https://doi.org/10.17221/334/2020-AGRICECON

Biofortification of tomatoes in Italy: Status and level of knowledge

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Citation: Foti V.T., Scuderi A., Bellia C., Timpanaro G. (2021): Biofortification of tomatoes in Italy: Status and level of knowledge. Agric. Econ. – Czech, 67: 227–235.

Abstract: Biofortification is a strategy to reduce micronutrient deficiency in humans by fortifying food through natural processes, agronomic practices and genetic modification. In this study, we seek to shed light on what consumers understand by the term 'biofortified products' and thus to understand their level of knowledge about these products, as well as the reasons that dictate their purchasing choices and the relationship between consumption choices and lifestyles. The analysis focuses on vegetables and, in particular, on tomatoes with a high lycopene content. Research shows that consumers of biofortified food products are generally confused and uninformed, even though they show a high willingness to pay. This confusion seems to result, moreover, from the lack of a clear definition of a biofortified product, as well as from the lack of clear information on the specifics of biofortified products and the benefits they can bring. The future of biofortified products can, therefore, be improved by the creation of clear standards and reference definitions and better information and transparency that would benefit the consumer.

Keywords: biofortified; consumer; food products; GMOs

Biofortification is the process by which the nutritional quality of food crops is improved through increased nutrient bioavailability (Bouis and Welch 2010; Bouis and Saltzman 2017). Increasing the amounts of bioavailable micronutrients in plant food for human consumption is a particularly important challenge for both developing and industrialised countries.

In developing countries, the biofortification of food can be useful to combat food insecurity and to reduce the mortality rate related to micronutrient malnutrition. In economically more developed countries, this process could be an added value for the product, as it could be a differentiation tool to increase product competitiveness (Hotz et al. 2012).

The process of food fortification is carried out through natural processes, agronomic practices, traditional plant breeding and genetically modified organisms (GMOs) (Katan and De Roos 2004). One of the problems related to biofortified products is the lack of clarity of the definition of biofortification. The dilemma concerning the definition of biofortified foods and the processes used to produce them also stems from the unclear revised definition proposed by the Codex Alimentarius Commission, according to which biofortification is as follows: 'Any process other than conventional addition to food which results in an increase in nutrient content or increased bioavailability in all potential food sources for the intended nutritional purposes' (Codex Alimentarius Commission 2018). The key question is whether the definition of biofortification should be broad enough to include GMOs (Haas et al. 2011).

This research offers a first approach to the issue, which has been deepened in another study in which the variables influencing consumers' purchasing behaviour toward biofortified products has been ana-

Supported by the research projects 'Sostenibilità economica, ambientale e sociale del sistema agroalimentare del mediterraneo' [Principal Investigator Prof. Claudio Bellia funded by PIAno di inCEntivi per la Ricerca di Ateneo (PIACERI) UNICT 2020/22 line 2, University of Catania (UPB: 5A722192154)].

https://doi.org/10.17221/334/2020-AGRICECON

lysed through the use of multivariate statistical analysis techniques (Timpanaro et al. 2020).

General framework for the definition of 'biofortified' and 'tomato biofortified'. From a regulatory point of view, the search for a possible definition of a biofortified product can be traced back to the regulation of so-called novel foods and, within this category, to functional foods, whose production in terms of principles and requirements of food law are explicitly identified in European Union (EU) Regulations (EC) 178/2002 and 2015/2283. Legislative standards include Regulation (EC) 1925/2006 on the addition of vitamins, minerals, and certain other substances with beneficial properties.

The scientific contributions to the biofortification process can be framed in four main lines of research:

i) society and food security, with the social implications of accessibility to food in the context of human health and demographic characteristics;
ii) technical and regulatory definitions of biofortified products;
iii) market and marketing in different areas of the world;
iv) consumption and factors that influence purchasing and communication choices.

