for children in developing countries (Rowe and others 2008; Moussa and others 2011; Chanadang and others 2016), with 20% solids content according to the recommendation from Webb and others (2011).

A weighted FBF flour (200 g) was mixed with cold water (400 mL) to prevent the formation of lump. The mixture was then added to boiling water (400 mL.), brought back to a boil, cooked with continuous stirring with a wooden spoon for 2 minutes for extruded FBFs and 10 minutes for non-extruded FBF. The sample was removed from the stovetop and cooled to the temperature of 45°C which is the typical consumption temperature by infant and young children (Mouquet and others 2006).

Descriptive sensory analysis

Descriptive sensory analysis was conducted by six highly-trained panelists at the Center for Sensory Analysis and Consumer Behavior, Manhattan, Kansas USA. All of these panelists had completed 120 h of general descriptive analysis panel training, and over 2000 h of evaluation experience with a wide array of food products including cereal-based products.

Sixteen sensory attributes, including 6 aroma and 10 flavor, were evaluated in all samples (Table 2-3). Ten out of sixteen attributes were published in Chanadang and others (2016).

Fifty grams of each prepared porridge was served in a 4 oz styrofoam cup (Dart container corporation, Mason, MI, USA) and labeled with a three-digit code to each panelist. All samples were evaluated on a numerical scale of 0-15 with 0.5 increments where 0 represents none and 15 represents extremely high. The samples were prepared and evaluated in triplicate in a randomized order.

Data analysis

Sixteen sensory attributes were evaluated for all porridge samples, however, panelists did not detect rancid and painty characteristics in all samples. Therefore, twelve sensory attributes beside rancid and painty characteristics were reported and analyzed in this study.

Data for each sensory attribute was analyzed by a one-way ANOVA mixed effect model (SAS version 9.4, The SAS Institute Inc., Cary, NC,USA) using PROC GLIMMIX to determine significant differences ($p \leq 0.05$) among porridge samples. Tukey's HSD test was used at the 5% level of significance to locate significant effect of sample on each sensory property. Principal component analysis (PCA) was performed in order to visualize the relationship among sensory attributes and samples using XLStat version 2015.3.01 (Addinsoft, New York, NY, USA).

Table 2-3 Aroma and flavor attributes, definitions, and references for descriptive analysis of porridge prepared from FBFs

Attribute	Definition	Reference[¥]
Aroma		
Overall Grain*	A general term used to describe the aromatics which includes musty, dusty, slightly brown, slightly sweet and is associated with harvested grains and dry grain stems.	Cereal Mix(dry) = 7.5. Preparation: Mix ½ cup of each General Mills Rice Chex, Wheaties and Quaker Quick Oats. Put in a blender and "pulse" blend into small particles. Serve 2 Tablespoon in a 12 oz brandy snifter, covered with a watch glass.
Toasted*	A moderately browned/baked impression	Crushed Post Shredded wheat = 2.5. Preparation: Crushe ¼ cup of Shredded wheat and served in a 12 oz brandy snifter, covered with a watch glass. Crushed General Mills Cheerios = 7.0. Preparation: Crushe ¼ cup of Cheerios and serve in a 12 oz brandy snifter, covered with a watch glass.
Beany	Aromatic characteristic of beans and bean products, includes musty/earthy, musty/dusty, sour aromatics, bitter aromatics, starchy and green/pea pod, nutty or brown.	Cooked Soy Bean = 4.0.Preparation: Soak ½ cup of soy bean overnight and boil the bean 2.5 hours. Serve 1 table spoon of cooked soy bean in a 12 oz brandy snifter, covered with a watch glass. Bush Pinto Beans (canned) = 7.0. Preparation: Drain beans and rinse with de-ionized water Place one table spoon in a 12 oz brandy snifter, covered with a watch glass.
Musty Overall*	A combination of one or more aromatic impressions characterized to some degree as being somewhat dry, dusty, damp, earthy, stale, sour, or moldy. If identifiable, attribute will be listed.	1,2,4Trimethoxybenzene 50,000 ppm = 4.0. Preparation: Dip an Orlandi Perfumer Strip #27995 2.2cm (second marking line) into solution and place dipped end up in a Fisherbrand Disposable Borosilicate Glass Tubes with Threaded End (15x150mm), cap.

Rancid	A somewhat heavy aromatic characteristic of old, oxidized, decomposing fat and oil. The aromatics may include painty, varnish, or fishy.	Microwaved Wesson vegetable oil (4 min at high) = 2.5. Preparation: Microwave 1 ½ cups oil on high power for 4 minutes. Let cool and serve ¼ cup in a 12 oz brandy snifter covered with a watch glass. Microwaved Wesson vegetable oil (5 min at high) = 5.0. Preparation: Microwave 1 ½ cups oil on high power for 5 minutes. Let cool and serve ¼ cup in a 12 oz brandy snifter covered with a watch glass.
Painty	The aromatic associated with rancid oil and fat, typically in the late stages of rancidity.	Microwaved Wesson vegetable oil (4 min at high) = 2.5. Preparation: Microwave 1 ½ cups oil on high power for 4 minutes. Let cool and pour into 1 oz cups. Serve covered. Microwaved Wesson vegetable oil (5 min at high) = 4.5. Preparation: Microwave 1 ½ cups oil on high power for 5 minutes. Let cool and pour into 1 oz cups.
Flavor		
Overall Grain*	A general term used to describe the light dusty/musty aromatics associated with grains such as corn, wheat, bran, rice, oats and soybean.	Cereal Mix (dry) = 8.0. Preparation: Mix ½ cup of each General Mills Rice Chex, Wheaties and Quaker Quick Oats. Put in a blender and "pulse" blend into small particles. Serve in 1 oz cup.
Toasted*	A moderately browned/ baked impression.	Post Shredded Wheat (Spoon size) = 3.5. Preparation: Serve in 3.25 oz cup. General Mills Cheerios = 7.0. Preparation: Serve in 3.25 oz cup.

Beany	Aromatic characteristic of beans and bean products, includes musty/earthy, musty/dusty, sour aromatics, bitter aromatics, starchy and green/pea pod, nutty or brown.	Cooked Soy Bean = 4.0.Preparation: Soak ½ cup of soy bean overnight and boil the bean 2.5 hours. Serve in 1 oz cup. Bush Pinto Beans (canned) = 7.5. Preparation: Drain beans and rinse with de-ionized water Serve in 1 oz cup.
Musty*	Aromatics associated with wet grain and damp earth.	Cooked American Beauty elbow macaroni = 5.0. Preparation: Bring 3 cups water to a rapid boil. Add 1 cup pasta & stir, returning to a rapid boil. Cook 6 minutes, stirring occasionally. Drain and place into 3.25oz cups.
Rancid	A somewhat heavy aromatic characteristic of old, oxidized, decomposing fat and oil. The aromatics may include painty, varnish, or fishy.	Microwaved Wesson vegetable oil (4 min at high) = 3.0. Preparation: Microwave 1 ½ cups oil on high power for 4 minutes. Let cool and serve in 1 oz cup. Microwaved Wesson vegetable oil (5 min at high) = 5.0. Preparation: Microwave 1 ½ cups oil on high power for 5 minutes. Let cool and serve in 1 oz cup.
Painty	The aromatic associated with rancid oil and fat, typically in the late stages of rancidity.	Microwaved Wesson vegetable oil (4 min at high) = 0.0. Preparation: Microwave 1 ½ cups oil on high power for 4 minutes. Let cool and serve in 1 oz cup. Microwaved Wesson vegetable oil (5 min at high) = 3.0. Preparation: Microwave 1 ½ cups oil on high power for 5 minutes. Let cool and serve in 1 oz cup.

Sweet*	A fundamental taste factor of which sucrose is typical.	2% Sucrose Solution = 2.0 4% Sucrose Solution = 4.0
Salt*	Fundamental taste factor of which sodium chloride is typical.	0.15% Sodium Chloride Solution = 1.5 0.20% Sodium Chloride Solution = 2.5
Bitter*	The fundamental taste factor associated with a caffeine solution.	0.01% Caffeine Solution = 2.0 0.02% Caffeine Solution = 3.5 0.035% Caffeine Solution = 5.0 0.05% Caffeine Solution = 6.5
Astringent*	The drying, puckering sensation on the tongue and other mouth surfaces.	0.050% alum solution = 2.5 0.100% alum solution = 5.0

¥ 0 to 15 – point numeric scale with 0.5 increments was used to rate the intensities of the sample and references.
* From Chanadang and others (2016).

Results and Discussion

The results showed that six out of twelve sensory attributes were significantly different among porridge samples ($p \leq 0.05$), including toasted and beany aroma and flavor, sweetness, and bitterness (Table 2-4).

Porridges prepared from extruded FBFs appeared to be higher in toasted aroma and flavor than non-extruded FBF (CSB+), although, not all extruded FBFs were significantly different from CSB+ in this sensory characteristic ($p > 0.05$). High temperature used in extrusion process might be the main reason for the increased toasted characteristic in extruded FBFs. Extrusion cooking of cereal normally involves thermally induced reactions, including the Maillard reaction that could generate chemical compounds that correspond to desirable aroma and flavor of the products (Bredie and others 1998; Bredie and others 2002). Parker and others (2000) reported that extruded cereal samples with high levels of Maillard reaction products, such as pyrazines and sulfur-containing alicyclic compounds, were generally described as having desirable toasted or roasted cereal aroma and flavor.

Besides processing technique, composition of FBFs seemed to be another important factor that affected sensory properties of the products. Porridges prepared from sorghum-cowpea blends, especially WSCB-V3, had significantly higher intensity in beany aroma and flavor ($p \leq 0.05$) than the ones prepared from sorghum-soy and corn-soy blends. Beany characteristics are often found in legume-containing products and are attributed to the action of the lipoxygenase enzyme, which catalyzes the lipid oxidation of linolenic and linoleic fatty acids (Sessa 1979; Kobayashi and others 1995). Since all products in this study contained legumes (either soybeans or cowpea), the difference intensity in beany characteristics among products was primarily due to the amount of legume used in each blend. This probably explained why sorghum-cowpea blends with higher amounts of legume (38.6% cowpea) were higher in beany aroma and flavor.

The variety of sorghum used in FBFs might be another factor that affected beany property of the products. The blend containing whole red sorghum flour (WSCB-V3) was significantly higher in beany flavor than the rest of FBFs, except the one that contained decorticated red sorghum flour (SCB-V3). Vara-Ubol and others (2004) indicated that beany was considered as a combination of attributes, including musty/dusty, musty/earthy, sour aromatics, and characterizing attributes such as green/pea pod, nutty or brown. Red sorghum varieties were reported to have higher dusty flavor (Brannan and others 2001) and porridges made with red sorghum were also reported to have higher overall flavor intensity (Anyango and others 2011). FBFs with red sorghum variety in this study might be higher in dusty flavor or overall intensity, and that resulted in an increased intensity of beany characteristics.

Porridges prepared from various FBFs were also significantly different in sweetness ($p \leq 0.05$). As expected, extruded FBFs with the addition of 15% sugar were significantly higher in sweetness than the traditional non-extruded FBF (CSB+) ($p \leq 0.05$). The addition of sugar into the FBFs formulation was not only to provide energy, but could also to increase the palatability and consumption of the products (Webb and others 2011). Iuel-Brockdorf and others (2016) also found that products with a sweeter flavor received better ratings in term of child and caregiver acceptability.

Salt was significantly different among FBFs porridges ($p \leq 0.05$), however, it was only a small difference (lower than 0.5 points on a 15 point scale). The higher intensity of salt in extruded FBFs was probably due to the higher amount of vitamin and mineral premix that had been added into the formulation.

Table 2-4 Mean scores[1] (Standard error) of sensory attributes for porridges prepared from FBFs

Treatment[2]	Overall Grain (a)[3]	Toasted (a)	Beany (a)	Musty Overall (a)	Overall Grain (f)	Toasted (f)	Beany (f)	Musty (f)	Sweet (f)	Salt (f)	Astringent (f)	Bitter (f)
SCB-V1 com	7.14 (0.07)	3.53^{ab}[4] (0.18)	3.28^{abc} (0.19)	3.36 (0.16)	7.36 (0.07)	2.97^{abc} (0.20)	3.58^{bcd} (0.15)	4.47 (0.15)	2.11^{a} (0.16)	1.42^{ab} (0.15)	2.64 (0.17)	2.89^{d} (0.18)
SCB-V1	7.17 (0.07)	3.89^{ab} (0.29)	3.28^{abc} (0.24)	3.11 (0.21)	7.36 (0.10)	3.28^{abc} (0.27)	3.64^{bc} (0.24)	4.36 (0.22)	2.03^{a} (0.15)	1.39^{ab} (0.15)	2.81 (0.25)	3.17^{bcd} (0.18)
SCB-V2	7.25 (0.08)	4.47^{a} (0.23)	3.19^{abc} (0.13)	3.17 (0.18)	7.42 (0.09)	3.22^{abc} (0.16)	3.64^{bc} (0.16)	4.33 (0.21)	2.00^{a} (0.19)	1.31^{ab} (0.14)	2.81 (0.15)	3.08^{cd} (0.20)
SCB-V3	7.22 (0.07)	4.53^{a} (0.30)	3.36^{ab} (0.19)	2.94 (0.19)	7.36 (0.09)	3.75^{a} (0.31)	4.19^{ab} (0.14)	4.69 (0.22)	1.97^{a} (0.12)	1.58^{a} (0.20)	2.68 (0.19)	3.31^{bcd} (0.13)
WSCB-V1	7.11 (0.08)	4.28^{ab} (0.18)	3.25^{abc} (0.19)	3.19 (0.18)	7.39 (0.08)	3.50^{ab} (0.23)	3.50^{bcde} (0.17)	4.58 (0.23)	2.00^{a} (0.10)	1.58^{a} (0.15)	2.78 (0.18)	3.28^{bcd} (0.20)
WSCB-V2	7.22 (0.07)	3.83^{ab} (0.24)	3.14^{abc} (0.18)	3.06 (0.18)	7.44 (0.08)	3.11^{abc} (0.23)	3.64^{bc} (0.18)	4.75 (0.22)	2.03^{a} (0.12)	1.50^{ab} (0.16)	2.72 (0.19)	2.97^{d} (0.19)
WSCB-V3	7.19 (0.07)	3.67^{ab} (0.23)	3.89^{a} (0.17)	3.44 (0.21)	7.33 (0.08)	3.33^{abc} (0.27)	4.44^{a} (0.19)	4.39 (0.24)	2.06^{a} (0.14)	1.47^{ab} (0.20)	2.83 (0.23)	3.36^{bcd} (0.20)
SS'B-V1 com	6.92 (0.10)	3.56^{ab} (0.21)	2.72^{bc} (0.21)	3.47 (0.22)	7.17 (0.07)	2.75^{abc} (0.11)	3.19^{cde} (0.10)	4.75 (0.18)	1.89^{a} (0.14)	1.31^{ab} (0.13)	2.97 (0.19)	3.31^{bcd} (0.17)
WSSB-V1	6.92 (0.06)	2.97^{b} (0.14)	2.69^{bc} (0.21)	3.19 (0.20)	7.19 (0.08)	2.36^{c} (0.13)	3.39^{cde} (0.21)	4.94 (0.25)	1.97^{a} (0.17)	1.58^{a} (0.18)	2.75 (0.13)	3.47^{bcd} (0.14)
WSS'B-V1 com	7.03 (0.16)	3.72^{ab} (0.21)	2.61^{bc} (0.16)	3.22 (0.18)	7.14 (0.17)	2.69^{bc} (0.14)	3.11^{cde} (0.15)	4.69 (0.21)	2.17^{a} (0.18)	1.44^{ab} (0.18)	2.67 (0.17)	3.22^{bcd} (0.18)
WSS'B-V1 com (pre-anti)	7.06 (0.08)	3.58^{ab} (0.19)	2.75^{bc} (0.18)	3.36 (0.13)	7.19 (0.06)	3.00^{abc} (0.16)	3.28^{cde} (0.16)	4.72 (0.18)	1.94^{a} (0.15)	1.44^{ab} (0.15)	2.86 (0.18)	3.31^{bcd} (0.21)
WSS''B-V1	7.00 (0.07)	3.00^{b} (0.17)	2.56^{c} (0.18)	3.75 (0.20)	7.25 (0.09)	2.50^{bc} (0.16)	3.17^{cde} (0.18)	4.94 (0.21)	1.86^{a} (0.08)	1.64^{a} (0.18)	3.06 (0.19)	3.81^{abc} (0.19)
CS'B com	6.94 (0.09)	3.89^{ab} (0.22)	2.64^{bc} (0.11)	3.28 (0.18)	7.19 (0.12)	2.53^{bc} (0.14)	3.03^{cde} (0.14)	4.42 (0.27)	2.03^{a} (0.17)	1.47^{ab} (0.17)	2.72 (0.23)	3.58^{bcd} (0.17)
WCS'B com	7.08 (0.14)	4.22^{ab} (0.24)	2.58^{bc} (0.16)	3.22 (0.19)	7.17 (0.11)	3.19^{abc} (0.19)	2.89^{de} (0.10)	4.50 (0.19)	2.11^{a} (0.19)	1.67^{a} (0.19)	2.67 (0.22)	3.89^{ab} (0.20)
WCS''B	7.03 (0.10)	4.50^{a} (0.24)	2.64^{bc} (0.18)	3.17 (0.14)	7.06 (0.07)	3.03^{abc} (0.14)	2.89^{de} (0.17)	4.75 (0.23)	1.89^{a} (0.21)	1.69^{a} (0.21)	3.08 (0.18)	4.53^{a} (0.20)
CSB+	7.33 (0.11)	2.97^{b} (0.20)	2.75^{bc} (0.19)	3.22 (0.15)	7.17 (0.11)	2.36^{c} (0.10)	2.83^{e} (0.15)	4.36 (0.18)	0.86^{b} (0.13)	1.14^{b} (0.13)	2.28 (0.14)	3.39^{cde} (0.18)

[1] Scores are based on a 0-15-point numeric scale with 0.5 increment (O=none and 15=extremely high). Each mean score intensity is calculated from six panelists with three replicate.
[2] W=Whole, 1st S = Sorghum flour, 1st C = Degermed corn flour, 2st S = Low-fat soy flour; S' = Medium-fat soy flour; S" = Full-fat soy flour, 2st C = Cowpea flour, V1&V2 = White variety of sorghum, V3 = Red variety of sorghum, com = Commercial milling, (pre-anti) = Antioxidant had been added to the binary blend before extrusion process.
[3] (a)=Aroma, (f)=Flavor
[4] Average for each parameter with different letter in the same column were significantly different ($p \leq 0.05$) between treatments.

Porridge prepared from binary blends with higher levels of lipids like whole corn with full-fat soybean blend (WCS"B) was significantly higher in bitterness than most of FBFs porridges ($p \leq 0.05$). The high temperature used in the extrusion process could have accelerate the degradation of lipids and the degraded lipids appeared to be associated with unpleasant flavors, such as astringent, bitter, and rancid (Rackis and others 1979; Bredie and others 1998; Drewnowski and Gomez-Carneros 2000). WCS"B with high levels of lipid was more likely to have higher amount of degraded lipid after the extrusion process and that could result in the higher bitter taste of the cooked porridge.

Principal component analysis (PCA) of twelve sensory attributes helped to visualize the differences among porridge samples (Figure 2-1). PC1 accounted for 38.79% of the variation, and seemed to differentiate among samples according to beany, toasted, grain, musty, and bitter attributes. PC2 accounted for 25.39% of the variation, and seemed to differentiate among samples according to flavor attributes, including astringency, sweetness, and saltiness. Current non-extruded FBF (CSB+) was separated from extruded FBFs due to the lower intensity in sweetness, saltiness, and astringency. Extruded corn-soy blends and extruded sorghum-soy blends were grouped together and had more pronounced bitter and musty attributes. As previously mentioned, the extruded products containing higher amount of lipids could be more bitter because of the high possibility of having more degraded lipids. Phenolic compounds, which can be found in sorghum, are also responsible for the bitterness of many foods and may cause a negative effect on products' acceptability (Drewnowski and Gomez-Carneros 2000; Kobue-Lekalake and others 2007). Therefore, the higher amount of sorghum (47.6% sorghum) used in sorghum-soy blends formulations was probably another reason that made the blends were more bitter.

All extruded sorghum-cowpea blends were grouped together. They were mainly characterized by toasted, grain, and beany attributes. Sorghum-cowpea binary blend that is used to make extruded sorghum-cowpea blends had lower levels of lipids compared to sorghum-soy and corn-soy binary blends (Joseph 2016). Feng and Lee (2014) reported that during extrusion lipid worked as a lubricant, and decreased temperature in the extruder barrel. The lower amount of lipids in sorghum-cowpea blend contributed to higher friction between the particle in the mix and between screw surface, and directly related to higher temperature in the extruder barrel. The higher temperature during the extrusion process could probably generate higher levels of chemical compounds from the Maillard reaction, which were responsible for desirable attributes, such as cereal-like, toasted, or roasted aromas (Bredie and others 1998; Parker and others 2000).

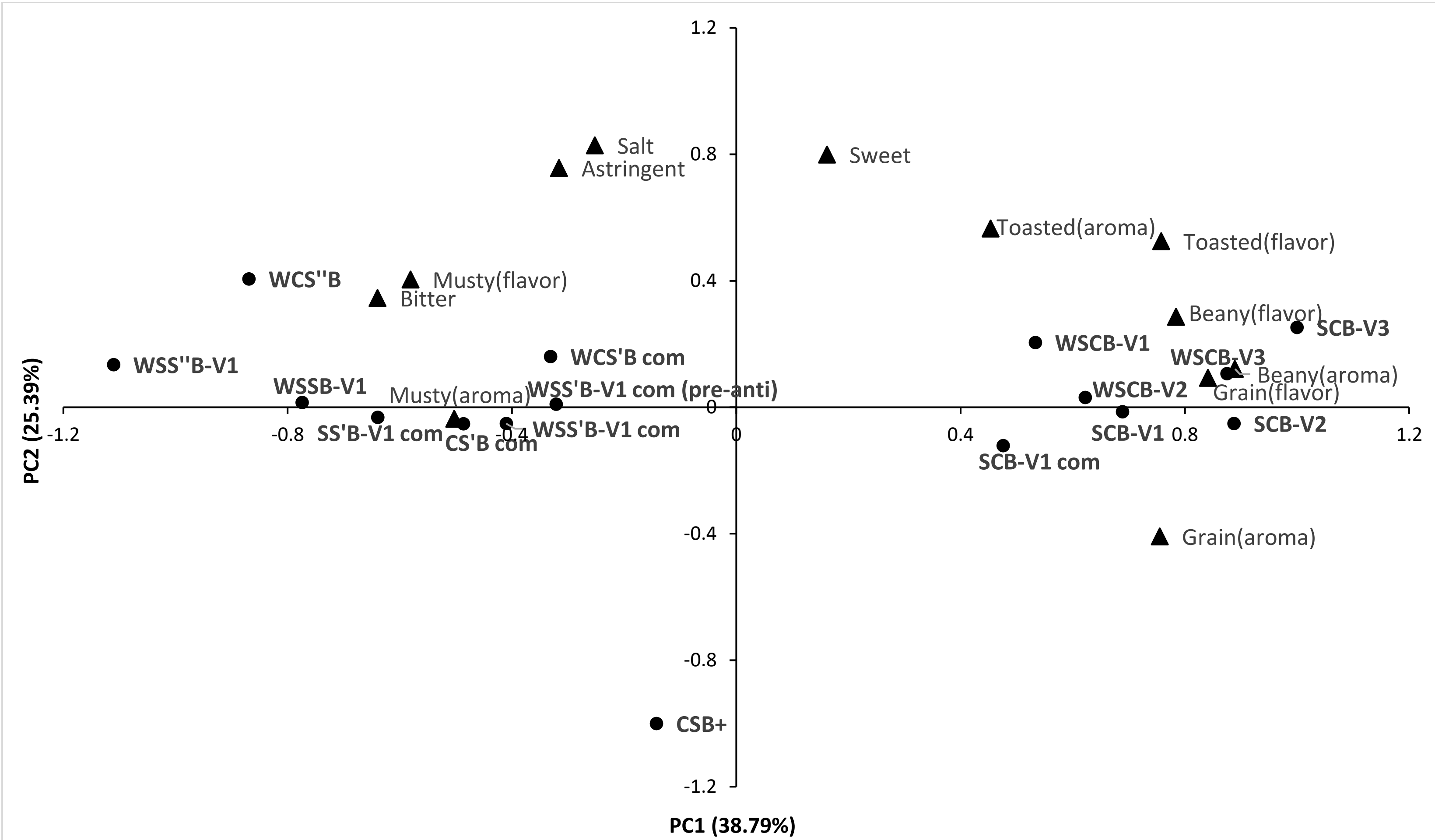

Figure 2-1 Principal component analysis of the porridges prepared from FBFs and sensory attributes.

For the FBFs, W=Whole, 1st S = Sorghum flour, 1st C = Degermed corn flour, 2st S = Low-fat soy flour; S' = Medium-fat soy flour; S'' = Full-fat soy flour, 2st C = Cowpea flour, V1&V2 = White variety of sorghum, V3 = Red variety of sorghum, com = Commercial milling, (pre-anti) = Antioxidant had been added to the binary blend before extrusion process. CSB+ represents the control sample (current non-extruded FBF).

Conclusions

The result from this study clearly identified the effects of processing techniques and ingredients used on sensory properties of the products. FBFs from the extrusion process had more pronounced toasted characteristics due to the higher temperature during extrusion. Types of milling, decortication process and the step of adding antioxidant to the blends did not show effects on sensory properties of FBFs in this study. Adding sugar and increasing the amount of vitamin-mineral premix into FBFs formulation could increase sweetness and saltiness of the products, respectively. The levels of lipids in binary blends was mainly responsible for bitterness of the product. In addition, legumes, such as soybean and cowpea were the main ingredient that contributed to beany characteristics of the products. The higher amount of legume used in the formulations, the more beany characteristics that could be perceived from the products.