In the first line of research, the most important contribution starts with a reflection on how micronutrient malnutrition, known as 'hidden hunger,' is a serious problem for more than half of the world's population. In this context, biofortification is considered a new method in support of public health to combat major nutritional deficiencies, especially in developing countries. With this technique, food crops (rice, wheat, corn, and potatoes) are enriched with micronutrients through cultivation techniques (Mayer et al. 2008; Garcia-Casal et al. 2017).

The second line of research shows how techniques to produce biofortified products lead to an overlap with functional foods. In this regard, the functional products are classified into the following categories: fortified food (food produced through a technological process of fortification that makes it more nutritious), enriched food (in which the percentage of one or more nutrients already present in nature is increased) or supplementary food (a subcategory of fortified foods). Biofortification can be achieved through genetic engineering (genetic manipulation of nucleotide sequences), certain classical genetic techniques (e.g. cross-breeding) or agronomic techniques (soil or leaf fertilisation). In terms of cultivation techniques, a broad scientific debate is underway, triggered by the concerns expressed by the Codex Alimentarius Commission, aimed at achieving a definitive distinction between 'biofortification' (nutrient augmentation with modern agronomic techniques) and 'conventional fortification' (nutrient addition during the production process) (Low et al. 2007).

In the third line of research, studies are aimed at analysing how consumers understand the meaning of 'biofortification' and the benefits of biofortification and how names and logos communicate the idea of biofortification to consumers (Birol et al. 2015; Uchitelle-Pierce and Ubomba-Jaswa 2017).

In the fourth line of research, the debate is often focused on the consumerism typical of rich countries because of the growth of per capita income and the choice of food increasingly influenced by sociocultural, ethical and religious factors and trends.

An increase in health products has been a response to several factors, for example:

i) agri-food scandals and the problem of safeguarding and protecting the health of the consumer;
ii) junk food, snacks and packaged food with no nutritional value and significant chemical additives (Urala and Lähteenmäki 2004);
iii) sedentary lifestyle, along with the various diseases of modern society;
iv) spread of food intolerances or allergies (the most common being milk or lactose, dairy products in general and wheat or gluten);
v) food increasingly perceived by the consumer as a source of well-being (Diplock et al. 1999).

The availability of foods enriched with beneficial substances such as antioxidants, vegetable fibres, vitamins and minerals has thus grown, incentivised by consumers (Katan and De Roos 2004) attracted by labels that claim health benefits. The institutional definition of functional foods is not unique in the context of the European Commission Concerted Action on Functional Food Science in Europe (Roberfroid 2002). Functional foods are considered as such if they are a normal food (they are not food supplements or a drug, nutraceutical, or herbal product in the form of tablets); if they are presented to the consumer in a manner consistent with the content of EU Regulation (EC) 1924/2006; or if they contain claims related to the improvement of a biological function or claims related to the reduction of disease risk. There are clear areas of overlap between enriched or supplementary foods and functional foods (so-called new foods) (Siro et al. 2008).

Although there is evidence that the terms 'biofortification' and 'biofortified food' on the product label are elements of consumer evaluation, in the light of the

https://doi.org/10.17221/334/2020-AGRICECON

codex evaluations, the EU prefers to omit the labelling related to the production technique of biofortified products in favour of the labelling related to nutrient bioavailability (Low et al. 2007).

A main protagonist of the Mediterranean diet is the tomato, particularly rich in compounds of high nutritional value such as simple sugars, provitamin A, vitamin C, lycopene, and beta-carotene. However, the content of flavonoids, precursors of anthocyanins and metabolites belonging to the class of polyphenols, is generally quite low, approximately 5 mg/kg of fresh weight, compared to that in many other horticultural products (Crozier et al. 1997). The functional properties of tomatoes are linked to antioxidant and anticancer properties due to the presence of a combination of biomolecules that are beneficial to human health. The scientific research carried out on this fruit aims to increase the percentage of anthocyanins to produce a biofortified and, therefore, functional tomato with beneficial health effects.

Significant technical progress has been made in increasing the nutritional content of tomato berries through biofortification techniques such as genetic engineering and agronomic practices (Piringer and Heinze 1954).