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Chapter 3 - Shelf Life Estimation of Novel Fortified Blended Foods under Accelerated and Real-time Storage Conditions

Abstract

Fortified blended foods (FBFs) must maintain their desired characteristics for long periods of storage due to the variability of transportation, distribution, and consumption. This study was conducted to estimate the shelf life of FBFs, including a traditional FBF (CSB+) and 13 possible novel extruded FBFs. All products were stored under accelerated and real time environments. The real time shelf life (RT) testing was set at 30°C and 65% RH, which was the representative condition of the expected location of product use. The accelerated shelf life (ASLT) testing was set at 50°C and 70% RH based on the Q_{10} factor of 2. Products were made into porridges and evaluated by a highly trained descriptive panel for 5 time points in each shelf life condition. Rancid characteristic was used as the key determining factor for the shelf life of products. RT and ASLT testing agreed that most novel extruded FBFs could have shelf lives of at least 2 years, which were comparable to the current non-extruded FBF (CSB+). However, ASLT testing failed to predict real time shelf life of two novel FBFs (SCB-V3 and WCS"B), which were estimated by RT testing to have shelf life longer than 2 years. This result indicated that most novel extruded FBFs have a high potential to be used successfully as alternative complementary food with the capability to maintain their quality for the long period of storage. Additionally, it is essential to conduct RT testing paralleled with ASLT testing, especially for the new products, in order to obtain a more precise estimation of products' shelf lives.

Introduction

Fortified blended foods (FBFs) have been used as complementary foods for vulnerable populations in many low-income countries (Perez-Exposito and Klein 2009; Fleige and others 2010). Although FBFs have been widely used in food aid programs for more than four decades, minimal changes have been made to their formulations. Moreover, these products do not perform well in the prevention of malnutrition or promote growth since they contain inadequate micronutrients and a low level of essential fatty acids and fats (Fleige and others 2010). Therefore, several recommendations have been suggested in order to improve the nutritional value of FBFs, such as increasing fat content, upgrading micronutrient compositions, and adding a flavor enhancer (Webb and others 2011). By following these recommendations, it is essential to ensure that the new formulated FBFs are able to maintain their desired characteristics for long period of storage due to uncertainties of shipping, distribution, storage conditions and consumption. A shelf life of 18 months is the requirement for this product category (USDA 2014).

Shelf life has been defined by the Institute of Food Science and Technology (IFST) Guidelines (IFST 1993) as "the time during which a food product remains safe; be certain to retain desired sensory, chemical, physical, microbiological and functional characteristics; and comply with any label declaration of nutritional data when stored under the recommended conditions". For many foods, their shelf life can be determined by the changes in microbiological characteristics without the need of sensory analysis (Lawless and Heymann 2010; Hough and Garitta 2012). However, the changes in sensory properties are used as a key determining factor for the shelf life of many foods that tend to be tolerant to microbiological changes such as baked goods and flour (Lawless and Heymann 2010).

Sensory shelf life estimation can be performed using any of the three major kinds of sensory testing, including discrimination, descriptive, or affective methodologies, depending on the objective of the study (Kilcast 2000). One of the popular approaches for sensory shelf life estimation is descriptive sensory analysis (Hough and Garitta 2012; Giménez and others 2012). This technique can be performed by measuring the intensity of the critical attributes throughout the storage and the shelf life of food can be estimated at the time that the intensities of critical attributes reach a predetermined value (Lawless and Heymann 2010). Several studies used oxidative-related sensory attributes, such as rancid, oxidized oil, and painty, as a key determining factor for shelf life of products that contained fat or lipid (Nielsen and others 1997; Keogh and others 2001; Nattress and others 2004; Chanadang and others 2016). However, critical sensory characteristics are not limited to only oxidation-related sensory attributes. While Lareo and others (2009) and Rocha and Morais (2003) estimated the shelf life of lettuce and apple based on changes in visual appearance, texture was used as a critical attribute for estimating shelf life of a rice snack (Siripatrawan and Jantawat 2008).

There are two methods for conducting shelf life studies, Real Time testing (RT) and Accelerated Shelf Life Testing (ASLT) (Rumpf 2007; Patra 2016). For RT testing, products have to be stored under actual environmental conditions and checked at regular intervals to determine the time they begin to deteriorate (Patra 2016). RT testing is an uncomplicated method and does not require additional calculation, however, it is more suitable for perishable food products that normally have short shelf lives (Patra 2016). ASLT has been developed and used to estimate the shelf life of food products that can last for several months or perhaps years, in order to minimize the cost and time of the study (Robertson 2009). ASLT requires that products are stored under extreme conditions, thus products are expected to reach the stage of failure in a shorter than normal time. This method has been widely used in the pharmaceutical industry, but it is not well accepted in the food industry, partly due to the insufficient basic data on the effect of extrinsic factors on the deteriorative rate (Robertson 2009). The ASLT model that has been successfully used to predict shelf life for one product may not be applicable for other similar products in the same category, since they may have different types of deterioration reactions (Kilcast 2000). Therefore, ASLT testing must be used with caution and should be validated the results with RT testing (Kilcast 2000; Magari 2003).

In this study, newly formulated FBFs had been developed based on the Food Aid Quality Review (FAQR) recommendations. These new FBFs are expected to have a long shelf life in order to be successfully used as complementary foods in various remote areas. Therefore, the objective of this study was to estimate the shelf life of novel FBFs under real time and accelerated storage conditions. Sensory attributes were used as the key factors to determine their shelf lives in both testing conditions. The validity of using ASLT to predict the shelf life of FBFs in comparison to using RT testing was also investigated.

Materials and Methods

Samples

Thirteen possible variations of extruded FBFs and one traditional non-extruded FBF were used in this study (Table 3-1).

Table 3-1 List of processing and ingredients used for each extruded FBFs

	Treatment	Product code	Cereal			Legume
			Cereal type	**Variety**	**Milling type**	
Extruded FBF[1]	1	SCB-V1 com	Sorghum - Decorticated	White-Fontanelle 4525	Commercial	Cowpea
	2	SCB-V1	Sorghum - Decorticated	White-Fontanelle 4525	Pilot	Cowpea
	3	SCB-V2	Sorghum - Decorticated	White-738Y	Pilot	Cowpea
	4	SCB-V3	Sorghum - Decorticated	Red-217X Burgundy	Pilot	Cowpea
	5	WSCB-V1	Sorghum - Whole	White-Fontanelle 4525	Pilot	Cowpea
	6	WSCB-V2	Sorghum - Whole	White-738Y	Pilot	Cowpea
	7	WSCB-V3	Sorghum - Whole	Red-217X Burgundy	Pilot	Cowpea
	8	SS'B-V1 com	Sorghum - Decorticated	White-Fontanelle 4525	Commercial	Soybean – High Fat
	9	WSSB-V1	Sorghum - Whole	White-Fontanelle 4525	Pilot	Soybean – Low Fat
	10	WSS'B-V1 com (pre-anti)	Sorghum - Whole	White-Fontanelle 4525	Commercial	Soybean – High Fat
	11	WSS"B-V1	Sorghum - Whole	White-Fontanelle 4525	Pilot	Soybean – Full Fat
	12	CS'B com	Corn - Degermed		Commercial	Soybean – High Fat
	13	WCS"B	Corn - Whole		Pilot	Soybean – Full Fat
Non-Extruded FBF	14	CSB+[2]	Corn			Soybean - Whole

[1] W=Whole, 1st S = Sorghum flour, 1st C = Degermed corn flour, 2st S = Low-fat soy flour; S' = Medium-fat soy flour; S" = Full-fat soy flour, 2st C = Cowpea flour, V1&V2 = White variety of sorghum, V3 = Red variety of sorghum, com = Commercial milling, (pre-anti) = Antioxidant had been added to the binary blend before extrusion process.

[2] CSB+ = Corn Soy blend plus.

Extruded FBFs

All extruded FBFs were formulated based on FAQR requirements (Webb and others 2011) (Table 3-2).

White sorghum flour – Variety V1 (Fontanelle 4575) as whole and decorticated was obtained from commercial source (Nu Life Market, Scott City, Kansas, USA). Corn flour as whole and degermed was purchased from Agricor, Marion, Indiana, USA. Defatted soy flour was purchased from American Natural Soy, Cherokee, IA, USA. The whole grains – two white (V1-Fontanelle 4575, V2-738Y) and one red (V3-217X Burgundy) sorghum (Nu Life Market, Scott City, Kansas, USA), corn (Agronomy Foundation Seed, Kansas State University, Manhattan, KS, USA), soybeans (Kansas River Valley Experiment Field, Kansas State University, Manhattan, KS, USA) and cowpea grains (LPD Enterprises LLC, Olathe, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA).

The cereal and legume flour were blended in appropriate ratios. For sorghum cowpea blends (n=7; 39% sorghum, 61% cowpea), sorghum flour-V1 or V2 or V3 as whole or decorticated were mixed with cowpea flour. For sorghum soy blends (n=4; 75% sorghum, 25% soy), whole or decorticated sorghum flour-V1 were mixed with low-fat (1.85%) or medium-fat (6.94%) or full-fat (16.93%) soybean flour. For corn soy blends (n=2; 76% corn, 24% soy), whole or degermed corn flour were blended with medium fat or full fat soybean flour. All binary blends were extruded on a single screw extruder X-20 (Wenger Manufacturing Inc., Sabetha, KS, USA) at screw speed ranged from 500-550 rpm with 18-24% process moisture. The extrudates were cut at the die exit with face-mounted rotary knife and then dried in a gas-fired double pass dryer at 104°C. The dried extrudates were ground using a Schutte Buffalo Hammer mill (Buffalo, NY, USA). The other ingredients; sugar (Domino Foods, Inc., Yonkers, NY, USA), non-gmo soybean oil (Zeeland Farm Services, Inc., Zeeland, MI, USA), whey protein concentrate with 80% protein content-WPC 80 (Davisco Foods International, Inc., Eden Prarie, MN, USA), and vitamin-mineral premix

(Research Products Company, Salina, KS, USA) were added after extrusion to prevent destruction of micronutrients in the mix. Antioxidants (BHA, butylated hydroxyanisole and BHT, butylated hydroxytoluene) were also added to all binary blends after the extrusion process, except whole sorghum with medium-fat soybean blend, which antioxidants had been added to before extrusion in order to determine whether the sequence of the addition of antioxidants affected product shelf life or not.

Table 3-2 Composition of extruded FBFs and non-extruded FBFs.

Ingredients (%)	Extruded FBFs[1]			Non-extruded FBF
	Sorghum-Cowpea blends (SCB; n=7)	**Sorghum-Soy blends (SSB; n=4)**	**Corn-Soy blends (CSB; n=2)**	**Corn soy blend plus (CSB+)**
Sorghum flour	24.7	47.6		
Cowpea flour	38.6			
Corn flour			48.1	
Corn (White or Yellow)				78.5
Whole soybeans				20.0
Soy flour		15.7	15.2	
Sugar	15.0	15.0	15.0	
Whey Protein Concentrate (WPC80)	9.5	9.5	9.5	
Soybean oil	9.0	9.0	9.0	
Vitamin & Mineral Premix	3.2	3.2	3.2	
Vitamin/Mineral				0.2
Tri-Calcium Phosphate				1.2
Potassium Chloride				0.2

[1] For extruded FBFs, antioxidants (BHA&BHT) had been added in all treatments. SSB and CSB with full-fat soy, WPC80 was increase from 9.5% to 13.0%, and soybean oil was decreased from 9% to 5.5%.

Current non-extruded FBF

Corn soy blend plus (CSB+) was produced by Bunge Milling (St. Louis, MO, USA) according to the USDA commodity requirements (USDA 2014) (Table 3-2).

Shelf life testing design

Two storage conditions were used in this study. The real time condition was set up at 30°C and 65% relative humidity (RH). These set points were based on tropical weather and the average annual relative humidity in Tanzania (Jack 2010; Makala 2013), the expected location of product use. The accelerated condition was at 50°C, 70% RH. These parameters were based on the Q_{10} factor (Robertson 2009). Q_{10} is a measure of the temperature sensitivity of reaction rate due to an increase by 10°C, as expressed by equation below (Robertson 2009):

$$Q_{10} = \theta_{s(T)}/\theta_{s(T+10)} \tag{1}$$

where

$\theta_{s(T)}$ = shelf life at temperature T°C

$\theta_{s(T+10)}$ = shelf life at temperature (T + 10)°C

A Q_{10} of 2 implies that the reaction rate doubles with each 10°C rise in temperature (Sewald and DeVries 2003). If the temperature difference ($\Delta = T_2 - T_1$) is rather than 10°C, the following equation is used (Robertson 2009):

$$(Q_{10})^{\Delta/10} = Q_{s(T_1)}/Q_{s(2)} \quad (2)$$

Therefore, with the assumption that Q_{10} for the deteriorative reaction was 2, the temperature difference $\Delta = 50 - 30 = 20\ (°C)$, the accelerated shelf life time intervals corresponding to real time shelf life intervals were shown in table 3.

The two shelf life conditions were conducted in two independent temperature and humidity controlled chambers (BIOCOLD Environmental Inc,Fenton, MO, USA). The temperature and relative humidity of each chamber was recorded every one hour with HOBO data loggers (onset, Bourne, MA, USA) that were placed in the chamber.

Table 3-3 Shelf life time interval (weeks) for the real time and accelerated storage conditions

Testing time point	**Real time (weeks)** 30°C, 65% RH	**ASLT (weeks)** 50°C, 70% RH
0	0	0
1	24	6
2	52	13
3	78	19
4	104	26

Shelf life sample preparation

Ball wide mouth quart jars (Jaeden Home Brands, Fishers, IN, USA) were used as storage materials for this study. The top-lids of the ball jars were replaced by actual packaging material for FBFs which were made from a 25 kilogram multiwall paper bag manufactured to meet Food and Drug Administration (FDA) requirements for food products (21 CFR 177.1520,as amended). The multiwall paper bag constructed of one inner plastic liner of low-density polyethylene (LLDPE) film, two layers of natural multiwall kraft (NMK) paper and one outer layer of wet strength natural multiwall kraft (WSNMK) paper (USDA 2014). Each sanitized canning jar was filled with 250 grams of FBF under a sanitized controlled environmental chamber, tightly sealed by screw lids, and placed in shelf life chambers (BIOCOLD Environmental Inc,Fenton, MO, USA). All fourteen FBFs were subjected to both shelf life testing conditions.

Descriptive sensory analysis

At each time point, descriptive sensory analysis was conducted to evaluate aromas and flavors of all samples using six-highly trained panelists of the Center for Sensory Analysis and Consumer Behavior at Kansas State University, Manhattan, KS, USA. These panelists have experienced more than 2000 hours of sensory testing, including grain products.

Samples for descriptive analysis were made into porridges with 20% solid content. The cooking process involved mixing 200 g of FBF with 400 mL of cold water to make a slurry. The slurry was gradually added to 400 ml of boiling water, brought back to a boil, and cooked for 2 minutes for extruded FBFs and 10 minutes for CSB+, while continuously stirred with a wooden spoon. Porridge was then cooled down to the serving temperature of 45°C. Approximately 50 g of porridge was served in 4 oz Styrofoam cup (Dart container corporation, Mason, MI, USA) labeled with a three-digit code. Samples were individually evaluated for 16 aroma and flavor attributes on a numerical scale of 0-15 with 0.5 increments (0=none, 15=extremely high). Each sample was evaluated in triplicate in a randomized order. Panelists used deionized water, unsalted crackers, and carrots to clean their palate between samples.

Data analysis

Data from fourteen samples and two storage conditions were analyzed separately. Analysis of variance (ANOVA) was used to assess whether differences occurred ($P \leq 0.05$) for each sensory characteristics across the storage time points for each sample and each testing condition. Fisher's protected Least Significant Difference (LSD), a *post hoc* means separation, at the 5% level of significance was used to determine which time points were significantly different for each of the measured properties. Statistical analyses were performed with SAS® statistical software (version 9.4, SAS Inst. Inc., Cary, N.C., U.S.A.).

Only the data of the key attributes (rancid characteristic) were presented in this paper.

Results and Discussion

Porridge samples prepared from all FBFs in this study were evaluated for 6 aromas and 10 flavors. The aromas consisted of overall grain, toasted, beany, musty, rancid, and painty. The flavors included overall grain, toasted, beany, musty, rancid, painty, sweet, salt, astringent, and bitter. Among those attributes, rancid and painty characteristics were greatly developed over storage time in some products, but not in others. Other measured properties, beside rancid and painty, showed only small changes over time (approximately ≤ 1.5 points on a 15 points scale) for each porridge sample (data not shown). In addition, rancid (a somewhat heavy aromatic characteristic of old, oxidized, decomposing fat and oil), and painty (the aromatic associated with rancid oil and fat, typically in the late stages of rancidity) were highly correlated ($r^2 > 0.90$). Therefore, rancid was chosen to be the key attribute to determine the shelf life of the products. Rancid and other off-note characteristics from lipid degradation in food often have low threshold values and are easily perceived by humans even at low concentration (Skibsted and others 1998; W[1]sowicz and others 2004; Jacobsen 2010). Rancidity-related sensory attributes were also used as critical descriptors for shelf life estimation for several products, such as extruded pet food (Chanadang and others 2016) avocado paste (Jacobo-Velázquez and Hernández-Brenes 2011), and spray-dried fish oil powder (Keogh and others 2001). For this study, the end of shelf life of all FBFs were determined as storage time at which the occurrence of significant increased ($p \leq 0.05$) in rancid characteristic.

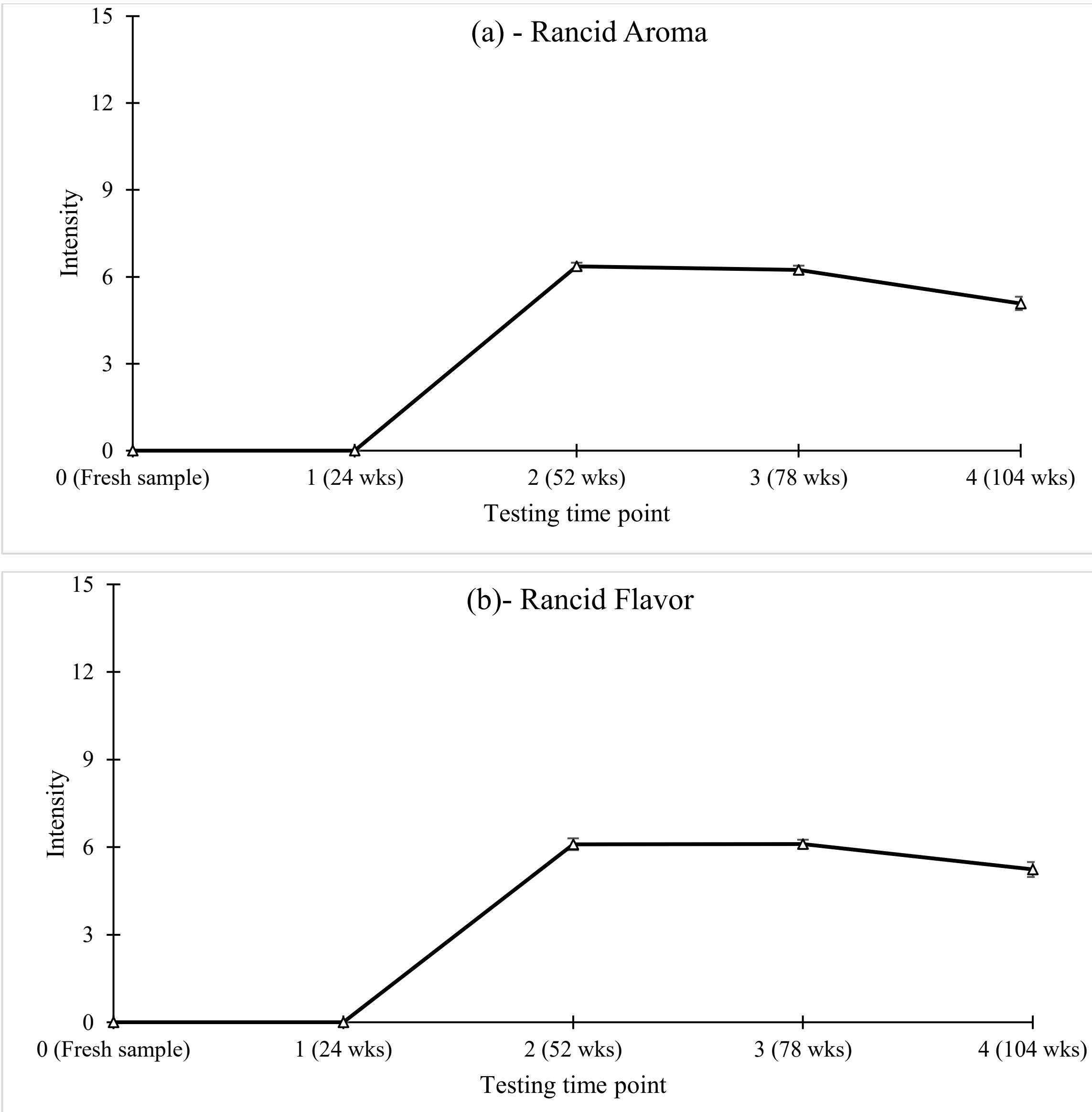

Figure 3-1 Development of rancid intensity during *real time storage condition (RT)* for WSS'B-V1 com (pre-anti). No other fortified blended foods showed any level of rancid intensity.

Data shown are the mean intensities calculated from six panelists with three replications (± standard error). W=Whole, 1st S = Sorghum flour, 2st S' = Medium-fat soy flour; V1 = White variety of sorghum, com = Commercial milling, (pre-anti) = Antioxidant had been added to the binary blend before extrusion process.

Figure 3-1 showed the development of rancid aroma and flavor of all FBFs during the real time storage condition. Thirteen out of fourteen FBFs in this study had no rancid aroma or flavor developed over 104 weeks or 2 years of storage time. Only the product that antioxidants (BHA and BHT) had been added to the blend before extrusion (WSS'B-V1 com (pre-anti)) showed significant increase ($p \leq 0.05$) in rancid intensities at 52 weeks or 1 year of storage time. Synthetic antioxidants, such as BHA and BHT, are commonly added to products containing fats and oils in order to prevent the oxidative decomposition of lipids and thus effectively extend products shelf lives (Allam and Mohamed 2002; Marmesat and others 2010). However, the effectiveness of most antioxidants tends to decrease during the high-temperature treatment (Allam and Mohamad 2002). Hamama and Nawar (1991) and Augustyniak and others (2010) also reported that synthetic antioxidants, especially BHA and BHT, are unstable, volatile, and can be decomposed during thermal processing. Antioxidants (BHA and BHT) that had been added to WSS'B-V1 com (pre-anti) in this study might be lost through volatilization and decomposition during the high-temperature extrusion process, and that resulted in the earlier development of off-note characteristics from lipid oxidation in WSS'B-V1 com (pre-anti) sample compared to all the rest.

Based on the predetermined criteria for products shelf lives, all novel extruded FBFs, except WSS'B-V1 com (pre-anti), were estimated to have a shelf life of at least 104 weeks or 2 years under real time storage condition. The estimated shelf life of most extruded FBFs were comparable to the current non-extruded FBF (CSB+) and considerably longer than 18 months, or approximately 78 weeks as is recommended in the USDA commodity requirements (USDA 2014). The shelf life of WSS'B-V1 com (pre-anti), on the other hand, was estimated to be somewhere before 52 weeks or 1 year which was shorter than the rest of products because of the loss of antioxidants during production process. The result from real time shelf life testing showed that the variations of ingredients used in FBFs formulations did not affect the products' stability over a 2-year period. However, it is recommended to add antioxidants to the blends after the extrusion process in order to maintain their effectiveness and prevent them from deterioration.

The result from accelerated storage condition (Figure 3-2) supported the conclusion from the real time storage condition for almost all FBFs, but not for SCB-V3, WCS"B, and WSS'B-V1 com (pre-anti). The data from accelerated condition showed that SCB-V3 had significant increases ($p \leq 0.05$) in rancid aroma and flavor during the 26-week of storage time. Thus, the shelf life of SCB-V3 was estimated to be lower than 26 weeks, which was equivalent to lower than 104 weeks or 2 years in real time condition. For WCS"B and WSS'B-V1 com (pre-anti), rancid aroma and flavor were significantly developed ($p \leq 0.05$) during 19 weeks of storage time, which was equivalent to 78 weeks or 18 months in real time condition. WCS"B that consisted of full fat soybean flour might contain higher levels of lipid degradation products after the extrusion process, and that could lead to the early formation of rancidity-related sensory attributes during storage (Bredie and others 2002; Ho and Shahidi 2005). However, this was not the case for WSS"B-V1 that also contained full fat soybean flour. Rancid characteristic tended to develop during 26 weeks of storage in WSCB-V3 product, however, the intensities of this off-note characteristic was not significantly different ($p > 0.05$) from the previous time points. Therefore, shelf life of WSCB-V3 was estimated to be longer than 26 weeks, which was equivalent to 104 weeks or 2 year in real time condition.