Genetic engineering uses modern molecular biology to achieve the goal of a tomato fruit with significant amounts of anthocyanins. Thus, plant varieties are improved to have a greater capacity for accumulating nutrients in edible plant tissues and increased bioavailability of nutrients. This process results in genetically modified tomato varieties, or GMOs. However, the release of GMO tomatoes on the market would provoke strong public resistance. To date, biotechnology products developed in the laboratory have not found significant commercial outlets, especially given the standards enforced in Europe relating to safety in agriculture and food.

For biofortified crops, germplasm analysis can be used to detect the increase in nutrient levels and estimate the concentration of micronutrients in the seeds. In many cases, the distinction between biofortified and non-biofortified food is easy to detect because the change is evident.

The agronomic model includes several techniques such as the following:

– cultivation of tomatoes in greenhouses, through efficient hydroponic systems, allowing high production levels with good qualitative characteristics of the fruits, including nutraceutical traits;
– control of environmental factors or cultivation techniques, such as light, temperature, development phase at harvest and fertilisation, which can affect the production and chemical composition of fruits, including the concentration of pigments such as anthocyanins.

Results of studies carried out on tomatoes (Moretti et al. 2010) have shown that the organoleptic, nutritional and health characteristics of the berries are modified by the environmental conditions in which the plants are grown. Specifically, the fruits cultivated in the Mediterranean climate are characterised by higher levels of flavonoids than are the fruits produced in northern Europe. More precisely, tomatoes from plants grown in greenhouses in spring and summer have a higher flavonoid content than those produced in greenhouses during other times of the year.

The flavonoid content of tomato berries depends on the daily dose of light energy received by the plant. A current field of investigation focuses on the possibility of increasing the added value of traditional foods through the identification and selection of varieties or lines with high health value and using techniques in addition to the manipulation of environmental conditions and agronomic practices. This line of study requires agronomic, physiological, and biochemical-molecular skills (Piringer and Heinze 1954).

In the case study analysed, the technique of herbaceous tomato grafting with different tomato varieties is also used. Depending on the tomato species used for grafting, there are variations in the quantities of anthocyanins in the tomato berries, even if in some cases these variations are minimal (Verhoeyen et al. 2002).

Biofortification makes it possible to meet the needs of the market and still obtain high yields and respect legislation. The fundamental objective is no longer increased production but better-quality agricultural products that are also healthy and nutritious. Therefore, on the one hand, there is a tendency to re-evaluate local varieties with qualitative characteristics; on the other hand, there is a tendency to improve the health and nutritional characteristics of the most common varieties in a specific area under specific environmental conditions.

Among the main factors that motivate the use of grafting in tomatoes are the following:

– reduction of the use of chemicals for the control of plant diseases;
– need to contain the increasing pressure of biotic and abiotic factors;
– growing demand from consumers for high-quality and wholesome food, which is increasingly associated with organic production;
– identification and selection of local varieties with high health value (Nawaz et al. 2016).

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In this research, we aimed to understand the degree of knowledge that consumers have about biofortified products (Foti et al. 2019), the reasons that dictate their purchasing choices, the relationship between consumption choices and lifestyles and the characteristics that influence the greater willingness to pay for these foods. In this experimental analysis, we focused on vegetables, in particular tomatoes with a high lycopene content.

MATERIAL AND METHODS

Sample characteristics. The analysis was aimed at understanding the perception that consumers have of biofortified products and was performed with a sample of 500 consumers in the last months of 2019. The size of the sample was defined in relation to the research objectives and the availability of resources. The individual units in the sample were selected using quota sampling, which is a non-probabilistic sampling method in which researchers create a sample involving individuals representing a population (Moser 1952). The subjects to be interviewed are chosen according to certain characteristics and specific qualities. Quotas are then created so that the samples obtained can be useful for data collection. The characteristic of this type of sampling is that the final sample is chosen on the basis of the knowledge of the population by the researcher.