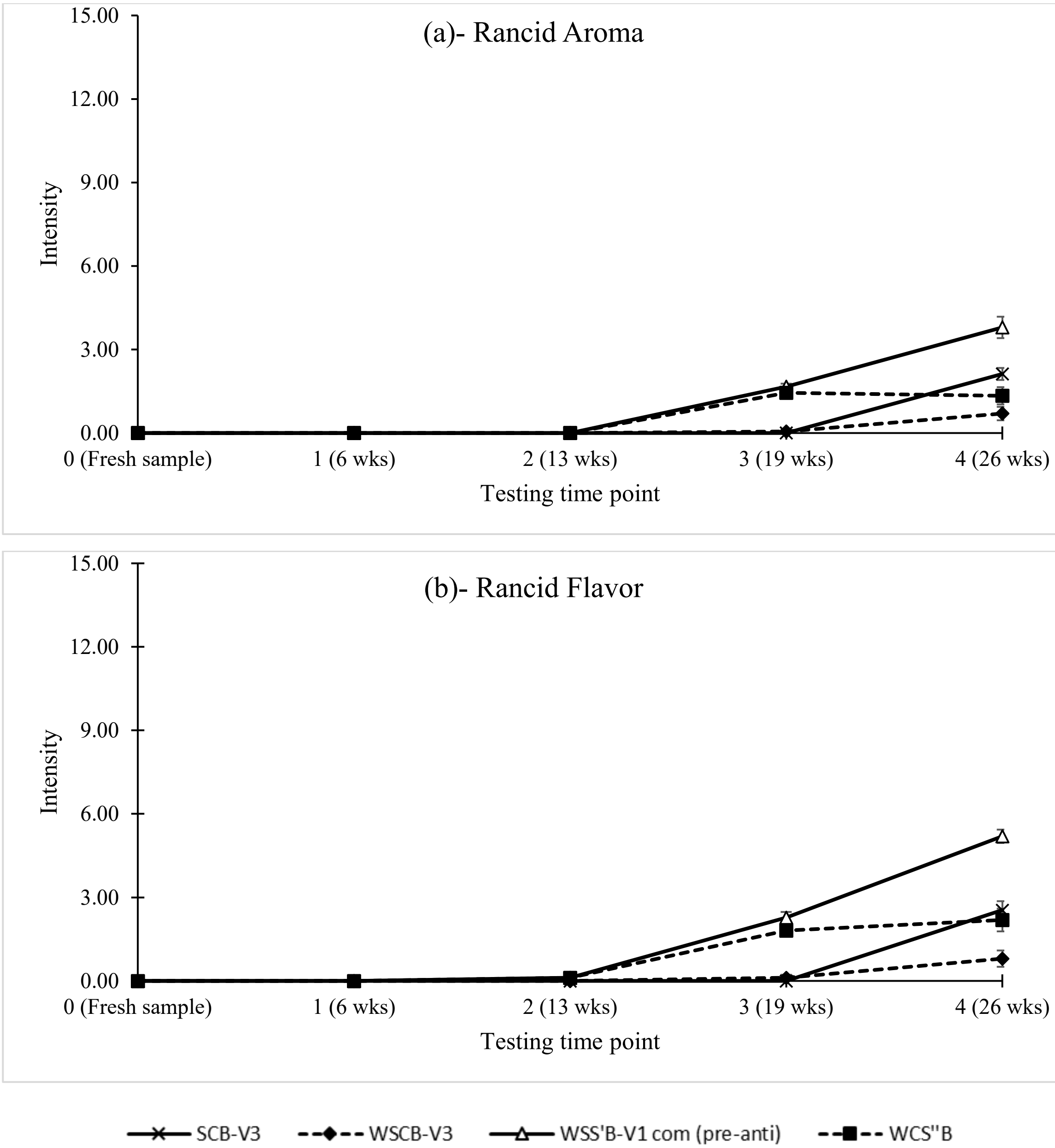

Figure 3-2 Development of rancid intensity during ***accelerated storage condition (ASLT)*** for SCB-V3, WSCB-V3, WSS'B-V1 com (pre-anti), and WCS"B. No other fortified blended foods showed any level of rancid intensity.

Data shown are the mean intensities calculated from six panelists with three replications (± standard error). For extruded FBFs: W=Whole, 1st S = Sorghum flour, 1st C = Degermed corn flour, 2st S' = Medium-fat soy flour; S" = Full-fat soy flour, 2st C = Cowpea flour, V3 = Red variety of sorghum, com = Commercial milling, (pre-anti) = Antioxidant had been added to the binary blend before extrusion process.

The product shelf life estimated from the accelerated storage condition was consistent with the real time shelf life for most FBFs. However, it failed to predict the real time shelf life for SCB-V3, WCS"B, and WSS'B-V1 com (pre-anti) samples. The real time storage condition in this study was actually a controlled condition in an environmental chamber with the temperature of 30°C and 65% RH. However, the temperature and humidity in the real location, which is Tanzania in this case, may not always be this stable during the year (Rowhani and others 2011). Even with the controlled condition, the accelerated storage condition still failed to predict or estimate the shelf life of some novel extruded FBFs. Thus, the estimated shelf life of FBFs under actual conditions at the real location could be quite different from the one obtained from the accelerated condition. Accelerated shelf life testing had to be conducted with care since the changes, including sensory properties, in the products at severe temperature might be different from those obtained from normal condition (Robertson 2016). Magari (2003) and Robertson (2016) also suggested performing shelf life testing under the actual environmental conditions to prove the result from the accelerated condition.

Conclusion

The shelf life testing under both real time and accelerated storage conditions agreed that most novel extruded FBFs could have shelf lives at least 2 years with no detection of off-note characteristics, and that were comparable to the shelf life of a current non-extruded FBF (CSB+). WSS'B-V1 com (pre-anti) appeared to have the shortest shelf life for both testing conditions due to the deterioration of antioxidant during extrusion. Even though accelerated testing predicted the shelf life of SCB-V3, and WCS"B to be somewhere lower than 2 years, the result from the controlled real time condition indicated that these two products could be stored longer than 2 years, which is similar to most FBFs. Therefore, it is essential to conduct shelf lift testing using real time condition, especially for the newly developed products, in order to validate the results from the accelerated condition and obtain a more precise estimation of product shelf life.

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Chapter 4 - Paired Preference Testing of Novel Fortified Blended Foods with Infants and Young Children in Tanzania

Abstract

The preference of porridge made from extruded fortified blended foods (FBFs) compared to current non-extruded product (Corn soy blend plus; CSB+) among infants and young children was studied in Mwanza region, Tanzania. Five extruded, fortified blends were chosen as novel FBFs in this study i) Corn soy blend 14 (CSB14); ii) White sorghum$_{\textit{Fontanelle 4525}}$ soy blend (SSB); iii) White sorghum$_{\textit{Fontanelle 4525}}$ cowpea blend (WSC1); iv) White sorghum$_{\textit{738Y}}$ cowpea blend (WSC2); and v) Red sorghum$_{\textit{217X Burgundy}}$ cowpea blend (RSC). Paired preference testing between CSB+ and each novel FBF was conducted, using approximately 600 children for each pair. Results showed that infants and young children prefer CSB14 and SSB over CSB+. However, children tended not to have a preference for the three sorghum cowpea blends (WSC1, WSC2 and RSC) vs CSB+ probably because of a distinct beany flavor from cowpea that they were not familiar with. This study indicated that novel FBFs have potential to be used successfully as supplementary food with higher preference or comparable in preference to FBF currently used in food aid programs.

Introduction

Fortified blended foods (FBFs) are the mixture of precooked cereals, legumes that are fortified with micronutrients and possible addition of oil and animal-based source protein (Webb and others 2011). They have been used worldwide in supplementary feeding programs as a complementary food because the cost of FBFs is low when compared to their nutritional value and other micronutrient-rich commodities (WFP 2002). Corn soy blend plus (CSB+), a mixture of partially cooked whole corn and soybeans, is the FBF that the United States Agency for International Development (USAID) currently distributes for food aid programs (USDA 2014). Although FBFs, including CSB+, are widely used as supplementary foods in many developing countries around the world, they have been criticized for their limited ability in treating young children with malnutrition (de Pee and Bloem 2009; Skau and others 2009). Food Aid Quality Review report (FQAR) by Webb and others (2011) recommended to improve the formulation of existing FBFs in various ways such as adding whey protein concentrate (WPC) to improve protein quality, adding vegetable oil to increase the energy content, and adding a flavor enhancer to increase acceptability and consumption. Consequently, the Micronutrient Fortified Food Aid Pilot Project was lunched at Kansas State University in order to develop the new cereal-based FBFs based on FQAR requirements and meet the goal of food security.

Besides developing new FBFs with high nutrition, it is important to assure that they are acceptable or preferred by target populations, which are infants and young children under the age of 5 years. Children will eat more foods that they like or preferr (Birch 1992; Anzman-Frasca and others 2012). Recent studies by Phan and Chambers (2016a; 2016b) also indicated that liking is the strongest motivation for food choices and is critical for most food selections at all eating occasions. The vast majority of research on food for children has been conducted with adults rather than children because of their ability to understand the instructions and express their decision (Leon and others 1999; Levin and Hart 2003). However, using adult responses might not be enough to predict success of products in children market since adults and children have a different definition of a favorable product (Chen and others 1996). The methods for measuring food acceptability or preference in children have to be simple in order to be easy to understand, but they should also be robust enough to measure their food preferences (Leon and others 1999). Conducting sensory and consumer research with infants (0-18 months) and toddlers (18-36 months) is a challenge because of the lack of ability to communicate verbally. Therefore, the effective way to evaluate children's responses mainly based on non-verbal cues such as facial expression and body movements (Leon and others 1999; Guinard 2000). This indirect approach had been used to assess young children's acceptability of sorghum peanut blend (SPB) and corn soy blend plus (CSB+) in Uganda, in which caregiver (typically mother) was asked to observe the child's response after tasted porridge and then translated into the degree of liking (Amegovu and others 2014). Iuel-Brockdorf and others (2015) and Iuel-Brockdorf and others (2016) also evaluated children's acceptability of improved supplementary foods in Burkina Faso by asking caregivers to evaluate their child appreciation of the food according to the child's reaction based on a 5-point hedonic scale. However, the result from hedonic scale testing might be inadequate for comparing products' acceptability as caregivers might have been reluctant to give poor acceptability scores and that may have resulted in small rating variability between the products (Iuel-Brockdorf and others 2015; Iuel-Brockdorf and others 2016). The paired preference test was another approach that could be successfully used to determine food preference in young children because of the simplicity of the task (Lawless and Heymann 2010). A study by Kimmel and Guinard (1994) indicated that children over the age of 2 years could reliably perform a paired preference test. More complex tests such as preference ranking and hedonic scales were more suitable for children over the age of 4 (Guinard 2000).

Among developing countries, Tanzania was the third rank in Africa for having large numbers of malnourished children due to poor feeding practices and lack of suitable complementary foods (UNICEF 2009; Muhimbula and others 2011; Victor and others 2014). Complementary foods with high nutritional value and acceptability should be developed and introduced to Tanzanian children in order to improve their nutritional status. Therefore, Tanzania has been selected as a pilot location for the Micronutrient Fortified Food Aid Pilot Project in order to determine the potential of newly formulated FBFs.

As product preference and acceptability play an important role in the success of the new product. Therefore, the objective of this study were to i) determine children's preference of new FBFs compared to the FBF currently used in Tanzanian food aid program and ii) evaluate sensory characteristics of each FBFs using descriptive sensory analysis in order to find the reason behind children's preference.

Material and methods

Sample

Extruded FBFs

Five extruded FBFs were selected as novel FBFs in this study i) Corn soy blend 14 coded as CSB14, ii) White sorghum (Fontanelle 4525 variety) soy blend coded as SSB, iii) White sorghum (Fontanelle 4525 variety) cowpea blend coded as WSC1, iv) White sorghum (738Y variety) cowpea blend coded as WSC2, and v) Red sorghum (217X Burgundy variety) cowpea blend coded as RSC.

Sorghum variety V1 (Fontanelle 4525), V2 (738Y), V3 (217X Burgundy) (Nu Life Market, Scott City, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA) to obtain decorticated flours. Soybeans (Kansas River Valley Experiment Field, Kansas State University, Manhattan, KS, USA) and cowpea grains (LPD Enterprises LLC, Olathe, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA). Commercially milled degermed corn flour was purchased from Agricor, Marion, Indiana, USA. Defatted soy flour was purchased from American Natural Soy, Cherokee, IA, USA.

All the binary formulations – sorghum cowpea (39% sorghum, 61% cowpea), sorghum soy (75% sorghum, 25% soy) and corn soy (76% corn, 24% soy) were extruded on single screw extruder X-20 (Wenger Manufacturing Co., Sabetha, KS, USA) at screw speed ranged from 500-550 rpm with 18-24% process moisture. The extrudates were cut at the die exit with face-mounted rotary knife and then dried in a gas-fired double pass dryer at 104°C. The dried extrudates were ground using a hammer mill fitted with 315 µm screen and mixed with quantities of sugar (Domino Foods, Inc., Yonkers, NY, USA), whey protein concentrate (WPC80) (Davisco Foods International, Inc., Eden Prarie, MN, USA), non-gmo soybean oil (Zeeland Farm Services, Inc., Zeeland, MI, USA), and vitamins and minerals (Research Products Company, Salina, KS, USA) to prepare the fortified blended foods (FBFs) based on FAQR requirements (Webb and others 2011). The proportion of various ingredients in each blend are shown in Table 4-1.

Current non-extruded FBF

Corn soy blend plus (CSB+) was produced by Bunge Milling (St. Louis, MO, USA) according to the USDA commodity requirements (USDA 2014). The composition of the blend is shown in Table 4-1.

Table 4-1 Composition of extruded and non-extruded FBFs.

Ingredient (%)	Extruded FBFs[1]	Non-Extruded FBF [2]
Extrudates	63.30	
Corn (White or Yellow)		78.5
Whole soy bean		20.0
Sugar	15.00	
Whey Protein Concentrate (WPC80)	9.50	
Vegetable Oil	9.00	
Vitamins and Mineral Premix	3.20	
Vitamin/Mineral		0.2
Tri-Calcium Phosphate		1.2
Potassium Chloride		0.2

[1]Extruded FBFs : CSB14, SSB, WSC1, WSC2, RSC
[2]Non-extruded FBF : CSB+

Sample preparation

All FBFs in this study were prepared into porridges which are the most common dishes made from cereal-based products and eaten by children, especially in developing countries (Rowe and others 2008; Moussa and others 2011; Chanadang and others 2016). Since FBFs in this study were intended to be used by people in developing countries with low education and had limited facilities, the preparation procedure for cooking porridge was created to be simple, repeatable and can be done with local utensils.

Extruded FBFs

One cup of extruded FBFs was mixed with one cup of cold water to prevent formation of lump. The mixture was then added into one cup of boiling water, brought back to a boil, and cooked for 2 minutes while continuously stirred with a wooden spoon. The sample was removed from the stovetop and cooled at room temperature. The cooked porridge had approximately 17% solid contents.

Non-extruded FBF

Porridge prepared from CSB+ followed the same cooking method used for extruded FBFs except it required more water and longer cooking time. One cups of CSB+ was mixed with two cups of cold water to prevent formation of lumps. The mixture was then added into two cups of boiling water, brought back to a boil, cooked for 10 minutes and continuously stirred with a wooden spoon. The sample was removed from the stovetop and cooled at room temperature. The cooked porridge had approximately 12% solid contents.

It appeared that cooked porridges from both extruded FBFs and non-extruded FBF from these cooking procedures had slightly lower solid contents than recommendations which were 20% solid contents for extruded FBFs (Webb and others 2011) and 13.79% solid contents for CSB+ (USDA 2014) . However, these issues should not have a major impact on sensory properties of porridges because these kind of products have high tolerance to variations in cooking procedures (Chanadang and others 2016).

Descriptive sensory analysis

Descriptive sensory analysis was conducted at the Center for Sensory Analysis and Consumer Behavior, Manhattan, KS, USA. The panel consisted of five highly trained panelists who have had 120 h of general descriptive analysis training, and over 2,000 h of evaluation experience with a wide array of food products, including cereal-based products. Thirty attributes including aroma, flavor, texture and appearance were used to describe samples. Twenty-five attributes were selected from sensory attribute lists developed for this product category by Chanadang and others (2016). Five new attributes were added to this study i) Beany aroma and flavor defined as the aromatics characteristic of beans and bean products, including musty/earthy, musty/dusty, sour aromatics, bitter aromatics, starchy and green/pea pod, nutty or brown; ii) Corn flavor defined as grain aromatics characteristic of corn; iii) Dairy process flavor defined as dry powdery impression found in nonfat dry milk or buttermilk solids; iv) Color intensity defined as the evaluation of color from light to dark of the product.

Porridge was evaluated at 45°C which is typical consumption temperature by infants (Mouquet and others 2006). Fifty grams of each test porridge was served in a 4 ounce Styrofoam cup (Dart container corporation, Mason, MI, USA) labeled with a three-digit code to each panelist. The porridge samples were individually evaluated on an intensity-point scale of 0-15 (0 = none to 15 = extremely high) with 0.5 increments. Porridge samples were prepared and evaluated in triplicate in a randomized order. Four samples were evaluated per day. The panelists used warm water, carrots and unsalted crackers to cleanse their palate between samples.

Paired preference test

Paired preference tests between CSB+ and each novel FBF were conducted in Mwanza region, Tanzania which were i) CSB+ *vs* CSB14; ii) CSB+ *vs* SSB; iii) CSB+ *vs* WSC1; iv) CSB+ *vs* WSC2; v) CSB+ *vs* RSC. About 3000 infants and young children were randomly selected from those who came to health facilities for nutritional status screenings. The children were not prequalified in any way other than being in the correct age group, available and willing to complete the test with the permission from the parent or caregivers. They were then assigned to one of the five pair preference tests, given approximately 600 children for each pair (50% children of age 6-24 months and 50% children of age 25-59 months). The number of children for each paired preference test was based on the guideline from ASTM (2012) that recommends to use between 300 to 600 consumers for each initial preference comparison.

Each child was asked to taste 2 products (CSB+ and one of novel FBF). Within each pair, half of children tasted porridge prepared from CSB+ first and half of children were served with porridge prepared from novel FBF first. After they finished tasting 2 products, enumerators asked children on which sample did they prefer. In the case of infants, mothers were asked to interpret their child preference based on their body movement or facial expression.

Data analysis

Descriptive sensory data were analyzed by a one-way ANOVA mixed effect (SAS version 9.4, The SAS Institute Inc., Cary, NC,USA) using PROC GLIMMIX to determine significant differences ($p \leq 0.05$) among porridge samples on each sensory attribute. Fisher's protected Least Significant Difference (LSD) at the 5% level of significance was used to determine which samples were significantly different for each of the sensory properties. Principal component analysis (PCA) for all measured sensory properties of porridges prepare from all samples was conducted using XLStat version 2015.3.01 (Addinsoft, New York, NY, USA).

Data from paired preference tests were analyzed by using *z*-test statistic to determine whether infants and young children had a preference for one product over the other. For each paired preference test, *z*-scores were computed for i) children within 6-24 months; ii) children within 25-59 months; iii) all children. The *z*-score associated with the results of specific paired preference test can be calculated as follows (Stone and Sidel 1978; Lawless and Heymann 2010) :

$$z = \frac{\left[\left(X - \frac{N}{2}\right) - 0.5\right]}{0.5\sqrt{N}} \qquad (1)$$

Within each pair, X was the number of preference children for the most preferred sample and N was the total number of children of each age group or in overall. A critical *z*-score of 1.96 was used for a two-sided test with alpha equal to 0.05. The calculated *z*-score had to be larger than 1.96 for the result to be statistical significant (Lawless and Heymann 2010).

Results and discussion

Descriptive sensory analysis

Descriptive sensory analysis was conducted to determine sensory characteristics of porridge prepared from each FBF. The result showed that porridges prepared from extruded and non-extruded FBFs samples were significantly different ($p \leq 0.05$) in most of measured sensory attributes except overall grain aroma, toasted aroma, starch flavor, uniformity of size, and mouth drying (Table 4-2).

Porridges prepared from sorghum-base products (WSC1, WSC2, RSC, SSB) were significantly higher in sorghum flavor and the one prepared from corn-base products were significantly higher in corn flavor ($p<0.0001$). In addition, porridges prepared from sorghum-base products (WSC1, WSC2, RSC, SSB) were also higher in musty aroma and flavor, and cardboard aroma.

All extruded FBFs were significantly higher in toasted and brown flavor than current, non-extruded FBF (CSB+) due to the extrusion process ($p\leq0.05$). This finding agreed with Parker and others (2000) who also found toasted cereal notes in oat flours which were produced as a result of the Maillard reaction during the extrusion process. Porridges prepared from novel FBFs were significantly higher in sweet ($p<0.0001$) and more noticeable in overall dairy flavor ($p=0.0009$) than CSB+ as a result from the addition of sugar and whey protein concentrate into the formula.

Sorghum cowpea and sorghum soy blend (WSC1, WSC2, RSC, SSB) were significantly higher in beany characteristics than corn-based products (CSB14, CSB+) ($p<0.0001$). The intensity of corn flavor in CSB14 and CSB+ might be high enough to suppress or decrease the perceived intensity of other sensory characteristics and that could have resulted in a lower intensity of beany flavor and aroma. The presence of beany aroma and flavor is often found in legumes such as soybeans and cowpeas (Sessa 1979; Kobayashi and others 1995). Lipid oxidation of linolenic and linoleic fatty acids, which is catalyzed by lipoxygenase, is a major contributor to the beany flavors in legume protein products (Sessa 1979; Kinney 2003). Wang and others (2001) and Bott and Chambers (2006) also indicated that beany flavor is an undesirable sensory characteristic and can significantly decrease the acceptability of the products.

Porridge from CSB+, as expected, was the thinnest porridge and had lower intensities in mouthfeel characteristics (gumminess, oily mouthfeel, and overall mouthcoating) because it had lower solid content compared to porridges prepared from novel FBFs. Porridge made from CSB14 was significantly higher in most of texture attributes compared to CSB+ and the other extruded blends. Considering among the novel FBFs, the thinner and lower in mouthfeel characteristics of porridges from sorghum-based products indicated possible re-aggregation of sorghum proteins during wet cooking and could limit starch swelling and gelatinization (de Mesa-Stonestreet and others 2012). In addition, starch granules embedded in sorghum protein matrix would have slow hydration and resulted in lower final viscosities due to fewer starch molecules released from the granules (Griess and others 2011). Porridges from sorghum-based products, especially RSC, had darker color than corn-based products. The darker color of porridge from RSC was due to the red pigmentation that is normally found in pericarp, endocarp, and stylar area in red sorghum variety (Nip and Burns 1969).

The principal component analysis (Figure 4-1) helps visualize the sensory characteristics of porridges prepared form each FBF. It was clearly seen that porridges prepared from novel FBFs had more complex sensory characteristics than porridge made from traditional FBF (CSB+). All porridges from novel FBFs had higher intensity in sweetness compared with CSB+. A sweet taste from sugar in novel FBFs formulations could help to increase products' acceptability, and also increase food consumption among undernourished children (Webb and others 2011). Porridges from sorghum-based products including WSC1, WSC2, RSC, and SSB were mainly characterized by beany and toasted cereal characteristics (toasted and brown aroma and flavor). These groups of products also were darker in color and porridge from RSC was the darkest. On the other hand, CSB14 was mainly characterized by texture and mouthfeel characteristics such as thickness, gumminess, adhesiveness, and overall mouth coating.

Table 4-2 Mean intensity scores[1] for sensory attributes of porridges prepared from extruded and non-extruded FBFs.

Attribute	Product						*p*-value
	CSB+	CSB14	WSC1	WSC2	RSC	SSB	
Aroma							
Overall grain	4.77	4.87	4.50	4.33	4.73	4.67	*0.3460*
Musty Overall	3.27[ab][2]	2.87[c]	3.27[ab]	3.37[ab]	3.57[a]	3.13[bc]	*0.0070*
Cardboard	2.70[bc]	2.67[c]	3.03[ab]	3.00[abc]	3.20[a]	2.87[abc]	*0.0218*
Toasted	2.70	2.70	2.93	2.80	3.07	3.03	*0.1330*
Brown	2.17[d]	2.33[cd]	2.50[bc]	2.43[bc]	2.93[a]	2.70[ab]	*<0.0001*
Beany	1.77[c]	1.93[c]	3.13[b]	3.07[b]	3.83[a]	2.87[b]	*<0.0001*
Flavor							
Overall grain	4.93[a]	5.20[a]	5.23[a]	5.20[a]	4.43[b]	4.80[ab]	*0.0121*
Sorghum	0.63[c]	1.70[b]	2.57[a]	2.30[ab]	2.20[ab]	2.30[ab]	*<0.0001*
Corn	4.57[a]	4.63[a]	0.80[bc]	0.87[b]	0.10[c]	0.90[b]	*<0.0001*
Beany	1.90[d]	1.97[d]	3.23[bc]	3.27[b]	3.83[a]	2.93[c]	*<0.0001*
Overall Dairy	0.07[b]	0.60[a]	0.67[a]	0.53[a]	0.07[b]	0.47[a]	*0.0009*
Musty	2.77[b]	3.03[ab]	3.17[a]	3.30[a]	3.17[a]	3.23[a]	*0.0188*
Starch	3.43	3.77	3.47	3.60	3.37	3.53	*0.1182*
Toasted	2.03[c]	2.33[b]	2.77[a]	2.87[a]	2.97[a]	2.77[a]	*<0.0001*
Brown	1.77[d]	2.10[c]	2.47[ab]	2.50[ab]	2.63[a]	2.23[bc]	*<0.0001*
Sweet	0.63[b]	2.20[a]	2.10[a]	2.03[a]	2.17[a]	2.30[a]	*<0.0001*
Bitter	2.80	2.63	2.73	2.57	3.00	2.63	*0.1663*
Sour	1.23[c]	1.33[bc]	1.70[a]	1.53[abc]	1.63[ab]	1.30[c]	*0.0150*
Astringent	2.10[a]	1.80[b]	1.77[b]	2.10[a]	2.13[a]	2.07[a]	*0.0044*
Texture							
Thickness/Viscosity	2.33[e]	5.13[a]	3.87[bc]	4.23[b]	3.70[cd]	3.33[d]	*<0.0001*
Particles	0.13[b]	1.33[a]	0.43[b]	0.20[b]	0.37[b]	0.30[b]	*<0.0001*
Lumpy(size)	0.17[b]	1.8[a]	0.53[b]	0.50[b]	0.53[b]	0.43[b]	*0.0010*
Uniformity of size	0.10	1.87	0.73	1.00	0.73	0.53	*0.1069*
Adhesiveness	0.53[b]	4.00[a]	1.40[b]	1.37[b]	1.17[b]	1.03[b]	*<0.0001*
Gumminess	0.00[c]	3.17[a]	0.80[b]	1.10[b]	0.67[bc]	0.50[bc]	*<0.0001*
Oily Mouthfeel	0.20[c]	1.87[a]	0.80[b]	1.17[b]	0.77[b]	0.87[b]	*<0.0001*
Residual Particles	0.37[b]	0.90[a]	0.20[b]	0.00[b]	0.17[b]	0.20[b]	*0.0008*
Mouth Drying	2.13	2.33	2.03	2.00	2.27	2.13	*0.1831*
Overall Mouthcoating	1.50[c]	3.03[a]	2.03[b]	2.00[b]	2.17[b]	1.80[bc]	*<0.0001*
Appearance							
Color Intensity	2.40[d]	2.47[d]	3.03[c]	3.30[bc]	5.83[a]	3.67[b]	*<0.0001*

[1]Scores are based on a 0-15-point numeric scale with 0.5 increments.

[2]Sample with different letters are significantly different from each other in that attribute ($p \leq 0.05$).

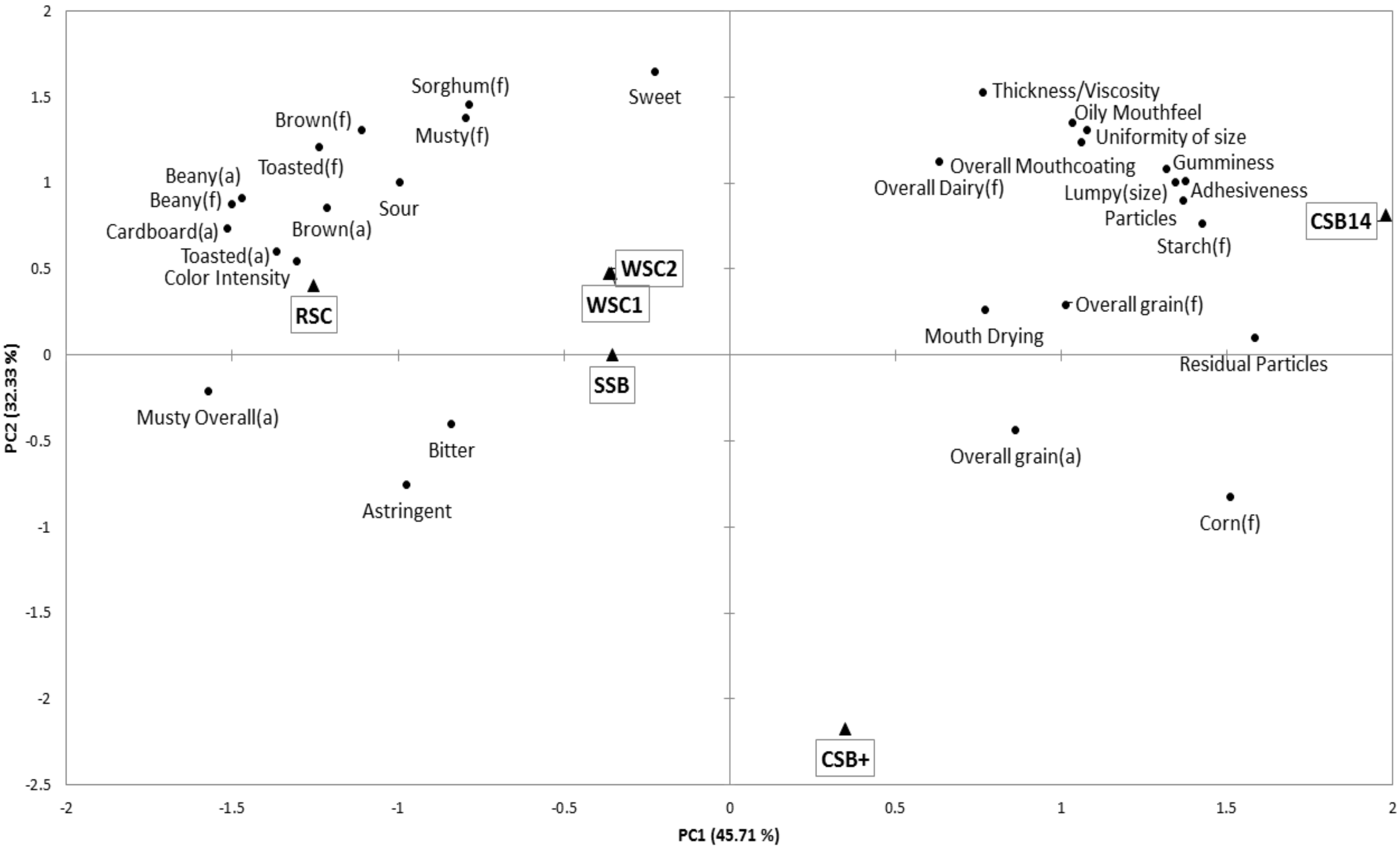

Figure 4-1 Principal component analysis representing sensory characteristics for porridge prepared from 6 fortified blended foods. This map represented 78.04% of the total variance with PC1 contributed 45.71% and PC2 contributed 32.33. (a)-Aroma; (f)-Flavor

Paired preference test

The results for paired preference tests between CSB+ and novel FBFs are shown in Table 4-3. It was clearly seen that children for both age groups (6-23 month old and 24-59 month old) preferred porridges prepared from CSB14 over the one made from CSB+, thus the higher intensities in texture characteristics of CSB14 did not negatively affect children preference. The result from paired preference between CSB+ vs SSB also showed the preference for SSB over CSB+. Children with the age of 24-59 months preferred SSB over CSB+. At the same time, younger children with the age of 6-23 months seemed to have a preference for SSB, although, the number of children who prefer this product was not significant.

Based on descriptive sensory analysis result, the preference of CSB14 and SSB over CSB+ was mainly due to the higher intensity in sweetness of the products. This is consistent with the finding that infants and young children like sweet tastes and this preference could be developed even before birth (Mennella and Beauchamp 1998; Birch 1999; Maciel and others 2001; Liem and Mennella 2002). When infants are fed with sweet solution, they appeared to have relaxed and smiley faces, and these were interpreted by adults as they liked or preferred it (Birch 1992; Mennella and Beauchamp 1998). In addition, children appeared to consume more of the foods they like or prefer, especially sweet foods (Birch 1992; Mennella and others 2016). A study on child acceptability of improved supplementary foods in Burkina Faso by Iuel-Brockdorf and others (2016) found that foods with a sweeter taste from the additional milk received better acceptability scores and some caregivers also added sugar to corn soy blend (CSB) porridge in order to increase the child's consumption of the products.

Surprisingly, children did not have a preference for porridges from extruded sorghum cowpea blends (WSC1, WSC2, RSC) compared to CSB+, although they had sugar in the formulation similarly to CSB14 and SSB. Considering for each age group, younger children with the age of 6-23 months showed preference for porridge from CSB+ over WSC1 and RSC. In contrary, the older children (24-59 months) preferred WSC1 over CSB+ and tended not to prefer WSC2 and RSC over the traditional FBF. This finding suggested that sweetness was not the only factor that influenced products' preferences. Food familiarization was reported as another component that could promote children's acceptance or preference of foods (Birch 1999; Birch and others 2007). For example, preschool children who were repeatedly exposed to tofu with either plain, salt, or sweet flavors, became to prefer the version that they were familiar with (Birch 1999).

Children with the age of at least 6 months in many developing countries, including Tanzania, generally received thin porridges as complementary foods along with breast milk (Muhimbula and Issa-Zacharia 2010). Traditional thin porridges in Tanzania were mainly made from cereals (e.g. corn, sorghum, millet), and tubers (e.g. potato, yam, cassava) (Muhimbula and Issa-Zacharia 2010; Victor and others 2014). Further, a field observation study of 30 low-income households in Tanzania by (Chanadang and others 2016) showed that thin porridges (aka *uji*) were typically prepared for children in the morning and 83.3% of households used corn as the main ingredient. This might explain why children in this study, especially with the age of 6-23 months, preferred traditional FBF (CSB+) over sorghum cowpea blends since they were more familiar with corn flavor. Children with the age of 24 to 59 months, on the other hand, showed no preference for CSB+. This might be due to the more opportunities that older children (24-59 months) could try and learn to accept a greater variety of foods which had more complex flavor than cereal-based products.

Beside cereals and tubers, young children in Tanzania infrequently consumed meat products, dairy products and legumes because of the limited and pour access to these foods (Victor and others 2014), and thus resulted in less experiences in those food flavors. Therefore, a distinct beany flavor from cowpea that children were not familiar with was probably another important reason for no preference on porridges prepared from sorghum cowpea blends. Previous studies also indicated that adding high levels of cowpea in fortified weaning foods could result in a reduction of products' acceptability due to the coarseness and beany flavor from cowpea (Adenuga 2010; Olapade and others 2012).

Several studies indicated that children's preference for novel foods could be increased by giving them repeated opportunities to consume those new foods (Birch 1999; Skinner and others 2002; Birch and others 2007; Ventura and Worobey 2013). It was noted that children's preference or acceptability appeared to be increased after they had repeated exposure to novel foods 6 to 15 times (Birch 1999; Ventura and Worobey 2013). Thus, preference testing, during and after 5 month feeding trials, will be conducted to determine if more exposure to novel FBFs can increase the preference of some alternative products that are at parity with the currently used product.

Table 4-3 Number of children who prefer each product in each paired preference test

Paired preference test	Child age	Number of children	Number of children		*z*-score	*p*-value[1]
			CSB+	CSB14		
CSB+ *vs* CSB14	6-23 months	305	107	198	5.15	*<0.0001*
	24-59 months	302	61	241	10.30	*<0.0001*
	Total	607	168	439	10.93	*<0.0001*
			CSB+	SCB1		
CSB+ *vs* SCB1	6-23 months	302	174	128	2.59	*0.0096*
	24-59 months	308	127	181	3.02	*0.0025*
	Total	610	301	309	0.28	*0.7768*
			CSB+	SCB2		
CSB+ *vs* SCB2	6-23 months	267	144	123	1.22	*0.2209*
	24-59 months	313	164	149	0.79	*0.4288*
	Total	580	308	272	1.45	*0.1461*
			CSB+	SCB3		
CSB+ *vs* SCB3	6-23 months	300	175	125	2.83	*0.0047*
	24-59 months	301	143	158	0.81	*0.4197*
	Total	601	318	283	1.39	*0.1655*
			CSB+	SSB		
CSB+ *vs* SSB	6-23 months	292	140	152	0.64	*0.5198*
	24-59 months	321	138	183	2.46	*0.0140*
	Total	613	278	335	2.26	*0.0237*

[1] *p*-value of two-sided test using *z*-test statistic, value in bold: significant at alpha = 0.05.

Conclusions

Descriptive sensory testing of novel FBFs (WSC1, WSC2, RSC, SSB, CSB14) and traditional FBF (CSB+) showed that novel FBFs were obviously higher in sweet taste and were more complex in sensory characteristics than CSB+. CSB14 was characterized by texture characteristics such as thickness, adhesiveness and gumminess, but the higher intensity in these attributes did not give a negative impact to children's preference. Sweetness of the products was considered as a key factor that influenced young children to prefer CSB14 and SSB over CSB+, however, it was not the case for sorghum cowpea blends (WSC1, WSC2, RSC). A distinct beany flavor and aroma of sorghum cowpea blends that children were not familiar with seemed to be an important factor that leaded children to have no preference for sorghum cowpea blends over CSB+.

Overall the result from this study showed that novel FBFs can be used successfully as a supplementary food with higher preference or comparable in preference to FBF currently used in food aid programs. Future study on preference testing during 5 months feeding trials will be conducted to see whether repeated exposure to novel FBFs can increase the preference of the products, especially sorghum cowpea blends which are currently equivalent to the traditional FBF.

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Chapter 5 - A Comparison of Children's Food Preference in Different Cultures: An Example in Tanzania and the U.S. with Fortified Blended Foods

Abstract

The child's food preference can vary across cultures, depending on the foods that have been introduced to them during the learning period. This study used five paired preference tests between the current fortified blended food (FBF) and each of the five novel FBFs to determine the child's preference for FBFs in Tanzania (the expected location for product use) compared to the child's preference in the U.S. The results from two groups of children (6-23 months and 24-59 months) showed significant differences in food preferences between Tanzanian and American children in some paired preference comparisons, but not in others. This indicated that the child's food preference in one country might not be a logical surrogate for another country. Therefore, conducting the study with real target population is recommended in order to receive accurate and robust information.

Introduction

Many food products are developed specifically for children (Guinard 2000), and those products must be well accepted by children in order to be successful in the market. Sensory and consumer tests with children can be used to determine their acceptability of the products (Popper and Kroll 2005). However, conducting consumer research with children, especially infants and toddlers, is not easy because of their inability to understand instructions and communicate verbally (Guinard 2000; Levin and Hart 2003). Many development plans for children's products are based on adult responses, but these may not be enough to predict success of those products in a child market (Chen and others 1996; Levin and Hart 2003). The study by Moskowitz (1994) also indicated that adults and children have different definition of an optimal product. Therefore, it is essential for children's products to be tested by children in order to obtain the appropriate direction for product development.

The techniques for measuring food preferences in children have to be simple in order to be fully understandable, but they should be robust enough to measure their food preferences reliably (Leon and others 1999). For infants (0-18 months) and toddlers (18-36 months), their food preferences are normally assessed from their non-verbal cues such as facial expression, sucking patterns, and body movements (Guinard 2000). Paired preference test is another technique that can be used successfully to determine food preferences in young children, normally over 2 years of age, because of the simplicity of the task (Lawless and Heymann 2010; Kimmel and Guinard 1994). The more complex sensory testing methods, such as intensity ranking, preference ranking, and hedonic scale are more appropriate for children over 4 years of age (Guinard 2000).

Not only sensory properties of the foods, but also cultural factors affect the acceptance of food by infants and young children (Blossfeld and others 2007; Nicklaus 2011). Food that children can consume are generally more limited than adult's diet (Birch 1999), but the child's diet can be dramatically different across cultures (Birch 1995). Cashdan (1998) mentioned that children primarily learn to accept a variety of foods in their cultures that have been introduced to them during the first 2 to 3 years of their lives, and that is probably difficult to change in adulthood. However, it is unclear whether infants and young children from different cultures really have differences in their food preferences or not.

Fortified blended foods (FBFs) have been widely used as complementary foods for infants and young children in many developing countries around the world for more than four decades (Perez-Exposito and Klein 2009; de Pee and Bloem 2009). Porridges are the most common dishes prepared from this product category and consumed by children (Rowe and others 2008; Moussa and others 2011). Recently, Webb and others (2011) recommended to improve the formulation of the existing FBFs in order to increase the nutritional and sensory quality of the products, and that resulted in the development of novel extruded FBFs at Kansas State University (Manhattan, KS, USA).

The objective of this study was to determine children's preferences for novel extruded FBFs compared to the current FBF using i) Tanzanian children 6-59 months of age, the target population for this product category and ii) American children 6-59 months of age, who are probably not familiar with FBFs products, to determine the effect of cultural background on children's product preferences.

Materials and Methods

Samples

Six different FBFs, including five extruded FBFs and one current non-extruded FBF, were used in this study.

Extruded FBFs

Extruded FBFs were developed at Kansas State University, Manhattan, KS, USA based on the recommendations from the Food Aid Quality Review (FQAR) (Webb and others 2011). Five extruded FBFs that were selected for this study included i) Corn soy blend 14 coded as CSB14; ii) White sorghum (Fontanelle 4525 variety) soy blend coded as SSB; iii) White sorghum (Fontanelle 4525 variety) cowpea blend coded as WSC1; iv) White sorghum (738Y variety) cowpea blend coded as WSC2; v) Red sorghum (217X Burgundy variety) cowpea blend coded as RSC.

Sorghum variety V1 (Fontanelle 4525), V2 (738Y), V3 (217X Burgundy) (Nu Life Market, Scott City, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA) to obtain decorticated flours. Soybeans (Kansas River Valley Experiment Field, Kansas State University, Manhattan, KS, USA) and cowpea grains (LPD Enterprises LLC, Olathe, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA). Commercially milled degermed corn flour was purchased from Agricor, Marion, Indiana, USA. Defatted soy flour was purchased from American Natural Soy, Cherokee, IA, USA.

All the binary formulations, which were cereal-legume flours, were blended in appropriate ratio using a ribbon blender and mixed for 5 minutes. For sorghum cowpea blends, 39% of decorticated sorghum flour was mixed with 61% of cowpea flour. For sorghum soy blend, 75% of decorticated sorghum flour was blended with 25% of soybean flour. For corn soy blend, 76% of degermed corn flour was blended with 24% of soybean flour. All binary blends were extruded on single screw extruder X-20 (Wenger Manufacturing Co., Sabetha, KS, USA) at screw speed ranged from 500-550 rpm with 18-24% process moisture. The extrudates were cut at the die exit with face-mounted rotary knife and then dried in a gas-fired double pass dryer at 104°C. The dried extrudates were then ground using a hammer mill (Buffalo, NY, USA) fitted with 315 µm screen. The other ingredients including sugar (Domino Foods, Inc., Yonkers, NY, USA), whey protein concentrate (WPC80) (Davisco Foods International, Inc., Eden Prarie, MN, USA), non-gmo soybean oil (Zeeland Farm Services, Inc., Zeeland, MI, USA), and vitamin-mineral premix (Research Products Company, Salina, KS, USA) were added after extrusion process to prevent the destruction of micronutrients in the blend. The quantity of all compositions in FBFs were shown in Table 5-1.

Current non-extruded FBF

Corn soy blend plus (CSB+) was produced by Bunge Milling (St. Louis, MO, USA) according to the USDA commodity requirements (USDA 2014) (Table 5-1).

Table 5-1 Composition of extruded and non-extruded FBFs.

Ingredient (%)	Extruded FBFs[1]	Non-Extruded FBF [2]
Extrudates	63.30	
Corn (White or Yellow)		78.5
Whole soy bean		20.0
Sugar	15.00	
Whey Protein Concentrate (WPC80)	9.50	
Vegetable Oil	9.00	
Vitamins and Mineral Premix	3.20	
Vitamin/Mineral		0.2
Tri-Calcium Phosphate		1.2
Potassium Chloride		0.2

[1]Extruded FBFs : CSB14, SSB, WSC1, WSC2, RSC

[2]Non-extruded FBF : CSB+

Sample preparation

All FBFs were prepared into drinkable porridges, which are the most common dishes made from cereal-based products and eaten by children, especially in low income countries which were the expected areas of product use (Rowe and others 2008; Moussa and others 2011; Chanadang and others 2016).

Porridges prepared from all FBFs were made with appropriate solid contents that were close to 20% solid contents for extruded FBFs (Webb and others 2011) and 13.79% solid contents for current non-extruded FBF (USDA 2014).

Extruded FBFs

The cooking process involved mixing one part of extruded FBF with one part of cold water to make a slurry. The slurry was then gradually added into one part of boiling water. The porridge was brought back to a boil, and cooked for 2 minutes while continuously stirred with a wooden spoon. The sample was removed from the stovetop and transferred to a thermos to keep the sample warm.

Non-extruded FBF

The cooking procedure for CSB+ was similar to the procedure for extruded FBFs, except it required more water and longer cooking time. One part of CSB+ was mixed with two parts of cold water to prevent formation of lumps. The slurry was added into two parts of boiling water, brought back to a boil, cooked for 10 minutes and continuously stirred with a wooden spoon. The cooked porridge was then removed from stovetop and transferred to a thermos to keep the sample warm.

Paired preference test

Five paired preference tests between CSB+ and each novel extruded FBF were conducted in two locations, Tanzania and the U.S.

Five paired preference tests included i) CSB+ vs CSB14; ii) CSB+ vs SSB; iii) CSB+ vs WSC1; iv) CSB+ vs WSC2; v) CSB+ vs RSC.

Paired preference tests in Tanzania

The study was conducted at health facilities in the Mara region of Tanzania. A total of 3,011 infant and young children were randomly selected from those who came to the health facilities for nutritional status screenings. To qualify for this study, children had to be 6-59 months of age and available to complete the test with permission from their parents. The qualified children were then assigned to one of the five paired preference tests, given approximately 600 children for each pair comparison (50% children of age 6-24 months and 50% children of age 25-59 months).

Each child was asked to taste 2 prepared porridges (CSB+ and one of novel FBF). Within each paired comparison, half of children tasted the porridge prepared from CSB+ first and another half were served with porridge prepared from novel FBF first. The local enumerators were then recorded the product that each child preferred. For 6-23 month old children, parents were asked to interpret their child's preference based on their facial expression and body reaction. The 24-59 month old children were asked by local enumerators or their parents on which product they preferred.

Paired preference tests in the U.S.

The study was conducted at the Center for Sensory Analysis and Consumer Behavior, Kansas State University, Olathe, KS, USA. Children who participated in this study were recruited from the consumer database. They had to be 6-59 months of age, have no food allergies, and get permission from their parents to participate in this study. Approximately 100 children (50% children of age 6-24 months and 50% children of age 25-59 months) were assigned to each paired preference test.

The procedure for conducting each paired preference test was similar to what had been done in Tanzania. However, parents were instructed to report the product that their child preferred through RedJade software (RedJade®, Redwood Shores, CA, USA).

Data analysis

The results from paired preferences tests were reported as the number of children who preferred each product. A binomial approximation z-test was used to analyze the data from paired preference tests to determine whether children had a preference for one product over the other. For each paired preference test and each location, z-scores were computed for i) children within 6-24 months; ii) children within 25-59 months; iii) total children. The z-score associated with the results of specific paired preference test can be calculated as follows (Stone and Sidel 1978; Lawless and Heymann 2010):

$$z = \frac{\left(X - \frac{N}{2}\right) - 0.5}{0.5\sqrt{N}} \tag{1}$$

Where, within each pair, X was the number of children for the most preferred sample and N was the total number of children of each age group or in overall. The critical z-score of 1.96 was used for a two-sided test (either product can be preferred) with $\alpha = 0.05$. The calculated z-score had to be larger than 1.96 for the result to be statistically significant (Lawless and Heymann 2010).

Pearson's chi-squared test statistic was also performed on the paired preference test data to determine whether differences in child's preference occurred between the two test locations. The analysis was performed with SAS® statistical software (version 9.4, SAS Inst. Inc., Cary, NC, USA).

Results and Discussion

The overall results of five paired preference tests between CSB+ and each novel extruded FBF conducted in Tanzania and the U.S. with infants and young children 6-59 months of age can be found in Table 5-2. The results indicated that, overall, children with the age of 6-59 months from both countries (Tanzania and the U.S.) showed a similar pattern in their product preferences. Infants and young children in both locations preferred cooked porridges from CSB14 and SSB over the one prepared from CSB+ ($p \leq 0.05$). The novel extruded FBFs, including CSB14 and SSB, contained sugar in the formulations, and that resulted in the higher sweetness intensity than the current non-extruded FBF (CSB+). A preference for sweet taste is a universal human trait and this is true for children or even newborns (Maciel and others 2001; Popper and Kroll 2005). Skinner and others (2002) and Cooke and Wardle (2005) also reported that children usually prefer sweet foods such as sweet fruit-flavored cereal, chocolate, and cookies over vegetables. Moreover, a study on the supplementary foods in Burkina Faso by Iuel-Brockdorf and others (2016) indicated that mothers sometimes added sugar to cooked porridges to increase their child's acceptability and consumption of the product. Therefore, the higher intensity in sweetness of CSB14 and SSB might be the main reason that made them more preferable to children than CSB+.

Table 5-2 Results of paired preference test for each product pair in Tanzania and the U.S. in overall.

Paired preference test	Country	Total number of children	Number of children who preferred each product		*z*-score	*p*-value[1]
			CSB+	CSB14		
CSB+ *vs* CSB14	Tanzania	607	168	**439**	10.93	*<0.0001*
	U.S.	100	37	**63**	2.50	*0.0124*
			CSB+	SCB1		
CSB+ *vs* SCB1	Tanzania	610	301	309	0.28	*0.7768*
	U.S.	100	49	51	0.10	*0.9203*
			CSB+	SCB2		
CSB+ *vs* SCB2	Tanzania	580	308	272	1.45	*0.1461*
	U.S.	100	49	51	0.10	*0.9203*
			CSB+	SCB3		
CSB+ *vs* SCB3	Tanzania	601	318	283	1.39	*0.1655*
	U.S.	100	51	52	0.00	*1.0000*
			CSB+	SSB		
CSB+ *vs* SSB	Tanzania	613	278	**335**	2.26	*0.0237*
	U.S.	101	39	**62**	2.19	*0.0286*

[1] *p*-value of two-sided test using *z*-test statistic, value in bold: significant at alpha = 0.05.