To conduct the survey, we used both face-to-face interviews and the Google Docs platform. The interviewees were administered a questionnaire to collect quantitative and qualitative information with closed or tied answers. The questionnaire, in addition to collecting general data about the interviewees, was subdivided into various sections, each of which was aimed at acquiring specific information about purchasing behaviour, knowledge about biofortified foods, reasons for and purchasing modalities of biofortified tomatoes and willingness to pay for biofortified tomatoes. The information and data collected with the questionnaire were processed according to a methodological scheme already used for the study of the characteristics of consumption of certain agri-food products (Aprile et al. 2016). The sample as a whole was described by using univariate statistical analysis to outline the consumers' knowledge of biofortified products. As already mentioned, this paper is a first step in the research; the data acquired during the interviews were analysed in this paper by using only descriptive statistical variables, whereas in another paper, the variables influencing consumer behaviour toward the purchase of biofortified tomatoes were analysed using multivariate statistical analysis techniques (Timpanaro et al. 2020).

The questionnaire contained questions with closed or bound answers (binary or multiple). The respondent was asked to select from a series of coded options based on his or her opinions or habits. We used qualitative questions to codify the opinions expressed by the consumers and quantitative questions to identify the frequencies and methods of consumption. We used a Likert scale to measure the respondents' attitudes and opinions. This is a rating scale used in many types of surveys to measure the opinions and attitudes of respondents with the aim of obtaining more meaningful answers than would be possible with a simple yes/no question. The scale requires that a list of items, linked to attitudes about which we want to conduct the analysis, is submitted to a group of individuals with the possibility to choose originally among five alternative answers, such as the following: completely agree, agree, uncertain, disagree, completely disagree (Edmondson 2005).

The analysis of the sample characteristics included demographic, social and economic factors: gender, age group, marital status, educational level, who does the purchasing, occupation, family size, and family income (Table 1).

The majority of respondents were female (56% female, 44% male), which confirms the representativeness of the sample with respect to Italian national demographic data. This finding reflects the greater reliability and availability of women during the interviews, as well as the fact that they are more active in family spending. Interviewees were urban residents from various cities in Italy, with oversampling in Sicily.

Table 1 shows that the sample interviewed was mainly represented by the age group of 20–40 years (51%), followed by the age groups of 40–60 years (41%) and older than 60 years (8%).

The sample had medium to high levels of education: 51% were diploma graduates and 34% had bachelor's degrees; only 5% of the population interviewed had a lower secondary school qualification, and the remaining 10% had a postgraduate qualification. High levels of education should indicate greater knowledge of and information about biofortified products and, in particular, about biofortified tomatoes. The sample represented diverse socioeconomic categories, with all the categories considered represented equally. The professions with the highest percentages were employees (25%), followed by students (21%), professionals (12%), pensioners and other categories.

https://doi.org/10.17221/334/2020-AGRICECON

An income of more than EUR 20 000 was reported by 52% of respondents, with 23% between EUR 20 000 and EUR 40 000 and 29% with more than EUR 40 000. An income between EUR 10 000 and EUR 20 000 was reported by 31%, and 17% reported an income less than EUR 10 000.

Table 1. Characteristics of the interviewed sample (%)

Question	%
Sex	
Males	56
Females	44
Age classes (years)	
20–40	51
40–60	41
Over 60	8
Civil status	
Single	27
Married	56
Divorced	17
Qualification	
Secondary school license	5
Diploma	51
Bachelor	34
Post-graduate degree	10
Purchasing manager	
Yes	78
No	22
Occupation	
Employee	25
Freelancer	12
Worker	7
Unemployed	8
Housewife	13
Retired	14
Student	21
Family size (members)	
1	21
2	25
3	29
4	18
5 or more	7
Annual family income (thousand EUR)	
Up to 10	17
10–20	31
20–40	23
Over 40	29

Source: Elaboration on directly measured data

The last component analysed was the number of family members, with more than 51% having three or more family members. The large sample size made it possible to investigate not only the respondents' interest in biofortified products but also that of the rest of the family members.