Children from both countries did not show a preference for cooked porridges from the three sorghum cow pea blends (WSC1, WSC2, RSC) over porridge made from CSB+, even though they contained the same amount of sugar as was used in CSB14 and SSB. This was probably due to a distinct beany flavor from cowpea that children were not familiar with. Wang and others (2001) and Bott and Chambers (2006) reported that the presence of beany characteristics in many foods, including legumes, is undesirable and can result in a decrease in products' acceptability. However, several studies indicated that the acceptability or preference for the food products can be increased with repeated exposures (Birch 1999; Skinner and others 2002; Birch and others 2007; Ventura and Worobey 2013). Therefore, giving children more opportunities to consume novel FBFs, especially the sorghum cowpea blends, might help to increase their product preferences.

The overall conclusion from Table 5-2 that infants and young children from Tanzania and the U.S. had similar product preferences might not always be valid, since the results were based on a wide range of children's age and that resulted in the possibility that some important information was overlooked. Table 5-3 shows the results of five paired preference tests from two test locations by separating children into two age groups (6-23 month old and 24-59 month old). The Pearson chi-squared test was performed for each paired preference test within each age group in order to determine whether infants and young children in Tanzania and the U.S. really had the same preferences for FBFs products. Results showed that children's preference for FBFs products in the two test locations were significantly different ($p \leq 0.05$) in some cases, but not in others.

Table 5-3 Results of paired preference test for each product pair in Tanzania and the U.S by each age group.

Paired preference test	Child age (months)	Country	Total number of children	Number of children who preferred each product		*z*-score	*p*-value[1]	χ 2 (df =1)	*p*-value[2]
				CSB+	CSB14				
CSB+ *vs* CSB14	6-23	Tanzania	305	107	**198**	5.15	*<0.0001*	0.02	*0.8998*
		U.S.	50	18	32	1.84	*0.0660*		
	24-59	Tanzania	302	61	**241**	10.30	*<0.0001*	7.74	*0.0054*
		U.S.	50	19	31	1.56	*0.1198*		
				CSB+	SCB1				
CSB+ *vs* SCB1	6-23	Tanzania	302	**174**	128	2.59	*0.0096*	3.22	*0.0726*
		U.S.	50	22	28	0.71	*0.4795*		
	24-59	Tanzania	308	127	**181**	3.02	*0.0025*	2.86	*0.0908*
		U.S.	50	27	23	0.42	*0.6714*		
				CSB+	SCB2				
CSB+ *vs* SCB2	6-23	Tanzania	267	144	123	1.22	*0.2209*	6.69	*0.0097*
		U.S.	50	17	**33**	2.12	*0.0339*		
	24-59	Tanzania	313	164	149	0.79	*0.4288*	2.34	*0.1263*
		U.S.	50	32	18	1.84	*0.0660*		
				CSB+	SCB3				
CSB+ *vs* SCB3	6-23	Tanzania	300	**175**	125	2.83	*0.0047*	10.25	*0.0014*
		U.S.	50	17	**33**	2.12	*0.0339*		
	24-59	Tanzania	301	143	158	0.81	*0.4197*	4.99	*0.0255*
		U.S.	53	34	19	1.92	*0.0544*		
				CSB+	SSB				
CSB+ *vs* SSB	6-23	Tanzania	292	140	152	0.64	*0.5198*	9.91	*0.0016*
		U.S.	50	12	**38**	3.54	*0.0004*		
	24-59	Tanzania	321	138	**183**	2.46	*0.0140*	1.76	*0.1839*
		U.S.	51	27	24	0.28	*0.7794*		

[1] *p*-value of two-sided test using *z*-test statistic, value in bold: significant at alpha = 0.05.

[2] *p*-value of Pearson's chi-square test statistic, df=1.

While Tanzanian children with the age of 24-59 months preferred CSB14 over CSB+, American children at the same age did not have a preference for porridge prepared from CSB14 compared to CSB+. Porridges made from grains, roots, and tubers are the primary supplementary food that children consume along with breast milk in many developing countries (Rowe and others 2008; Moussa and others 2011; Victor and others 2014). This was consistent with the finding from this study that porridges from cereal-based products were the main complementary food for Tanzanian children. Additionally, corn and sorghum were reported as the first two cereal grains that are commonly used to prepare porridges. American children, on the other hand, have the opportunity to be exposed to a variety of food products other than porridges, such as pureed fruits or vegetables and crunchy snack foods. From this finding, Tanzanian children should be more familiar than American children with the flavor of porridges from FBFs that were used in this study. Therefore, it should be easier for Tanzanian children to accept the flavor of novel FBFs, which have grains as main ingredients similar to their current complementary food. Nicklaus (2011) also mentioned that more exposure to one type of food could enhance the acceptability of other similar foods in the same category. Moreover, sweet taste has been reported to promote the child's preference especially in familiar food contexts (Birch 1999). This possibly explains why Tanzanian children had an explicit preference for CSB14 over CSB+.

For the preference comparison between CSB+ and SCB3, children within 24-59 months of age from Tanzania and the U.S. were also significantly different in their product preferences. American children tended to have a preference for CSB+ over SCB3 (p=0.0544), but this was not the case for Tanzanian children in this age group. This was probably because American children in this age group were more familiar with corn flavor rather than the flavor from sorghum or cowpea, since there are many corn-based products available in the U.S. market. Also, Cashdan

(1994) found that the willingness to consume a wide variety of foods, including novel foods, starts decreasing when children are older than 2 years of age.

American children with younger age group (6-23 months) showed a preference for WSC2, RSC, and SSB over CSB+ ($p \leq 0.05$). On the other hand, Tanzanian children with the same age had no preference for WSC2 and SSB compared to the current product (CSB+) ($p > 0.05$) and preferred CSB+ over SCB3 ($p \leq 0.05$). Some of these results contradicted with the overall result from Table 5-2 which stated that children from both test locations preferred SSB over CSB+ and did not have a preference for all sorghum cowpea blends over CSB+. A distinct beany flavor, especially in sorghum cowpea blends (WSC1, WSC2, and RSC), might be considered as a new flavor for children 6-23 months of age in both test locations (Tanzania and the U.S.). However, Cashdan (1994) and Cashdan (1998) reported that children younger than 2 years of age, in general, are more open and willing to try new foods than adults. This might be the reason why American children younger than 2 years of age preferred novel FBFs over CSB+. Tanzanian children within this age group probably get used to uncomplex flavors of their current complementary foods, which mainly consist of only cereal grains (eg. Corn, sorghum), and that resulted in the more preferable in the current FBF (CSB+).

By dividing children into small age groups (6-23 months and 24-59 months), the differences in the child's preference for some paired preference tests between Tanzania and the U.S. occurred, and this was contradicted with the overall conclusions made from children 6-59 months of age. Individual patterns of food preferences could be developed in the very early years of life (Cashdan 1998; Nicklaus 2011). While children are more willing to learn to accept a wide variety of foods during the first two years, this willingness decreases over the next three years (Cashdan 1998). Therefore, foods that children younger than two years of age prefer may not be the same as foods that older children do. The overall conclusions drawn from children with a wide range of ages have to be used with caution, and should be validated with the results from children in small sub-age groups.

This study also showed that culture plays an important role in development of individual food preferences, even in infants and young children. There is generally limited type of foods that can be consumed by infants and young children, but those foods can vary across cultures (Fallon and others 1984; Birch 1995; Shutts and others 2009). Porridges prepared from cereal-based products are the main complementary food for Tanzanian children (Chanadang and others 2016), and that could help them accept new FBFs that are still in the same food category more easily. In contrary, American children are able to access larger variety of complementary food (e.g. pureed fruit and vegetable, crunchy snack foods) and might learn to accept those foods rather than cereal-based porridges during their leaning period. This implies that children from different cultures might not have the same preferences in food products. Therefore, it is essential to conduct consumer studies (acceptability or preference test) with the real target population in the location where the products are expected to be used in order to get useful and logical results.

Conclusions

This study showed that culture really plays an important role in food preferences, even with children who have less experience in a variety of foods than adults. Infants and young children learn to accept or prefer foods that are the same or similar to what they have consumed during their learning period, which can vary across cultures. Therefore, food preferences of children in one culture may not be a valid predictor for food preferences of children in other cultures. Conducting the study with the real target population is recommended in order to get accurate results. Also, the results drawn from a wide age range of children should be used with caution and have to be confirmed with the results from children in each sub-age group.

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Chapter 6 - The Effect of Repeated Exposure on Children's Preference of Novel Fortified Blended Foods

Abstract

Novel fortified blended foods (FBFs) have been developed to use in food aid situations, especially among weaning children around the world. It is important to ensure that novel FBFs are acceptable to infants and young children, and the repeated exposure to a new food is one of the key determinants of its acceptance. This study was conducted to determine children's preference of FBFs and the effect of prolonged product exposure on children's preference of the FBFs. A 20-week field trial was conducted in the Mara region of Tanzania. Qualified children were divided into seven clusters based on geographical locations. Cluster 1 – 6 were randomly assigned to one of the six FBFs - extruded sorghum cowpea blends (two white: WSC1, WSC2, and one red: RSC), a white sorghum cowpea blend (WSS), an extruded corn soy blend (CSB14), or a traditional corn soy blend (CSB+), and cluster 7 was assigned to a group that did not receive any FBFs during the study duration. Paired preference tests between FBF that children received versus other FBFs were conducted in cluster 1-6 and the tests between CSB14 and other FBFs were performed in cluster 7. Results showed that CSB14 was highly preferred by children due to its sweetness and corn flavor that children were already familiar with, little or no repeated exposure was needed in this case. SSB, WSC1, WSC2 and RSC that contained novel ingredients tended to require more time and number of exposures in order to be preferred over other FBFs. For CSB+ that was lower in sweetness, repeated presentation of this product to children could not help to enhance its preference to the point that would it would be preferred over novel FBFs. This study indicated that repeated product exposure could effectively increase children's food preference, but it could be less powerful if the exposed products lack of preferable characteristics.

Introduction

Introducing new foods to infants and young children is often a challenge for parents (Blissett and Fogel 2013). Children's willingness to accept new foods can be influenced by several factors such as children's taste perception, neophobia, sensory properties of foods, and children feeding practices (Nicklaus 2011; Blissett and Fogel 2013). Familiarity, a function of the child's early experience, is one of feeding practices that has been defined as an important determinant of children's food preference or acceptance (Birch 1992; Aldridge and others 2009; Nicklaus 2011). A study from Cooke (2007) also indicated that children's food preference are strongly associated with the strength to individual's familiarity – the more familiar the food is, the more it is liked or preferred. Children's familiarity with foods can be strengthen by giving them more opportunities to expose to the foods (Aldridge and others 2009; Nicklaus 2011). Sullivan and Birch (1994) reported that children's acceptance of novel green vegetables (green beans or peas) increased after they had been exposed to this food 10 times. In addition, repeated exposure was shown to be effective even for the foods that were initially refused by children at the beginning of weaning process (Maier and others 2007).

Food familiarity can occur from either direct taste exposure or mere exposure, however, taste exposure is believed to be the strongest method of forming acceptance and preference for a novel food (Aldridge and others 2009). Nicklaus (2011) also supported that taste exposure to novel foods is sufficient on its own in young children to enhance food preference and acceptance. Providing children with additional information on benefits of foods or offering a reward to the children if they agree to taste the foods showed only small impacts on children's food acceptance (Wardle and others 2003a; Wardle and others 2003b).

Fortified blended foods (FBFs) are a combination of cereals and legumes that fortified with micronutrient and the possible addition of oil and animal-based source protein (Webb and others 2011). FBFs were developed in the 1960s by the United States Agency for International to Development (USAID) to provide a source of nutrition for vulnerable population, especially infants and young children, in developing countries around the world (Perez-Exposito and Klein 2009; Fleige and others 2010). Although FBFs have been widely used in food aid program, there is limited evidence of their effectiveness on improving nutritional outcomes (de Pee and Bloem 2009; Fleige and others 2010). In 2011, the evaluation of FBFs by Tufts University (Webb and others 2011) had recommended improving the current FBFs formulation to improve their quality and ability to meet nutritional needs. These recommendations include improving protein quality by adding whey protein concentrate (WPC), upgrading micronutrient and macronutrient, increasing fat content by the addition of vegetable oil, improving the acceptability of FBFs by adding a flavor enhancer, and increasing nutrient density by increasing solids content of food prepared from FBFs to 20% (Webb and others 2011).

Novel FBFs have been developed according to the recommendations from Webb and others (2011). It is important to ensure that novel FBFs are acceptable to target population, which are infants and young children in developing countries. Therefore, paired preference tests of FBFs throughout a 20-week field trial were conducted to determine i) children's preference of the FBFs and ii) the effect of prolonged product exposure on children's preference of the FBFs.

Materials and Methods

Sample

Extruded FBFs

Five extruded FBFs were selected as novel FBFs in this study i) CSB14 - Corn soy blend 14 ; ii) SSB - White sorghum (Fontanelle 4525 variety) soy blend; iii) WSC1 - White sorghum (Fontanelle 4525 variety) cowpea blend; iv) WSC2 - White sorghum (738Y variety) cowpea blend coded; v) RSC - Red sorghum (217X Burgundy variety) cowpea blend.

Sorghum variety V1 (Fontanelle 4525), V2 (738Y), V3 (217X Burgundy) (Nu Life Market, Scott City, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA) to obtain decorticated flours. Soybeans (Kansas River Valley Experiment Field, Kansas State University, Manhattan, KS, USA) and cowpea grains (LPD Enterprises LLC, Olathe, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA). Commercially milled degermed corn flour was purchased from Agricor, Marion, Indiana, USA. Defatted soy flour was purchased from American Natural Soy, Cherokee, IA, USA.

All the binary formulations - sorghum cowpea, sorghum soy and corn soy were blended in appropriate ratios and were extruded on single screw extruder X-20 (Wenger Manufacturing Co., Sabetha, KS, USA) at screw speed ranged from 500-550 rpm with 18-24% process moisture. The extrudates were cut at the die exit with face-mounted rotary knife and then dried in a gas-fired double pass dryer at 104°C. The dried extrudates were ground using a hammer mill fitted with 315 µm screen and mixed with quantities of sugar (Domino Foods, Inc., Yonkers, NY, USA), whey protein concentrate (WPC80) (Davisco Foods International, Inc., Eden Prarie, MN, USA), non-gmo soybean oil (Zeeland Farm Services, Inc., Zeeland, MI, USA), and vitamin-mineral premix (Research Products Company, Salina, KS, USA) to prepare the fortified blended foods (FBFs) based on FAQR requirements (Webb and others 2011). The proportion of various ingredients in the blend were shown in Table 6-1.

Current non-extruded FBF

Corn soy blend plus (CSB+), a partially cooked product, was produced by Bunge Milling (St. Louis, MO, USA) according to the USDA commodity requirements (USDA, 2014) (Table 6-1).

Table 6-1 Composition of extruded and non-extruded FBFs

Ingredient (%)	Extruded FBF					Non Extruded FBF
	CSB14	SSB	WSC1	WSC2	RSC	CSB+
Sorghum flour		47.6	24.7	24.7	24.7	
Cowpea flour			38.6	38.6	38.6	
Soy flour	15.2	15.7				
Corn Flour	48.1					
Corn (White or Yellow)						78.4
Whole soy bean						20.0
Sugar	15	15	15	15	15	
Whey Protein Concentrate (WPC80)	9.5	9.5	9.5	9.5	9.5	
Vegetable Oil	9.0	9.0	9.0	9.0	9.0	
Vitamins and Mineral Premix	3.2	3.2	3.2	3.2	3.2	
Vitamin/Mineral						0.2
Tri-Calcium Phosphate						1.2
Potassium Chloride						0.2

Sample preparation

All FBFs in this study were prepared into drinkable porridges that were the most common complementary food made from cereal-based products and eaten by children in developing countries, the expected areas of products use (Rowe and others 2008; Moussa and others 2011; Chanadang and others 2016).

Extruded FBFs

Extruded FBFs in this study are considered as fully cooked products that do not need any additional preparation other than adding water, however, cooking the extruded products before consumption is recommended because of the poor water quality in many areas that these products will be used.

One cup of extruded FBFs was mix with one cup of cold water to prevent formation of lump. The mixture was then added into one cup of boiling water, brought back to a boil, and cooked for 2 minutes while continuously stirring with a wooden spoon. The cooked porridge was removed from stovetop and transferred to thermos to keep porridge warm.

Non-extruded FBF

Porridge prepared from CSB+ was followed the same cooking procedure used for extruded FBFs except it required more water and longer cooking time. One cup of CSB+ was mix with two cups of cold water to prevent formation of lump. The mixture was then added into two cups of boiling water, brought back to a boil, cooked for 10 minutes and continuously stirring with a wooden spoon. The cooked porridge was removed from stovetop and transferred to thermos to keep porridge warm.

Subject recruiting, clustering, and randomization

The study was conducted in the Mara region of Tanzania. Screening sessions were performed by community mobilizers and trained enumerators at twenty-one local health facilities. To qualify for this study, children had to meet the following criteria: i) had to be 6-53 months of age in order to allow children to complete the 20-week study before their 5^{th} birthday ii) had weight-for-height z score > -3 (not severe undernutrition) (World Health Organization and Unicef 2009), iii) were referred to health facilities for the following care, iv) had hemoglobin levels < 10.5 mg/dl, and v) got permission from their parents or guardians to participate in the study.

Twenty-one health facilities were assigned to 7 clusters based on geographical location (Table 6-2). Cluster 1 – 6 were randomly assigned to one of the six FBFs, and cluster 7 was assigned to control group that did not receive any products during the study.

For cluster 1-6, mothers or caregivers received the assigned FBF for cooking and feeding to their child at home every 2 weeks for 20 weeks. At the first day of field trial (baseline), local enumerators gave an instruction to caregivers on how to prepare porridge from each FBF properly. However, they could adjust the cooking procedure if needed. Caregivers were also instructed to feed their child with the porridge prepared from received FBF three times per day (breakfast, lunch, dinner) for 20 weeks.

Table 6-2 Products, health facilities, and number of children for each cluster

Cluster	Product	Health Facilities	Number of children[1]
1	CSB+	Sazira, Mcharo, Mugeta	260
2	CSB14	Kabasa, Machimweru, Nyamatoke	267
3	SSB	Sarawe, Ikizu, Kurusanga, Mariwanda	253
4	WSC1	Marambeka, Salama A, Salama K	253
5	WSC2	Mekomarilo, Kangetutya	274
6	RSC	Kuzungu, Mihale, Hunyari, Nyanburundu	269
7	Control (no product)	Guta, Nyangere	270
Total			1846

[1]Number of children who completed paired preference tests for a 20-week trial period.

Paired preference test

Participants in each cluster were divided into three groups randomized to one of the three paired preference tests (Table 6-3). For cluster 1-6, three paired preference tests were conducted within each cluster to compare child preferences between the FBF they were receiving and 3 other FBFs. For example, cluster 1compared child preferences between CSB14 (received product) and 3 other FBFs. Cluster 7 also compared child preferences between CSB14 and 3 other FBFs, however, children in this cluster were not receiving any FBFs during a 20-week field trial.

Table 6-3 Paired preference tests for each cluster

Cluster	Treatment	Paired preference test		
1	CSB+	CSB+ vs. SSB	CSB+ vs. WSC1	CSB+ vs. CSB14
2	CSB14	CSB14 vs. SSB	CSB14 vs. WSC1	CSB14 vs. RSC
3	SSB	SSB vs. WSC1	SSB vs .WSC2	SSB vs. CSB14
4	WSC1	WSC1 vs. WSC2	WSC1 vs. RSC	WSC1 vs. CSB14
5	WSC2	WSC2 vs. CSB+	WSC2 vs. RSC	WSC2 vs. CSB14
6	RSC	RSC vs. CSB+	RSC vs. SSB	RSC vs. CSB14
7	Control (no product)	CSB14 vs. SSB	CSB14 vs. WSC1	CSB14 vs. RSC

Paired preference tests were conducted at local health facilities at 3 time points – baseline (first day of study), midline (week 10), and end line (week 20). At each time point, each child tasted 2 porridges prepared from 2 FBFs according to the pair that they were assigned. After the child finished tasting the 2 FBFs, a local enumerator recorded which sample the child preferred. For 6-23 month old children, preference was interpreted from their reaction to both porridges by their mothers or caregivers. The older children, 24-59 month old children, were asked by local enumerators or their caregivers which FBF they preferred. Each child tasted the same pair of porridges at study baseline, midline, and end line.

Data Analysis

Results of paired preference tests were reported as the number of children who preferred each product. Data within pairs were analyzed separately because children had different prior experiences with the products at the midline and end line tests.

Data from each pair of each time point was analyzed by a binomial approximation z-test to determine whether children had a preference for one product over the other. The z-score associated with the results of specific paired preference test can be calculated as follows (Stone and Sidel 1978; Lawless and Heymann 2010):

$$z = \frac{\left(X - \frac{N}{2}\right) - 0.5}{0.5\sqrt{N}} \quad (1)$$

Where, within each pair, X was the number of children for the most preferred sample and N was the total number of children. The critical z-score of 1.96 was used for a two-sided test (either product can be preferred) with $\alpha = 0.05$. The calculated z-score had to be larger than 1.96 for the result to be statistical significant (Lawless and Heymann 2010).

Results and Discussion

Children's preference at the initial exposure to FBFs

Children's preference for each FBF over a 20-week trial were presented in Table 6-4. Children were first introduced to porridges prepared from their assigned FBF and one other FBF at the first day of the study (baseline). At this time point, children's preference on porridges from all novel FBFs appeared to be significantly higher ($p<0.05$) or comparable to the one made from current FBF (CSB+).

While corn (78.4%) and soybean (20%) were the only two main compositions for CSB+, novel FBFs were formulated with more ingredients other than those in CSB+ such as sugar and oil. Novel FBFs contained 15% sugar in formulations, and that resulted in a higher intensity of sweetness than CSB+. Several previous studies indicated that infants and children usually preferred sweet-tasting food and beverages since sweetness is a signal for calories and also has ability to reduce pain continues during childhood (Pepino and Mennella 2005; Mennella and others 2010; Ventura and Mennella 2011; Drewnowski and others 2012; Ventura and Worobey 2013; Mennella and Bobowski 2015). This probably explained why children in this study preferred porridges from novel FBFs (CSB14, SSB, and WSC1) to the one made from CSB+, even the first time they had been tasted these products. Vegetable oil that had been added to novel FBFs could also enhance the child preferences of the products. The lubricating action of fat and oil could help in decreasing in size of lumps of cooked porridges (Drewnowski and Almiron-Roig 2010; Chanadang and others 2016) and make them easier to be eaten and swallowed by infants and young children.

Table 6-4 Children's preference for each FBF over a-20 week period

Cluster	Paired preference test: Received product	Paired preference test: Compared product	Total number of children	Baseline: Number of children who preferred each product		z-score	Midline: Number of children who preferred each product		z-score	End line: Number of children who preferred each product		z-score
				CSB+	Compared product		CSB+	Compared product		CSB+	Compared product	
1	CSB+	SSB	91	35	**56**	2.10*	45	46	0.00	35	**56**	2.10*
		WSC1	89	33	**56**	2.33*	47	42	0.42	40	49	0.85
		CSB14	80	28	**52**	2.57*	30	50	2.12	32	48	1.68
				CSB14	Compared product		CSB14	Compared product		CSB14	Compared product	
2	CSB14	SSB	84	44	40	0.33	**57**	27	3.16**	**56**	28	2.95**
		WSC1	93	**63**	30	3.32***	**77**	16	6.22***	**90**	3	8.92***
		RSC	90	**65**	25	4.11***	**65**	25	4.11***	**82**	8	7.69***
				SSB	Compared product		SSB	Compared product		SSB	Compared product	
3	SSB	WSC1	96	47	49	0.10	**67**	29	3.78**	**61**	35	2.55*
		WSC2	77	**52**	25	2.96**	**65**	12	5.93***	**66**	11	6.15***
		CSB14	80	37	43	0.56	39	41	0.11	35	45	1.01
				WSC1	Compared product		WSC1	Compared product		WSC1	Compared product	
4	WSC1	WSC2	89	**61**	28	3.39**	52	37	1.48	**55**	34	2.12*
		RSC	79	**49**	30	2.03*	**65**	14	5.63***	**63**	16	5.18***
		CSB14	85	40	45	0.43	25	**60**	3.69**	33	52	1.95
				WSC2	Compared product		WSC2	Compared product		WSC2	Compared product	
5	WSC2	CSB+	88	53	35	1.81	**68**	20	5.01***	**71**	17	5.65***
		RSC	103	**66**	37	2.76**	**69**	34	3.35**	58	45	1.18
		CSB14	83	28	**55**	2.85**	42	41	0.00	43	40	0.22
				RSC	Compared product		RSC	Compared product		RSC	Compared product	
6	RSC	CSB+	95	57	38	1.85	**71**	24	4.72***	**81**	14	6.77***
		SSB	89	41	48	0.64	**64**	25	4.03**	**58**	31	2.76**
		CSB14	85	41	44	0.22	**57**	28	3.04**	**65**	20	4.77***

[1] ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.; value in bold: significant preference

Children did not have a preference on porridges prepared from WSC2 and RSC over CSB+. Cowpea, the main composition in sorghum cowpea blends, are infrequency added to complementary food for Tanzanian children, because of the limited opportunities to access to these ingredients (Victor and others 2014). In addition, legumes including soybean and cowpea normally have beany flavor that sometimes are considered as undesirable flavors for consumers (Bott and Chambers 2006; Martin and others 2010; Glover-Amengor and others 2013), especially for the ones who do not regularly consume this type of product. Therefore, children in this study might not be familiar with beany flavor from cowpea and tended not to have a preference on these products for their first consumption.

Among novel FBFs, CSB14 and SSB had higher preference ($p<0.05$) or comparable in preference to the three sorghum cowpea blends (WSC1, WSC2, and RSC). Based on their formulations, sorghum cowpea blends contained higher amount of legume (cowpea) compared to those in CSB14 and SSB. Thus, porridges made from sorghum cowpea products should have higher intensity of unfamiliar beany flavors, resulting in a lower preference for sorghum cowpea blends in some paired preference tests, but not in others.

Children's preference after repeated exposure to their assigned FBF

Once children started to expose to porridge made from their assigned FBF and repeatedly consumed for 20 weeks, the preferences on their received product increased at midline and end line testing in most cases (Table 6-4). Several previous studies also reported the effectiveness of repeated exposure on promoting children's food preference (Sullivan and Birch 1994; Maier and others 2007; Cooke 2007; Howard and others 2012; Anzman-Frasca and others 2012), even for the food that were initially refused by children (Maier and others 2007).

Children's preference for porridge from the current FBF (CSB+) were improved when children had more opportunities to expose to this product. However, the repeated exposure to CSB+ could not help to enhance children's preference to the point that children would prefer CSB+ over the 3 novel FBFs. This was probably due to the bland flavor and lack of sweetness in CSB+ since its flavor primary came from the only 2 main components – corn and soybean. Several studies mentioned that sweetness has a powerful hedonic appeal, especially for infants and young children (Popkin and Nielsen 2003; Drewnowski and others 2012; Mennella and Bobowski 2015). Even though children get more familiar with the flavor of CSB+, it was still difficult for this product to compete with novel FBFs that had higher intensity in sweetness. More than half of caregivers reported that they usually added sugar to CSB+ porridge when they cooked this product at home in order to increase the child's acceptability and consumption.

For CSB14 cluster, children's preference for the received product also increased when they were repeatedly exposed to the product. This preference pattern might not clearly seen when compared CSB14 with WSC1 and RSC since it was initially preferred over the other 2 novel FBFs at the beginning of the study. Before participating in this study, the majority of children (66.35%) typically consumed porridges prepared from maize or corn flour. This implied that children in this study were already familiar with corn flavor. Thus, no surprise that novel FBFs that had corn as the main ingredient as CSB14 was accepted by children quickly, even at the first day of the study. In addition, the sweetness in CSB14 also promoted children's preference of the product.

Children's preferences for SSB, WSC1, WSC2 and RSC also increased when children exposed to these products more frequently. However, the preferences for SSB, WSC1, and WSC2 did not show any improvement over time when compared with CSB14. This probably due to the strong familiarity with corn flavor in CSB14. Cashdan (1998) and Nicklaus (2011) reported that individual patterns of food preferences could be developed in the early years of life. Therefore, children in this study might already learn to accept or prefer corn flavor before participating in the field trial and it was difficult to change. The preference for RSC, on the other hand, was increased over CSB14 when children repeatedly consumed porridges made from RSC for 20 weeks. Red sorghum was another cereal grain, besides corn, that had been used previously to prepare home-cooked porridge for children in this study. Although red sorghum was not frequently used compared to corn, children should already had some familiarity with red sorghum flavor. The early-life experience of red sorghum product could probably encourage children to accept and learn to prefer porridge prepared from RSC that also had red sorghum as an ingredient more easily.

Comparison of children's preference when they were repeatedly exposed to different stimuli

When looking at the same paired preference tests, children had different patterns of their food preferences over time when they were repeatedly exposed to different products (Table 6-5). Children who received CSB14 showed a higher preference for CSB14 over the 3 other products (SSB, WSC1, RSC) for the entire study duration, even though all of them had the same level of sweetness. As mentioned previously, corn porridge was the most typical complementary food that children in this study consumed at home. The early exposure to a corn based product could effectively promote children's preference of new product - CSB14 that had been formulated mainly with corn flour. Remy and others (2013) indicated that the child's preference of new food at complementary feeding might depend on previous feeding experience. Birch (1999) also mentioned that young children are normally preferred sweet-tasting food but only when it is in familiar food context. This might explain why children in this study had strong preference for CSB14 over other novel FBFs.

Children who received SSB and WSC1 did not prefer these two products over CSB14, even after they were repeatedly exposed to these two novel FBFs. SSB and WSC1 might be considered as completely new products to children since they were composed of unfamiliar ingredients including white sorghum, soybean, and cowpea. Although repeated exposure to SSB and WSC1 could increase children's familiarity for these two products, it might not be as strong as the familiarity that they had for corn flavor in CSB14. Therefore, it might be difficult for SSB and WSC1 to have a higher preference than CSB14 that had more familiar flavor for children in this study. Cooke (2007) reported that children's food preference are associated with the strength to the individual's familiarity with a certain food – the more familiar the food is, the more it is preferred.

Children showed a higher preference for RSC over CSB14 when they had more opportunities to consume this product. RSC also contained cowpea that children in this study were not familiar with and this ingredient could negatively affect product preference. However, this unfamiliar ingredient was blended with red sorghum that children might had some familiarity through their early experience. Therefore, children might need less time for repeated exposure to RSC than SSB and WSC1 in order to have the same level or stronger familiarity compared to CSB14, and this could resulted in a quick development of children's preference for RSC. Previous studies reported that mixing or pairing novel or unfamiliar food with familiar ones could increase the acceptance of novel food items (Pliner and Stallberg-White 2000; Bingham and others 2005). Birch (1992) and Aldridge and others (2009) also indicated that unfamiliar food are more quickly and frequently preferred and consumed when they are linked with the familiar items.

Table 6-5 Children's preference when they were repeatedly exposed to different stimuli

Stimulus[1]	Paired preference test	Total number of children	Baseline		z-score	Midline		z-score	End line		z-score
			Number of children who preferred each product			Number of children who preferred each product			Number of children who preferred each product		
	CSB14 *vs* SSB		CSB14	SSB		CSB14	SSB		CSB14	SSB	
1	Received CSB14	84	44	40	0.33	**57**	27	3.16**[2]	**56**	28	2.95**
2	Received SSB	80	37	43	0.56	39	41	0.11	35	45	1.01
3	No products received	102	45	57	1.09	52	50	0.10	**62**	40	2.08*
	CSB14 *vs* WSC1		CSB14	WSC1		CSB14	WSC1		CSB14	WSC1	
1	Received CSB14	93	**63**	30	3.32***	**77**	16	6.22***	**90**	3	8.92***
2	Received WSC1	85	45	40	0.43	**60**	25	3.69**	52	33	1.95
3	No products received	84	44	40	0.33	**60**	24	3.82**	**69**	15	5.78***
	CSB14 *vs* RSC		CSB14	RSC		CSB14	RSC		CSB14	RSC	
1	Received CSB14	90	**65**	25	4.11***	**65**	25	4.11***	**82**	8	7.69***
2	Received RSC	85	44	41	0.22	28	**57**	3.04**	20	**65**	4.77***
3	No products received	84	51	33	1.85	43	41	0.11	**54**	30	2.51*

[1] 1- Children received CSB14 over a 20-week trial, 2- Children received either SSB, WSC1, or RSC over a 20-week trial, 3- Children did not receive both of products over a 20-week trial.

[2] ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.; value in bold: significant preference

Surprisingly, children who did not received any FBFs throughout the field trial showed a higher preference for CSB14 over the 3 compared products during study duration. This indicated that repeated exposure might not be necessary for CSB14 in order to be highly preferred or accepted by children. Although children in this group did not receive any tested products for a 20-week study, they were still consuming porridge that was primarily prepared from corn (more available and accessible ingredients in that area) during that period and this made them were familiar with corn flavor. A study by Birch and Sullivan (1991) showed that sweetness and familiarity were the two important determinant of children's food preference. The familiar ingredient used in CSB14 and its sweetness probably make CSB14 more superior than any other FBFs and typical commentary food currently used in that area, and thus contributed to a higher preference level for this product.

Conclusion

In general, repeated exposure to FBFs could be able to increase children's food preference. However, repeated exposure might be less effective if the exposed product lacks of preferable sensory properties such as sweetness. Novel FBFs with the ingredients that children are already familiar with are more easier to be highly preferred by children, even for the first time they have been exposed to this product. For novel FBFs with novel ingredients, on the other hand, might need more time and number of exposures to allow children to have experience and familiar with the food before being personally satisfied or preferred that food. This indicated that characteristics of each FBF are the key determinants of the effectiveness of repeated exposure on children's food preferences.

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Chapter 7 - The Child's Acceptability and Household Level Behaviors of Novel Fortified Blended Foods

Abstract

Novel fortified blended foods (FBFs) have been developed to deliver sufficient nutrients for children's growth and development. These products must be acceptable to the target population: children who eat the food and caregivers who prepare it. A 20-week field trial was conducted to determine children's acceptability of FBFs and to measure household level behaviors including preparation, consumption, and storage practices. Five extruded FBFs and one current FBF (corn soy blend plus; CSB+) were made. Acceptability test of porridges made from each FBF among children were conducted in Mara region of Tanzania. An interview and a household visit were conducted to collect information on household level behaviors. Acceptance testing showed that children's acceptability of porridges prepared from all FBFs increased overtime due to the repeated exposure to the products. However, CSB+ porridge had lower acceptability from children at the end of the study, probably due to the lack of sweetness. At the same amount of porridges that children consumed, the ones from novel FBFs appeared to provide more energy and nutrients than CSB+. Moreover, porridges made from novel FBFs required less cooking time than CSB+ and no ingredients needed to be added compared to CSB+ where sugar and milk were common additions. This indicated that novel FBFs have potential to be used as alternative supplementary food with higher acceptability and more nutrient density to currently used CSB+. In addition, the simple cooking for novel FBFs make them valuable to caregivers with limited time and access to energy sources and nutrient-rich ingredients.

Introduction

Malnutrition or undernutrition is an important problem in many developing countries and affects adversely the health and growth of children (Nyaruhucha and others 2007). Food aid can be used as an important tool in addressing malnourishment and certain food insecurity issues. In fiscal year 2015, the United State Government provided nearly $1.9 billion of food assistant and procured about 1.5 million metric tons of food, to serve a total of 36 million beneficiaries in 43 countries (USAID 2015). Food commodities provided by the U.S. Government include whole grains, pulses, vegetable oil, and cereal-based foods fortified with macronutrient and micronutrient (USAID 2015; Rowe and others 2008). Most of these food commodities are distributed in Africa (83%) (USAID 2015).

Fortified blended foods (FBFs) are a combination of binary blends of cereals and legumes with the addition of oil along with added micronutrients and the possible addition of an animal-based source of protein (Wood and others 2008; Webb and others 2011). Corn-Soy Milk (CSM) and Wheat-Soy Milk (WSM) were the first two original formulations of FBFs developed in 1967 by the United States Agency for International Development (USAID). Corn-Soy Blend (CSB) was later developed in the 1980s to replace CSM and WSM due to the increasing cost and shortage of non-fat dry milk, the main component for CSM and WSM (Perez-Exposito and Klein 2009; Fleige and others 2010; Webb and others 2011). There were some modifications that had been made to the FBFs in the early of 1990s, however, no significant changes had been done to their formulations in order to improve their quality (Fleige and others 2010).

The recent evaluation of FBFs by Tufts University had recommended changing the current formulation of FBFs to improve their quality and ability to meet nutritional needs (Webb and others 2011). These recommendations included upgrading micronutrient and macronutrient composition in FBFs, increasing protein quality by using animal-source protein, increasing fat content through the addition of vegetable oil, improving the acceptability and consumption of FBFs by adding a flavor enhancer, and exploring the new grains or legumes that could be used beyond corn and soybeans (Webb and others 2011). Increasing solids content of food prepared from FBFs to 20% in order to increase nutrient content is another recommendation from (Webb and others 2011). However, food prepared from the current FBFs at this concentration might be too viscous for consumption by infants and young children (Black and others 2009). Extrusion is a cooking process with high temperature that can cook or gelatinize the starchy ingredients in FBFs, resulting in less viscous cooked porridges, which make them more suitable for delivering higher density energy meals at lower viscosities for infants and young children (Ozcan and Jackson 2005). By following these recommendations, the novel FBFs have been developed in order to meet the goal of food security.

It is important to determine the ability of novel FBFs to meet the needs of target population including children who eat the food and mothers or caregivers who prepare it. Therefore, a 20-week field trial had been conducted to obtain observational and interview data regarding the household level behaviors such as preparation techniques and storage practices of these new formulated, extruded FBFs. The child's acceptability of the products also evaluated during field trial in order to determine the potential of using novel extruded FBFs as an alternative complementary food.

Materials and Methods

Sample

Five extruded FBFs and one current non-extruded FBF were used in this study (Figure 7-1).

Extruded FBFs

Five extruded FBFs were selected as novel FBFs in this study i) Corn soy blend 14 coded as CSB14; ii) White sorghum (Fontanelle 4525 variety) soy blend coded as SSB; iii) White sorghum (Fontanelle 4525 variety) cowpea blend coded as WSC1; iv) White sorghum (738Y variety) cowpea blend coded as WSC2; v) Red sorghum (217X Burgundy variety) cowpea blend coded as RSC.

Sorghum variety V1 (Fontanelle 4525), V2 (738Y), V3 (217X Burgundy) (Nu Life Market, Scott City, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA) to obtain decorticated flours. Soybeans (Kansas River Valley Experiment Field, Kansas State University, Manhattan, KS, USA) and cowpea grains (LPD Enterprises LLC, Olathe, KS, USA) were milled at Hall Ross Flour Mill (Kansas State University, Manhattan, KS, USA). Commercially milled degermed corn flour was purchased from Agricor, Marion, Indiana, USA. Defatted soy flour was purchased from American Natural Soy, Cherokee, IA, USA.

All the binary formulations – sorghum cowpea (39% sorghum, 61% cowpea), sorghum soy (75% sorghum, 25% soy) and corn soy (76% corn, 24% soy) were extruded on single screw extruder X-20 (Wenger Manufacturing Co., Sabetha, KS, USA) at screw speed ranged from 500-550 rpm with 18-24% process moisture. The extrudates were cut at the die exit with face-mounted rotary knife and then dried in a gas-fired double pass dryer at 104°C. The dried extrudates were ground using a hammer mill fitted with 315 μm screen and mixed with quantities of sugar (Domino Foods, Inc., Yonkers, NY, USA), whey protein concentrate (WPC80) (Davisco Foods International, Inc., Eden Prarie, MN, USA), non-gmo soybean oil (Zeeland Farm Services, Inc., Zeeland, MI, USA), and vitamin-mineral premix (Research Products Company, Salina, KS, USA) to prepare the fortified blended foods (FBFs) based on FAQR requirements (Webb and others 2011). The proportion of various ingredients in the blend were shown in Table 7-1.

Current non-extruded FBF

Corn soy blend plus (CSB+), a partially cooked product, was produced by Bunge Milling (St. Louis, MO, USA) according to the USDA commodity requirements (USDA, 2014) (Table 7-1).

Table 7-1 Composition of extruded and non-extruded FBFs.

Ingredient (%)	Extruded FBFs[1]	Non-Extruded FBF [2]
Extrudates	63.30	
Corn (White or Yellow)		78.4
Whole soy bean		20.0
Sugar	15.00	
Whey Protein Concentrate (WPC80)	9.50	
Vegetable Oil	9.00	
Vitamins and Mineral Premix	3.20	
Vitamin/Mineral		0.2
Tri-Calcium Phosphate		1.2
Potassium Chloride		0.2

[1]Extruded FBFs : CSB14, SSB, WSC1, WSC2, RSC

[2]Non-extruded FBF : CSB+

Sample preparation

All FBFs in this study were prepared into porridges which were the most common dishes made from cereal-based products and eaten by children, especially in developing countries (Rowe and others 2008; Moussa and others 2011; Chanadang and others 2016).

Porridges from all FBFs were prepared with appropriate solid contents that were close to 20% solid contents for extruded FBFs (Webb and others 2011) and 13.79% solid contents for current non-extruded FBF (USDA 2014) (Figure 7-1). Since FBFs in this study were intended to use by people in developing countries with low level of education and had limited facilities, a simple porridge cooking procedure had been developed. The procedure was easy to follow, repeatable and can be done with local utensils.

Extruded FBFs

One cup of extruded FBFs was mix with one cup of cold water to prevent formation of lump. The mixture was then added into one cup of boiling water, brought back to a boil, and cooked for 2 minutes while continuously stirring with a wooden spoon. The sample was removed from the stovetop and transferred to thermos to keep porridge warm.

Current non-extruded FBF

Porridge prepared from CSB+ was followed the same cooking procedure used for extruded FBFs except it required more water and longer cooking time. One cups of CSB+ was mix with two cups of cold water to prevent formation of lump. The mixture was then added into two cups of boiling water, brought back to a boil, cooked for 10 minutes and continuously stirring with a wooden spoon. The sample was removed from the stovetop and transferred to thermos to keep porridge warm.

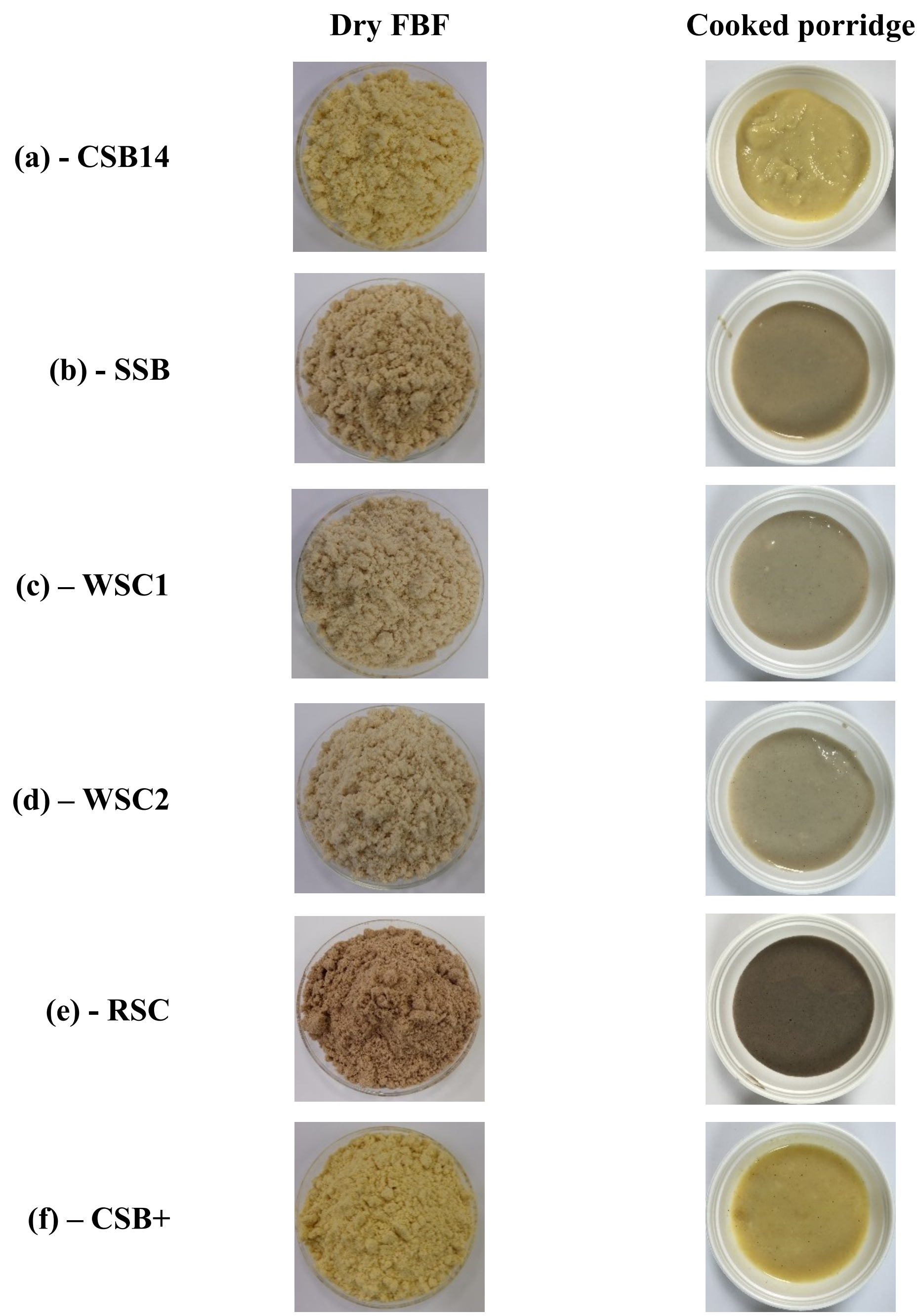

Figure 7-1 FBFs used in a 20-week field trial and cooked porridge prepared from each FBF.
(a) to (e)- Extruded FBF, (f)- Current non-extruded FBF.

A 20-week field trial

The study was conducted in the Mara region of Tanzania. Screening sessions were performed by community mobilizers and trained enumerators at nineteen local health facilities. To qualify for this study, children had to meet the following criteria: i) had weight-for-height z score > -3 (not severe undernutrition) (WHO and Unicef 2009), ii) were referred to health facilities for the following care, iii) had hemoglobin levels < 10.5 mg/dl, iv) had to be 6-53 months of age in order to allow children to complete the 20-week study before their 5th birthday and v) got permission from their parents or guardians to participate in the study.

Nineteen health facilities were assigned to 6 clusters based on geographical location and sample size, and then randomized to one of six FBFs (Table 7-2). A total of 1774 children were qualified and participated at the beginning of the study. However, 182 children dropped out during the study period due to their health issues or changes of location. The number of children who completed the study were also shown in Table 7-2.

Table 7-2 Products, health facilities, and number of children for each cluster

Cluster	**Product**	**Health Facilities**	**Number of children**[1]
1	CSB+	Sazira, Mcharo, Mugeta	253
2	CSB14	Kabasa, Machimweru, Nyamatoke	276
3	SSB	Sarawe, Ikizu, Kurusanga, Mariwanda	261
4	WSC1	Marambeka, Salama A, Salama K	253
5	WSC2	Mekomarilo, Kangetutya	280
6	RSC	Kuzungu, Mihale, Hunyari, Nyanburundu	269
Total			1592

[1]Number of children who completed a 20-week study.

Mothers or caregivers received one of the six FBFs for cooking and feeding of their child at home every 2 weeks for 20 weeks. At the first day of field trial (baseline), local enumerators gave an instruction to mothers or caregivers on how to prepare porridge from each FBF properly (Figure 7-2). However, they could adjust the cooking procedure if needed.

Local enumerators from Project Concern International (PCL) were trained by staff from Kansas State University (KSU) to collect data from children and their caregivers during the food distributions and household visits (Table 7-3). The child's acceptability of tested products was collected as well as household level behaviors including consumption, preparation, and storage practices (Figure 7-2).

(a) (b) (c) (d)

Figure 7-2 Activities during a 20-week field trial.

(a)-Enumerator taught caregivers to prepare porridge from each FBF; (b)-Enumerators collected sensory data from the child and caregiver; (c)-Local enumerators weighted FBF for each child; (d)-Caregivers received the assigned FBF and bring it back home to cook for their child.

Table 7-3 Data collection for a 20-week field trial.

Time period	Child's acceptability		Household behavior			Household visit[3]
	Child's response[1]	Caregivers perception[2]	Cooking practice	Ease of cooking	Additional ingredient	
Baseline (First day)	X		X	X	X	
2 weeks		X	X	X	X	
4 weeks		X	X	X	X	
6 weeks		X	X	X	X	
8 weeks		X	X	X	X	
Midline (10 weeks)	X		X	X	X	X
12 weeks		X	X	X	X	
14 weeks		X	X	X	X	
16 weeks		X	X	X	X	
18 weeks		X	X	X	X	
Endline (20 weeks)	X	X	X	X	X	

[1]Local enumerators cooked porridges at local health facilities for children to measure their acceptability of the product.
[2] Caregivers reported their child's overall acceptability of porridge prepared from the received product, which cooked at their home.
[3] Approximately 100 participant households for each cluster were visited by community mobilizers to collect data including viscosity of cooked porridge, preparation, storage and consumption behavior.

Data collection during food distributions

Acceptability testing was designed to determine children' acceptability of the tested (eaten) product and the effect of repeated exposure to that product over an extended period.

At baseline (first day), midline (10 weeks), and endline (20 weeks), children tasted porridge prepared at local health facilities for the product they received for the study duration. After tasting, the overall acceptability of prepared porridge was collected using a 5-point hedonic scale (1=Dislike very much, 5=Like very much). For 6-23 month old children, overall acceptability was interpreted from facial, hand, or head movements by their caregivers. For 24-59 month old children, they were asked by their mothers or local enumerators to score their overall acceptability.

At baseline, mothers or caregivers were asked to report the complementary food that they typically prepared for their child and preparation techniques for that food including cooking time, ease of cooking, and additional ingredients. At midline and endline, caregivers were also asked to report individual preparation techniques for FBF they received during field trial.

During food distribution outside of baseline, midpoint and endline, mothers or caregivers were asked to report their FBF preparation method and their child's overall acceptability of porridge cooked at home using the 5-point hedonic scale.

Data collection during household visit

Approximately one hundred households (50% of children aged 6-23 months and 50% of children aged 24-59 months) in each cluster were randomly selected for a household visit during the middle of the field trial to collect information on household level behavior. During the household visit, interview and observational data on the use of FBFs including cooking time, additional ingredients, consumption, and storage practices were collected by community mobilizers from PCI. Porridge viscosity at serving time was measured by a Bostwick Consistometer (CSC Scientific Company Inc., Fairfax, VA, U.S.A.) as an indicator of solids content of the product. The recommended flow rate for FBFs is between 9.0-21.0 cm/min (USDA 2010). The Porridge temperature at the time when measuring viscosity was recorded using a Thermapen ® Mk4 (ThermoWorks, American Fork, UT, USA). Measuring cups were used as portion size estimation aids in order to obtain more accurate measures of the amount of porridge eaten per meal and per day by the study child. Serving size estimated from measuring cups were then converted to a metric unit of volume (milliliter; ml).

Data analysis

Acceptability data from each cluster was analyzed by analysis of variance (ANOVA) with repeated measures overtime (SAS version 9.4, The SAS Institute Inc., Cary, NC, USA). Tukey's HSD test was used to determine the effects of time on the comparison of acceptability of the products, with significance at $p<0.05$.

ANOVA was also used to test whether differences occurred across products for household level behaviors including serving size, cooking time, porridge temperature, and porridge consistency. Tukey's HSD test was used at the 5% level of significance to locate significant effect of product on each parameter.

Other household level behaviors (e.g. additional ingredient, storage method for left over porridge) were summarized with basic statistics (including means, standard deviations, and percentages) in Excel (Microsoft Corporation, Redmond, WA).

Results and Discussion

Current complementary food

At the first day of the trial, mother reported complementary food that they typically prepared and fed to their child (Table 7-4). As expected, porridge was the supplementary food that children below the age of 5 in this study commonly consumed. The majority of participated children were given either porridge prepared from whole maize (corn) flour (66.35%) or red sorghum flour (22.75%). This finding was consistent with the study by Nyaruhucha and others (2007), which indicated that the most common complementary food that children in Simanjiro District of Tanzania consume is porridge from maize. Mamiro and others (2005) and Victor and others (2014) also reported that the main food that typically given to children in Tanzania are mainly prepare from cereal grains, roots and tubers. Meat products, legumes, fish and vitamin A-rich food are infrequently consumed by young children, mainly due to the limited opportunities to access these foods (Dang and others 2005; Victor and others 2014).

Total time that caregivers used to cook porridges varied widely from household to household with the average of 32.29 minutes. These differences could be probably due to many factors such as type of energy sources, ingredients, cooking locations, and the amount of porridge that caregivers have to cook each time. This cooking pattern was similar to the field study conducted in Uganda, Malawi, and Guatemala (Rowe and others 2008).

Table 7-4 Current complementary food consumed by children (n=1592)

Parameter	
Current complementary food (%)	
Porridge from whole maize flour (Dona)	66.35
Porridge from white sorghum flour	2.41
Porridge from red sorghum flour	22.75
Porridge from cassava flour	1.08
Porridge from a mixture of flours- with cereals like maize, sorghum, rice and legumes like chick peas , and oilseeds like groundnuts	4.31
Normal adult food –mainly comprising of solid staples like maize and sorghum	3.11
Cooking time for current porridge (min)	
Minimum	10
Maximum	85
Average	32.29

Child's acceptability

The child's acceptability of porridge prepared from each FBF was measured based on either responses of children or perceptions of mothers over a 20-week study. Figure 7-3 showed the acceptability of each product from children responses (they tasted porridges at local health facilities and their acceptability were recorded by local enumerators) at the first day, 10 weeks, and 20 weeks. The acceptability for porridge made from SSB started with the higher score than other products and remained stable until the end of the study. It appeared that the number of children who currently consume porridge prepared from sorghum in SSB cluster (30%) was higher than most of other clusters (19% - 25%). This implied that more children in SSB cluster might be already familiar with sorghum flavor, and that could resulted in the higher acceptability score for

SSB than the others at the beginning of the study. Food familiarity was reported to be one of the important keys to promote product acceptability (Birch 1999).

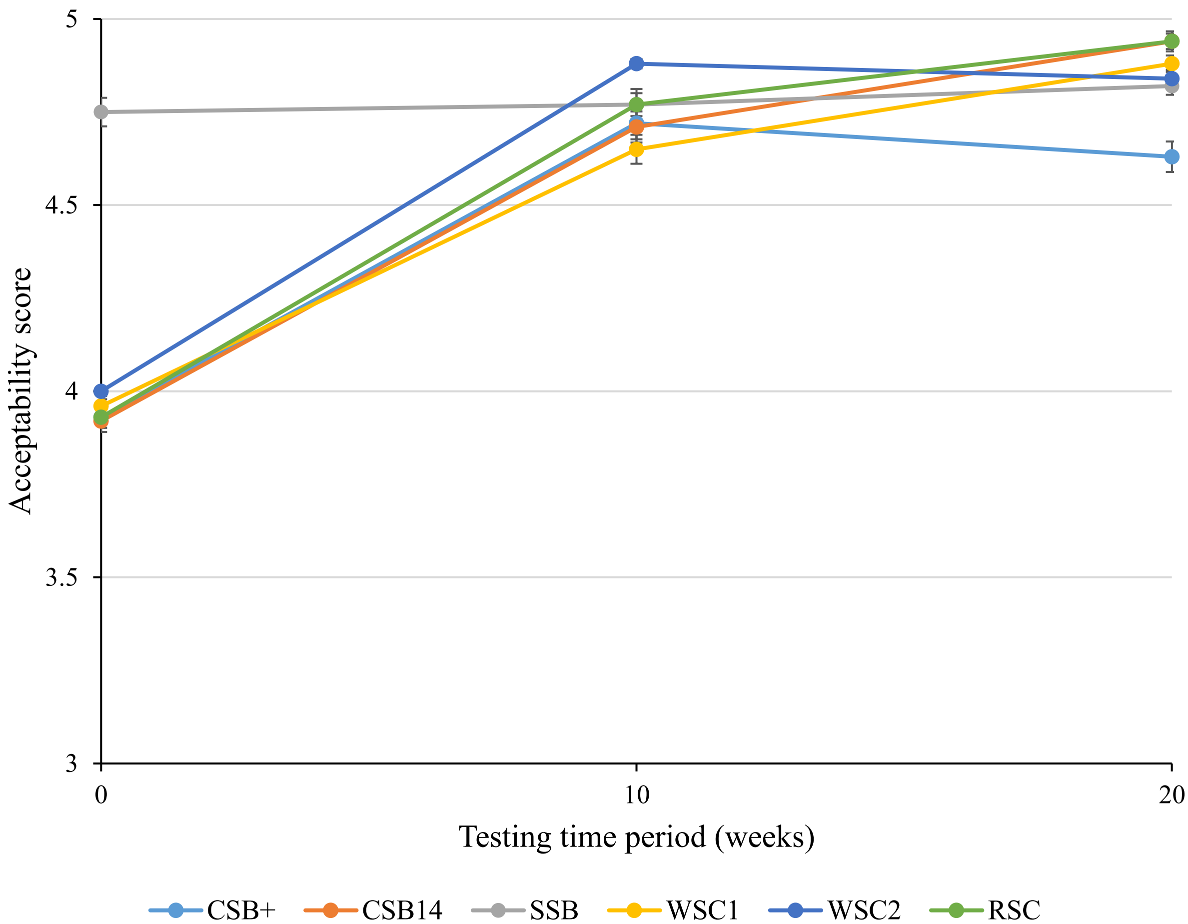

Figure 7-3 Actual child's acceptability of porridge prepared from each FBF over a 20-week trial period.

Scores are based on a 5-point hedonic scale (1=dislike very much, 5=like extremely). The sample size were n=253 for CSB+, n=276 for CSB14, n=261 for SSB, n=253 for WSC1, n=280 for WSC2, n=269 for RSC.

The child's acceptability of porridges prepared from CSB+, CSB14, WSC1, WSC2, and RSC started with "slightly like" range score (approximately 4 out of 5-point hedonic score) and then significantly increased ($p \leq 0.05$) over a 20-week trial period. At the time that children in these five clusters (CSB+, CSB14, WSC1, WSC2, and RSC) were first introduced to their assigned FBF, they might not have been familiar with the flavor of some ingredients in tested FBFs such as legumes (soy and cowpea) that were rarely added to their typical porridges. Kinney (2003) and Bott and Chambers (2006) reported that beany flavors that are often found in legumes and considered as undesirable characteristics might have a negative impact on products acceptability. However, once children started to consume porridge prepared from their assigned FBF continuously, their familiarity to FBFs flavors could be increased and that resulted in the higher acceptability of the products at the end of the study. Giving children more exposure to food products is one of the important determinants of products acceptance (Nicklaus 2011). A study by Maier and others (2007) also showed that repeated exposure to food products could effectively increase children's acceptance even for the ones that initially refused by children such as green vegetables.

Although the child's acceptability for porridge prepared from the current FBF (CSB+) increased over time, the score at the end of the study (20 weeks) appeared to be lower than the acceptability scores for porridges from all novel FBFs. This was probably because of the lower sweetness intensity due to the absence of sugar in CSB+ formulation and that could lead to the lower acceptability of the product. This acceptability pattern was similar to several studies which indicated that sweet food are usually more preferable or acceptable by infants and young children across all races and cultures (Birch 1999; Skinner and others 2002; Popkin and Nielsen 2003; Drewnowski and others 2012). This finding indicated that flavors of food products also played an important role in food acceptance along with the familiarity of the products.

Table 7-5 showed the comparison between the acceptability scores of each FBF overtime that had been collected based on children responses and mothers' perceptions. At week 2 to week 8 and week 12 to week 18, the child's acceptability of all FBFs were reported by their parents based on their perception when they fed their child with the assigned product at home. The results showed that mothers or caregivers tended to report higher scores for their child's acceptability than the scores received from the actual children responses at the first day, week 10 and week 20 of the study. Moreover, while the scores from children responses clearly showed an increasing trend of product acceptability overtime, the acceptability scores remained stable for most of FBFs products when those scores were reported based on mothers' perceptions. This implied that the child's acceptability of the products reported from mothers or caregivers were not a good predictor for the actual children's acceptance of the products. A previous study by Adu-Afarwuah and others (2011) indicated that mothers or caregivers might avoid giving poor ratings to products if they believed that those products had a positive effect on their child's health. Moreover, food acceptability of the caregivers, as adults, may be different from those of infants and young children since they probably have different definition of a favorable product (Moskowitz 1994; Adu-Afarwuah and others 2011; Iuel-Brockdorf and others 2016). Therefore, it is recommended to conduct acceptability tests for children's products with children (real target consumers) in order to obtain the logical results and have the right direction for product development.

Table 7-5 Child's acceptability of each FBF over time based on children responses and mother perception

	Time period (weeks)	**CSB+** (n=253)	**CSB14** (n=276)	**SSB** (n=261)	**WSC1** (n=253)	**WSC2** (n=280)	**RSC** (n=269)
Child response[1]	0	3.93[c3] (0.37)	3.92[c] (0.43)	4.75[b] (0.62)	3.96[d] (0.32)	4.00[b] (0.21)	3.93[d] (0.45)
	10	4.72[b] (0.69)	4.71[b] (0.68)	4.77[b] (0.50)	4.65[c] (0.62)	4.88[a] (0.21)	4.77[c] (0.64)
	20	4.63[b] (0.66)	4.94[a] (0.44)	4.82[b] (0.38)	4.88[b] (0.36)	4.84[a] (0.37)	4.94[ab] (0.32)
Mother perception[2]	2-8	4.94[a] (0.25)	4.90[a] (0.42)	4.95[a] (0.24)	4.89[b] (0.43)	4.93[a] (0.33)	4.89[b] (0.39)
	12-18	4.98[a] (0.23)	4.96[a] (0.31)	4.98[a] (0.19)	4.99[a] (0.08)	4.98[a] (0.19)	4.97[a] (0.21)
	p-value	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

[1]Each child tasted porridge at the test location and their responses were recorded.
[2]Mothers were asked to report their perception on the child's acceptability of the product.
[3]Average (Standard deviation) with different letters in the same column are significantly different ($p \leq 0.05$) across time period. Scores are based on a 5-point hedonic scale (1=dislike very much, 5=like extremely).

Household level behaviors

Cooking time

The recommended cooking instructions of each FBF were given to mothers at the first day of the study, however, those techniques could be modified by mothers or caregivers if needed. The recommended cooking time after porridges started boiling was 10 minutes for CSB+ and 2 minutes for all novel FBFs (CSB14, SSB, WSC1, WSC2, and RSC). Although the novel extruded FBFs in this study are considered as fully cooked products and technically do not need any additional preparation other than adding water, it is still advisable to cook the extruded products before consumption because of the poor water quality in many locations where these products will be distributed.

During food distribution time that occurred every 2 weeks of the study, mothers had to report the time they used to cook porridge from the assigned FBF at their home. Overall, the average cooking time that mothers used for all tested FBFs (Table 7-6) were much lower than average cooking time of the typical porridges that were reported at the first day of the trial (Table 4). Based on the interviewed data (data not shown), it took about 8 weeks for mothers to have a stable cooking time for all FBFs. Unsurprisingly, data reported by caregivers showed that porridges prepared from CSB+ used significantly longer cooking time than porridges from all novel FBFs ($p<0.0001$). These cooking times had similar pattern from the ones observed by enumerators during household visit.

Table 7-6 Cooking time, serving temperature and consistency of porridge prepared from each FBF

Parameter	**CSB+**	**CSB14**	**SSB**	**WSC1**	**WSC2**	**RSC**	***p*-value**
Cooking time (min.)							
Reported by caregivers[1]	11.81[a4] (4.55)	7.64[d] (3.59)	8.95[c] (3.04)	9.46[b] (4.49)	8.67[c] (4.69)	9.42[b] (4.17)	<0.0001
Observed by enumerators[2]	15.32[a] (7.59)	8.42[b] (4.10)	8.98[b] (3.31)	9.81[b] (3.18)	9.73[b] (5.79)	9.08[b] (5.06)	<0.001
Time to get familiar with cooking procedure (weeks)[3]	10	2	2	6	2	4	
Porridge temperature at serving time(◦F)[2]	121.90 (10.26)	123.89 (10.63)	124.87 (14.45)	122.27 (12.00)	123.53 (21.23)	127.20 (22.57)	0.5746
Porridge consistency at serving time (cm./min.)[2]	19.58 (5.35)	18.86 (4.29)	20.75 (3.62)	18.80 (4.34)	18.56 (4.01)	19.82 (4.19)	0.3920
Porridge consistency that met requirement (% of household)[2]	53	61	58	65	68	53	

[1]Calculated from interviewed data of week 8 – week 20 where cooking times were stable for each product. The sample size were n=253 for CSB+, n=276 for CSB14, n=261 for SSB, n=253 for WSC1, n=280 for WSC2, n=269 for RSC.
[2]Data collected during a household visit with n=100 for CSB+, CSB14, SSB, WSC1, WSC2 and n=102 for RSC. The recommended porridge consistency is 9-21 cm./min. (USDA 2010).
[3]The number of weeks where the scores for ease of cooking were not significantly lower than the highest scores for ease of cooking reported by caregivers for each product; 4.96-5.00 out of a 5-point rating scale (1=very difficult, 5=very easy).
[4]Average (Standard deviation) with different letters in the same row are significantly different ($p \leq 0.05$) between products.

Besides cooking time, mothers were asked to rate the ease of cooking for their tested FBF based on a 5-point rating scale (1-very difficult, 5=very easy). The ease of cooking scores for all FBFs increased overtime (data not shown) and mothers in all clusters reported that it was very easy (4.96-5.00 points out of 5 points) for them to cook the assigned FBF by the end of the study. However, mothers in CSB+ cluster took longer time than other clusters to get familiar or easy with cooking techniques (Table 7-6). Mothers who had to cook CSB+ reported that although they first already mixed the product with cold water, many lumps were formed when the mixture was added to boiling water. This was probably due to the starch in this product that was not fully gelatinized prior to cooking as it is with the extruded products (Lindhauer 1997). This might be the reason why mothers who cooked CSB+ used longer time to get used to cooking technique and understand the nature of the product.

Porridge temperature and consistency at serving time

During household visits, trained enumerators measured temperature and consistency of porridges at the time that they were ready to be served to children. The results in Table 7-6 showed that there were no significantly different (p>0.05) across products in temperature and consistency of porridges at serving time. The average serving temperature of porridges made from all FBFs were between 121.90°F – 127.20°F (50°C - 53°C). These serving temperature were slightly higher than the one recommended by Mouquet and others (2006) which was 113°F or 45°C.

USDA (2010) recommended that porridge prepared from fortified blended foods should have consistency between 9 – 21 cm./min., and the results showed that more than half of households in each cluster could prepared porridges that had consistency within this requirement.

CSB+ is a partially cooked product that still has some intact starch granules. These starch granules can absorb 10 or more times their weight in water during cooking process, and results in a thick porridge (Pomeranz 1988; Fleige and others 2010). On the contrary, extrusion process that used to produce novel extruded FBFs could gelatinized and dextrinized the starch granules, resulting in a lower consistency when product is cooked and cooled to serving temperature (Fleige and others 2010). Therefore, when considering porridges at the same consistency or viscosity value, porridges prepared from novel extruded FBFs should have higher solids content than the one prepared from CSB+.


(a) (b) (c) (d)

Figure 7-4 Household visit

(a)- Typical kitchen utensils; (b) to (c) – mothers cooked porridges from the received FBF for their child; (d) – Enumerator used Bostwick consistometer to measure viscosity of cooked porridge.

Serving size of porridges

Table 7-7 showed serving size of porridge prepared from each FBF for children in each meal. The results showed that there were no significantly different in the amount (volume; mL) of porridges that children in all six clusters consumed in each meal (p>0.05). However, children who consumed porridges prepared from novel FBFs (CSB14, SSB, WSC1, WSC2, RSC) should receive higher energy and nutrient density than children in CSB+ group because porridge from all novel extruded FBFs appeared to have higher solids content as stated in the previous section.

As expected, older children (24-59 months) consumed more porridges than children 6-23 months old for all meals. This pattern was observed in all clusters, even though, there were no significantly different between age groups in SSB cluster for some meals.

Table 7-7 Serving size (mL.) of each porridge for children in each meal

Serving time	Child age (months)	CSB+ (n=100)	CSB14 (n=100)	SSB (n=100)	WSC1 (n=100)	WSC2 (n=100)	RSC (n=102)	*p*-value
Morning	6-23	451.70[b1] (193.11)	434.95[b] (164.11)	370.74[b] (146.08)	432.40[b] (197.25)	437.44[b] (199.80)	357.13[b] (160.56)	*0.4796*
	24-59	576.96[a] (181.62)	524.78[a] (164.29)	515.02[a] (168.54)	542.19[a] (187.87)	567.16[a] (201.28)	556.29[a] (176.22)	*0.3660*
	p-value	*0.0014*	*0.0078*	*<0.0001*	*0.0053*	*0.0017*	*<0.0001*	
Lunch	6-23	406.12[b] (190.78)	383.78[b] (151.99)	347.03[b] (120.35)	419.79 (196.44)	407.19[b] (209.89)	346.02[b] (163.74)	*0.5684*
	24-59	530.34[a] (204.80)	475.40[a] (192.93)	479.47[a] (213.30)	575.73 (272.54)	535.86[a] (205.47)	534.35[a] (279.68)	*0.6811*
	p-value	*0.0031*	*0.0113*	*0.0010*	*0.1795*	*0.0026*	*<0.0001*	
Dinner	6-23	427.39[b] (182.63)	416.10[b] (139.68)	345.34[b] (124.02)	422.66 (211.34)	404.66[b] (205.37)	346.02[b] (148.43)	*0.4889*
	24-59	524.51[a] (201.17)	496.56[a] (176.32)	496.79[a] (177.04)	555.61 (294.35)	522.44[a] (201.21)	508.01[b] (163.42)	*0.9508*
	p-value	*0.0165*	*0.0150*	*<0.0001*	*0.2571*	*0.0047*	*0.0002*	
Overall	6-23	428.40[b] (144.08)	411.61[b] (134.89)	354.37[b] (122.96)	424.84 (199.50)	416.43[b] (201.28)	349.72[b] (153.92)	*0.5008*
	24-59	543.93[a] (183.64)	498.91[a] (162.74)	497.09[a] (177.70)	490.77 (163.57)	541.82[a] (188.86)	547.51[a] (181.43)	*0.2571*
	p-value	0.0024	0.0051	<0.0001	0.0726	0.0018	<0.0001	

[1]Average (Standard deviation) with different letters in the same column are significantly different ($p \leq 0.05$) between age group within each serving time.

Table 7-8 Additional ingredients added in porridge made from each FBF over a 20-week trial period

Product	Time period (weeks)	Additional ingredient (%)[1]									
		Milk	Sugar	Groundnut	Vegetable	Fruit	Cassava	Other grains	Meat	Fish	Lemon
CSB+ (n=253)	Current product	47.35	69.37	5.28	0.70	0.35	9.51	26.76	0.35	0.70	11.97
	2	24.71	47.13	2.30	1.72	1.72	1.72	2.30	1.72	1.72	6.90
	10	28.09	54.83	0.00	0.00	0.00	0.00	15.22	0.00	0.00	8.21
	20	27.67	51.78	0.00	0.00	0.00	0.00	11.86	0.00	0.00	7.11
CSB14 (n=276)	Current product	33.50	63.05	2.96	0.49	0.00	8.37	22.66	0.00	0.99	6.40
	2	2.13	2.84	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00
	10	2.86	0.71	0.00	0.00	0.00	0.00	2.38	0.00	0.00	1.19
	20	2.83	0.71	0.00	0.00	0.00	0.00	2.47	0.00	0.00	1.41
SSB (n=261)	Current product	57.31	65.35	9.45	0.39	0.39	7.87	36.22	0.00	0.00	7.48
	2	1.63	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10	1.36	0.00	0.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00
	20	0.77	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.38
WSC1 (n=253)	Current product	65.53	67.58	12.63	0.34	0.34	12.63	35.15	0.00	0.00	8.53
	2	11.50	7.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
	10	3.75	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00
	20	1.97	0.39	0.00	0.00	0.00	0.00	1.57	0.00	0.00	0.39
WSC2 (n=280)	Current product	34.77	63.25	5.96	0.00	0.00	13.58	22.85	0.00	0.00	12.25
	2	6.16	4.79	0.00	0.00	0.00	0.00	4.79	0.00	0.00	0.00
	10	5.19	0.43	0.00	0.00	0.00	0.00	3.46	0.00	0.00	0.00
	20	4.64	2.14	0.00	0.00	0.00	0.00	3.21	0.00	0.00	0.00
RSC (n=269)	Current product	58.20	72.27	8.59	0.39	2.34	14.45	33.20	0.39	0.39	16.41
	2	6.92	5.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.31
	10	4.20	0.44	0.00	0.00	0.00	0.00	1.11	0.00	0.00	0.44
	20	4.92	0.76	0.00	0.00	0.00	0.00	1.52	0.00	0.00	0.76

[1]Reported by mothers/caregivers during interview session in each time period

Additional ingredients

The additional ingredients that mothers added to porridges during a 20-week trial were shown in Table 7-8. At the first day of the study, mothers reported that they added different types of ingredients to their current porridges. The majority of mothers added milk, sugar, and other grains (e.g. millet) to their typical porridge to improve the child's acceptability and increase the nutrient quality of the products. Few of them were adding groundnut, cassava, and lemon. Vegetable, fruit, meat and fish were rarely added to their current porridges probably because of the limited access to these ingredients. This finding was similar to that reported in previous studies conducted in Tanzania (Nyaruhucha and others 2007; Victor and others 2014).

Once mothers received the assigned FBF and used that product to prepare porridge for their child at home, the number of mothers who added other ingredients to tested porridges were deceased overtime compared with the current product in all clusters. However, more than half of mothers who received CSB+ still added sugar and milk into their cooked porridge until the end of the study. Lemon and other grains were also added to CSB+ porridge in some household. On the other hand, few of mothers were adding additional ingredients to porridges prepared from all novel FBFs. The results recorded by trained enumerators during household visit (Figure 7-5) also showed that many households decided to add sugar (64%) and milk (32%) to CSB+ porridge, while just a few number of households who received novel extruded FBFs added these additional ingredients to their tested porridges.

These results indicated that porridge prepared from novel extruded FBFs themselves were already well accepted from children. Moreover, mothers might have an impression that these novel FBFs already provided enough essential nutrient to their children. Therefore, no need to add other ingredients to porridges from novel extruded FBFs. On the other hand, porridge prepared from

CSB+ alone might not be well accepted by children and mothers. This might be the reason why mother still added other ingredients (e.g. sugar, milk) to this type of porridge until the end of the trial in order to increase the child's acceptability and consumption of this food.

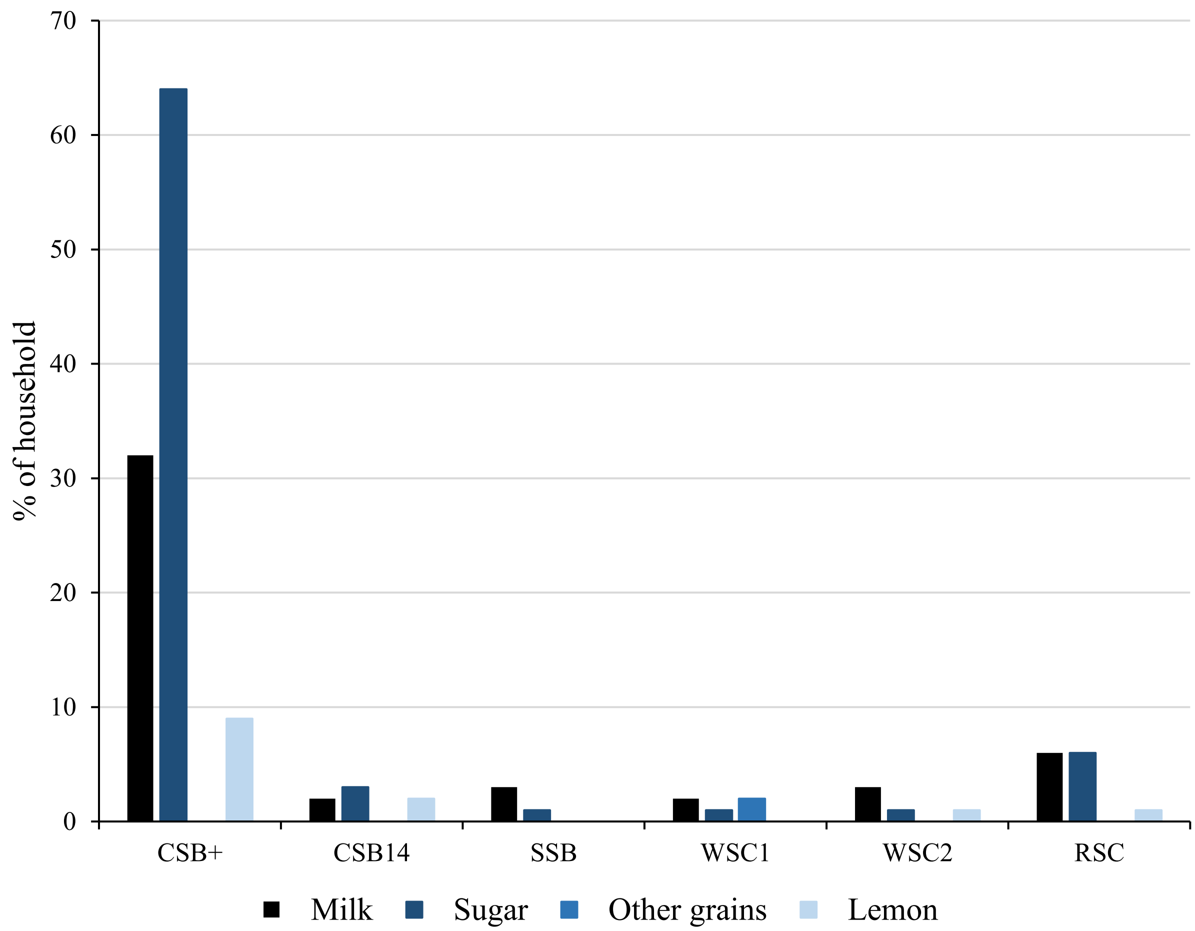

Figure 7-5 Additional ingredients in porridge prepared from each FBF recorded by local enumerators during a household visit.

The sample size were n=100 for CSB+, n=100 for CSB14, n=100 for SSB, n=100 for WSC1, n=100 for WSC2, n=102 for RSC.

Storage behavior

All dry FBFs in this study were typically stored in either original tote bags or plastic containers in order to prevent products from insect infestation (Figure 7-6). More than half of observed households stored CSB14 in plastics containers, whereas the majority of the households that received CSB+, WSC2 and RSC stored dry products in the tote bags that were originally given to them at the beginning of the study. SSB and WSC1 were either stored in original tote bags or plastic containers, in approximately the same proportion of households. The field study by Rowe and others (2008) also reported that household storage practices for food aid commodities could be varied from area to area. While fortified communities in Africa were commonly stored in the original USAID packages, Guatemalan recipients stored dry communities in the sealed plastic bags inside metal or ceramic containers (Rowe and others 2008).

Most of observed households cooked porridges only once per day in the morning, and used that porridges to feed their children for the entire day (Figure 7-7). This result was consistent with the preliminary field study in Tanzania by Chanadang and others (2016). Households that received WSC2 were more likely to transfer left over WSC2 porridges into plastic containers and reheated porridges before serving to children later times that day. The majority of left over porridges prepared from CSB+, CSB14, SSB, WSC1, and RSC were transferred into double walled thermos to keep porridges warm without reheating. Very few of households chose to cook porridges fresh before every serving time or stored the left over porridges in original pots that were used to cook porridges.

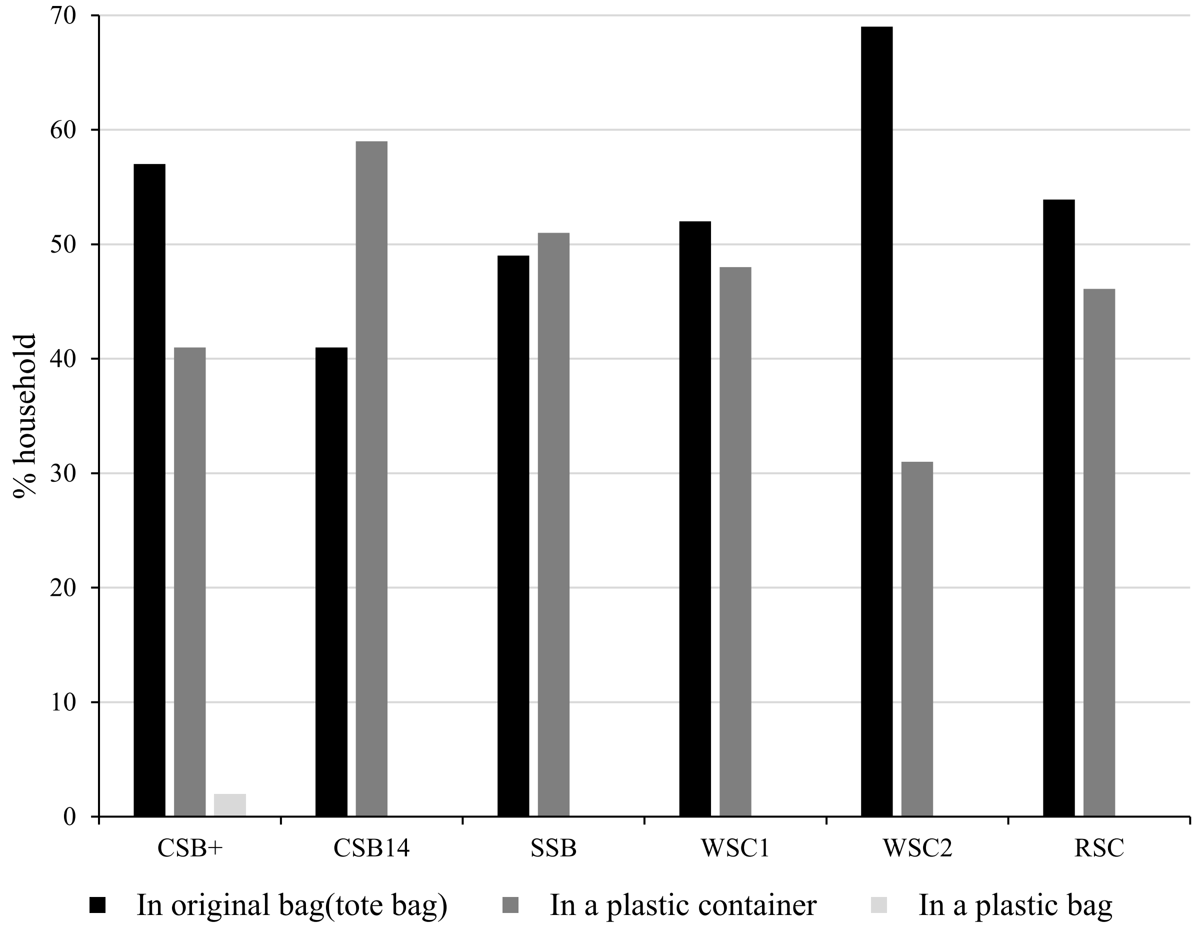

Figure 7-6 Storage practice for each dry FBF.

The sample size were n=100 for CSB+, n=100 for CSB14, n=100 for SSB, n=100 for WSC1, n=100 for WSC2, n=102 for RSC.

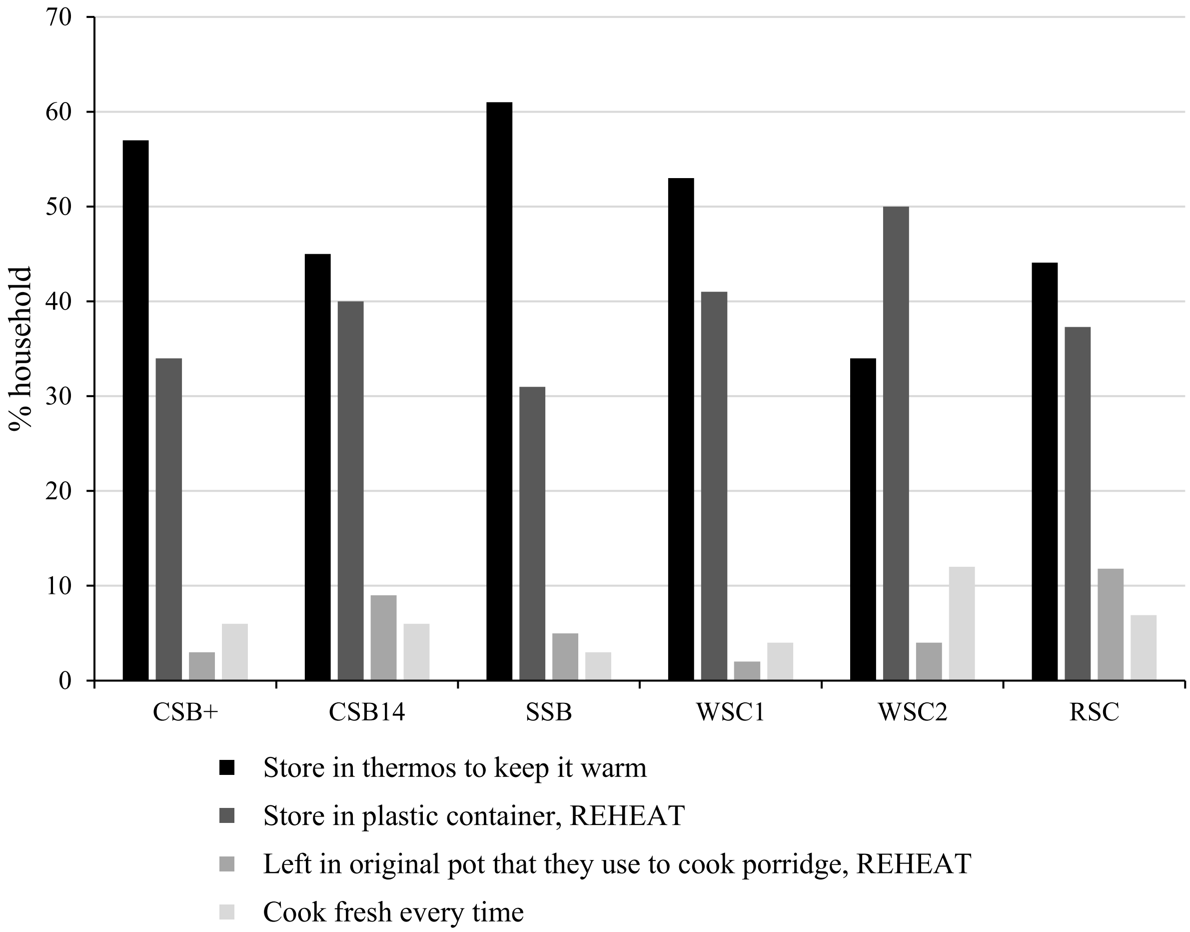

Figure 7-7 Storage practice for left over porridges.

The sample size were n=100 for CSB+, n=100 for CSB14, n=100 for SSB, n=100 for WSC1, n=100 for WSC2, n=102 for RSC.

Data obtained from interviewed sessions and household visit helped to understand more about household level behaviors for each FBFs. Although there were variations from household to household in most of measure parameters, it was clearly seen that novel extruded FBFs were superior to the traditional FBF (CSB+). Novel extruded FBFs could make into drinkable porridges with higher solids concentration than CSB+. Thus, at the same amount of consumption, children who consumed novel FBFs porridges should receive more nutrient density and energy compared to the ones who consumed CSB+ porridge. Porridges prepared from novel extruded FBFs required less cooking time than CSB+. This implied that less energy sources were required in order to cook these products and mothers or caregivers would have more time for other household activities. Moreover, porridges from all novel extruded FBFs did not require any additional ingredients compared to CSB+ porridge, and this made them valuable to people with low income and had limited access to nutrient-rich food or ingredients.

(a) (b) (c)

Figure 7-8 Storage container for dry FBFs.

(a)- Original tote bag; (b)-Plastic bag; (c)- Plastic container

(a) (b) (c)

Figure 7-9 Storage container for left-over cooked porridge.

(a)- Original pot caregiver used to cook porridge; (b)- Plastic container; (c)- Double wall thermos

Conclusion

The data from a 20-week field trial showed that repeated exposure to the porridges prepared from FBFs could effectively increase children's acceptability of the products. However, porridge from CSB+ tended to have lower acceptability from children at the end of the study, probably due to the lack of strong sensory characteristics like sweetness. In addition, it is recommended to measure the food acceptability directly from children, the target consumers, in order to obtain results that are more conclusive. Within the same range of consistency value, porridges from all novel extruded FBFs appeared to provide more energy and nutrient density than CSB+ porridge. Additionally, porridges prepared from all novel FBFs required less cooking time than CSB+ and no ingredients needed to be added compared to CSB+ where sugar and milk were common additions.

These results indicated that novel extruded FBFs have potential to be used as supplementary food with higher or comparable acceptability to currently used CSB+. The simple cooking for the novel FBFs make them valuable to caregivers with limited time and access to energy sources and nutrient-rich ingredients.

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Chapter 8 - General Conclusions

Novel extruded FBFs were developed based on FQAR recommendations to improve their effectiveness on improving nutritional outcomes. At the beginning stage, fifteen possible extruded FBFs varied in processing techniques and ingredients were produced. Descriptive sensory analysis was performed on these fifteen extruded FBFs along with the traditional FBF (CSB+), and results indicated that processing techniques and ingredients used in FBFs had significant impacts on their sensory properties. Novel extruded FBFs had more pronounced toasted characteristics than CSB+, due to the higher temperature during extrusion process. Novel FBFs were also significantly higher than CSB+ in sweet taste because of the added sugar in the novel formulation. In addition, novel FBFs that had higher amount of legumes (e.g. soybean, cowpea) in their formulations, especially for all sorghum cowpea blends, showed higher intensity in beany characteristics. Shelf life testing of novel FBFs was also performed during this stage to estimate the length of time that each FBFs could maintain their desire characteristics. Results from real time testing condition showed that all novel FBFs, except the one that antioxidants were added before extrusion process, could have shelf lives at least 2 years with no detection of off-note characteristics and that were comparable to shelf life of current FBF (CSB+).

After the beginning stage, five novel FBFs (CSB14, SSB, WSC1, WSC2, RSC) were selected to use in a field trial study along with a traditional FBF (CSB+). Before an actual field trial study, paired preference tests were conducted in the Mara region of Tanzania (the expected location of product use) to determine children's preference of the five novel FBFs compared to FBF (CSB+) currently used in food aid program. The preliminary investigation indicated that new FBFs have potential to be used successfully as supplementary food with higher, or comparable, preference to CSB+. The same paired preference tests were performed with American children, and results showed that food preferences of American children were different from the one previously observed from Tanzanian children. This indicated that children's food preference in one country might not be a logical surrogate for another country, thus conducting the study with real target population is recommended.

During a 20-week field trial, several sensory tests were conducted to determine prolonged product exposure impacts on children's preference and acceptability of the FBFs. In addition, observational and interview data regarding the household level behaviors of FBFs were collected during this period. The results showed that repeated exposure could increase children's acceptability or preference of all FBFs, but its effectiveness could be varied based on the characteristics of each FBF. The familiar ingredient used in CSB14 and its sweetness make this product clearly superior to other FBFs and children could accept or prefer this product very quickly. Other novel FBFs (SSB, WSC1, WSC2, SSB) that contained novel ingredients might not be highly preferred by children at the beginning of the study, but repeated exposure to these products could successfully increase children's preference in most cases. However, repeated exposure showed less effective in CSB+, probably due to the lack of sweetness which is considered as preferable sensory property for children. Data obtained from household visit and interview sessions showed that porridges prepared from novel FBFs appeared to provide more energy and nutrient density than the one from CSB+, when considering the same amount of porridge that children consume. Moreover, porridges prepared from novel FBFs required less cooking time than CSB+ and did not require additional ingredients compared to CSB+. The simple cooking of novel FBFs make them more preferable to caregivers, especially the ones who had limited time and access to energy sources and nutritious ingredients.

Appendix A - Survey for Preference test Ballot (During Screening) for Tanzanian children – Chapter 4 and 5

ID # ________________

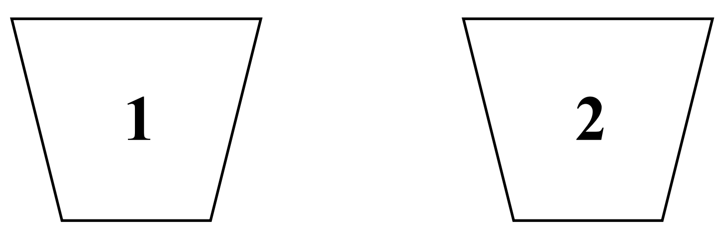
Instruction:

The children will taste product on the left first , and the product on the right second

When they've tasted both products, the enumerator will ask children/mother which one do they/their children prefer? Please choose one.

Remark: *Children 6-23 month old -> mother will be asked to interpret their children reaction*

Children 24-59 month old -> enumerator will ask children to tell their preference



Complementary food feeding *(answer by mother)*:

Is the child currently consuming foods other than breast milk? *YES* *NO*

If yes, which complementary foods does the child currently consume? (Enumerator asks about each of the following and select all that apply)

a. Porridge from whole maize flour (Dona)
b. Porridge from sorghum
c. Porridge from millet
d. Porridge from cassava flour
e. Porridge from rice
f. Porridge from a mixture of flours- with cereals like maize, sorghum, rice and legumes like chick peas , and oilseeds like groundnuts
g. Normal adult food –mainly comprising of solid staples like maize and sorghum
h. Others (specify) …………….. ……………………………………

Appendix B - Survey for Preference test Ballot (During Screening) for U.S. children – Chapter 5

Date: ______________ **ID # _____**

<u>For children 6-23 months</u>

Parent Instructions:

Today you will be feeding your child 2 pairs of hot cereal samples. You will be asked to indicate which sample you think your child liked the best based on his/her reaction to the product.

If your child indicates that he/she does not want to eat one or both of the samples, please do not force the child to eat the product. If your child does not taste either sample, please indicate that on the ballot.

<u>For children 24-59 months</u>

Parent Instructions:

Today your child will be tasting 2 pairs hot cereal samples. He/she will be asked to indicate which sample they liked the best. You will be asked to provide feedback about your child's response to each product. You will also be asked an additional question about your child's diet at the end of the survey.

If your child indicates that he/she does not want to eat one or both of the samples, please do not force the child to eat the product. If your child does not taste either sample, please indicate that on the ballot.

Please give your child some water to clean his/her mouth before tasting the samples in front of him/her.

Please feed your child the sample on ***the left first***, and the sample on ***the right second***.

1. Regarding the samples your child currently has, which of the following statement is most correct
   - ☐ My child tasted only one sample (answer Q2, Q4-5)
   - ☐ My child tasted both samples (answer Q3-5)
   - ☐ My child didn't taste either sample (answer Q4-5)

2. If your child tasted only one sample, which sample did your child taste?
   - ☐ __________
   - ☐ __________

3. If your child tasted both samples, which does he/she prefer?
   (you must select one)
   - ☐ __________
   - ☐ __________

4. Please list any comments about your child's reaction to
   sample on your left

   ____

   ____

   ____

5. Please list any comments about your child's reaction to
   sample on your right

   ____

   ____

   ____

Appendix C - Survey for sensory analysis at baseline, midpoint, and endpoint – Chapter 6 and 7

Date: __________ ID # _________ HF:__________

Section A: Children

Acceptability Question: *(For children who will receive food during study, children in control group who will not receive food during study DO NOT have to do this test)*

Instruction:
Please feed your child the sample you receive
How much do you think ***your child*** **LIKE/DISLIKE** the test porridge in **OVERALL**?

☐	☐	☐	☐	☐
Dislike very much	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like very much

Pair preference Question: *(For all children group)*
Instruction:

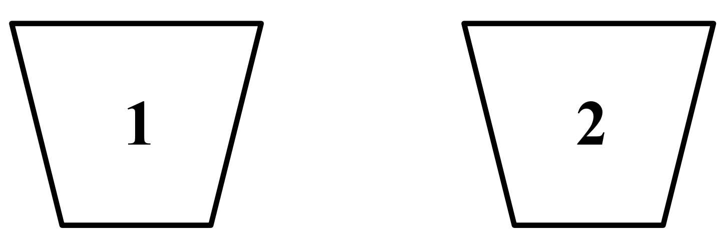
Please feed your children the sample on the left first, and the sample on the right second

When they've tasted both products, the enumerator will ask children/mother ***which one does the CHILD prefer?*** Please choose one.

DO NOT force children to eat sample.

Remark: *Children 6-23 month old -> mother will be asked to interpret their children reaction*

Children 24-59 month old -> enumerator will ask children to tell their preference/ enumerator may ask mother to ask their children on their preference



Comments about samples and children's expression:

____

____

____

Section B-1 : Mother/Caregiver at baseline

General Questions about <u>current porridge</u>:

1. Which complementary foods does the child currently consume? <u>*(enumerator asks about each of the following and select all that apply)*</u>
    1. Porridge from whole maize flour (Dona)
    2. Porridge from white sorghum
    3. Porridge from red sorghum
    4. Porridge from cassava flour
    5. Porridge from a mixture of flours- with cereals like maize, sorghum, rice and legumes like chick peas , and oilseeds like groundnuts
    6. Normal adult food –mainly comprising of solid staples like maize and sorghum
    7. Others

2. When you prepare porridge at home, how long do you <u>***normally cook the current porridge?***</u> __________ min.

3. How ***EASY/DIFFICULT*** it is to prepare the current porridge?

☐	☐	☐	☐	☐
Very Difficult	Slightly Difficult	Neither Easy nor Difficult	Slightly Easv	Very Easy

4. What do you usually add to the <u>***current porridge***</u>? <u>*(enumerator asks about each of the following and select all that apply)*</u>

☐ Milk	☐ Sugar	☐ Ground Nuts
☐ Vegetable	☐ Fruit	☐ Cassava
☐ Other grains	☐ Meat	☐ Fish including "Dagaa"
☐ Lemon	☐ Nothing	☐ Others (mention):_____

Section B-2 : Mother/Caregiver at midpoint and endpoint

General Questions about <u>cooked porridge they have been receiving</u>:

1. How long do you ***<u>cook the porridge you have been receiving</u>***? __________ min.

1. How ***EASY/DIFFICULT*** to prepare the test porridge?

☐	☐	☐	☐	☐
Very Difficult	Slightly Difficult	Neither Easy nor Difficult	Slightly Easv	Very Easy

2. What do you usually add to ***<u>the porridge you have been receiving</u>***? *(enumerator asks about each of the following and select all that apply)*

☐ Milk	☐ Sugar	☐ Ground Nuts
☐ Vegetable	☐ Fruit	☐ Cassava
☐ Other grains	☐ Meat	☐ Fish
☐ Lemon	☐ Nothing	☐ Others (mention):_____

Appendix D - Survey for sensory analysis during food distribution time (week 2-8, week12-18) – Chapter 7

Date: ___________ ID # _____________ HF:_____________

Acceptability Question:

The enumerator will ask mother/care giver on their child acceptability of the ***porridge they have been receiving and cooking at home.***

Mark an X in the box that best represents your answer.

How much do you think ***your child*** **LIKE/DISLIKE** the test porridge you cook at home in **OVERALL**?

☐	☐	☐	☐	☐
Dislike very much	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like very much

General Questions:

1. How long do you ***cook the porridge you have been receiving***? __________ min.

2. How ***EASY/DIFFICULT*** it is to prepare the test porridge?

☐	☐	☐	☐	☐
Very Difficult	Slightly Difficult	Neither Easy nor Difficult	Slightly Easy	Very Easy

3. What do you usually add to ***the porridge you have been receiving***? *(enumerator asks about each of the following and select all that apply)*

☐ Milk	☐ Sugar	☐ Ground Nuts
☐ Vegetable	☐ Fruit	☐ Cassava
☐ Other grains	☐ Meat	☐ Fish (including Dagga)
☐ Lemon	☐ Nothing	☐ Others (mention):_____

Appendix E - Survey for household visit – Chapter 7

Date: ________________ ID # _____ Product __________

HF____________

1. How long do you usually ***cook the porridge you have been receiving***? __________ min.

2. What do you usually add to ***the porridge you have been receiving***? *(enumerator asks about each of the following and select all that apply)*

☐ Milk ☐ Sugar ☐ Ground Nuts

☐ Vegetables (list)_____ ☐ Fruit (list)______ ☐ Cassava

☐ Other grains(list)______ ☐ Meat ☐ Fish (including Dagga)

☐ Lemon ☐ Nothing ☐ Others (list):_____

3. What do you do with left over porridge from when you first cook it each day?
   - ☐ Store in thermos to keep it warm
   - ☐ Left in original pot that they use to cook porridge, NO REHEAT for next consumption.
   - ☐ Left in original pot that they use to cook porridge, REHEAT for next consumption.
   - ☐ I don't have left over porridge – I cook fresh every time
   - ☐ Other(list):_____________

4. Where do you store the porridge flour?
   - ☐ In the original bag you receive from health facility (tote bag)
   - ☐ In a plastic container
   - ☐ In a plastic bag
   - ☐ Other(list):_____________

5. What is the viscosity of the porridge they have been receiving and cooking at home? (measured by enumerator using bostwick)

   5.1 Porridge temperature __________°C

   5.2 Porridge viscosity_________ cm./min.

6. What is the serving size for each child(in the study) and how many times per day?
(Enumerator ask to see the serving containers they use for their kids and then get a volumetric amount from that by using measuring cups)

Children ID	Age	Serving size				
		Time 1- morning	Time 2 - lunch	Time 3- dinner	Time 4 - extra	Time 5 - extra