This work is only a first approach to the issue, which has been deepened in another study in which, through the use of multivariate statistical analysis techniques (analysis of the main components), the main variables that influence the consumption of biofortified products were analysed (Timpanaro et al. 2020).

RESULTS AND DISCUSSION

The results were analysed to determine the knowledge about and consumption of functional products, biofortified products in general and tomatoes in particular. Developing a global strategy on the dissemination of biofortified crops requires understanding consumers' perceptions, intuitions and behaviours on certain issues that revolve around or are related to the biofortification process.

Before starting the interview, all potential respondents were asked if they understood the term 'functional products'. A positive answer was needed to proceed with the interview; however, a later question revealed that 16% of the interviewees did not know the characteristics of functional products (Table 2).

Purchases made at the supermarket accounted for 45%, whereas the other places of purchase ranged between 7% and 16%, with the exception of direct sales, with a frequency of twice a week.

Interviewees were asked about the places of purchase and about the factors that contribute to purchasing decisions, rated on a Likert scale from 1 to 5 (with 1 meaning strongly disagree and 5 meaning strongly agree). The average sum of the scores for each interviewee's responses over the whole series of questions represented the individual's position on the statement under investigation.

The most important factors were food safety, certification, origin, nutritional content, and organic product, whereas brand had marginal influence on purchasing decisions. Price also assumed a lesser role, as consumers are conscious of their diet and therefore are willing to pay more for functional products. This answer, on the whole, confirmed the confusion about functional products that existed among those interviewed; in many cases, functional products were equated with those that the consumer believes are good for health.

https://doi.org/10.17221/334/2020-AGRICECON

Moreover, brand did not play a large role in purchasing decisions because the guarantee of quality is thought to exist in the intrinsic components of the product.

For the specific question on knowledge about biofortified foods, more than half of the sample stated that foods with demonstrated beneficial health properties are considered functional foods. However, examples given of functional foods included, in the order of response prevalence, citrus, pomegranate, walnuts, ginger, and tomato. For this question, both truly biofortified products were included, such as the iodine potato and the selenium potato, but also many other products that are not biofortified, such as black cabbage, black tomato, and pomegranate.

Table 2. General information on the consumption and purchase of food products (%)

Question	%
Do you know the characteristics of biofortified products?	
Yes	84
No	16
Places of purchase	
Superstore	7
Supermarket	45
Hard discount	9
Traditional retail	16
Local market	9
Direct sale	14
What factors influence your purchases?	
Food security	19
Certifications	17
Seasonal product	11
Origin	13
Nutritional content	12
Produced by organic farming	15
Brand	4
Price	9
Foods with beneficial properties are considered functional foods?	
Yes	58
No	42
What are the techniques using for biofortification?	
Conventional agronomic techniques	63
Organic farming practices	35
Use and application of GMOs	2
Are you interested in regularly buying biofortified products?	
Yes	28
No	72

Source: Elaboration on directly measured data

To deepen the level of knowledge of biofortified foods, we asked respondents whether they considered functional foods (those enriched with trace elements and vitamins) biofortified. The majority of consumers replied that biofortified products are products produced by means of practices that meet organic farming standards; the second group in order of magnitude considered that biofortified products comply with traditional agronomic techniques. When asked specifically about the use of GMOs for the production of biofortified products, more than 80% believed that production using transgenic techniques (GMOs) should be prohibited. However, the provocative question of whether biofortified products are always products of organic farming showed that more than 60% of the sample misunderstood the concept of biofortification.

Finally, the better to characterise consumer behaviour, we asked respondents whether they intended to purchase biofortified food in the future; 72% answered that they were not inclined to buy these products regularly, and only 28% were willing to buy them regularly. This finding confirms that although the responding sample was attentive to functional foods, it is not clear to them what role biofortified products have in their diets.

The analysis of biofortified tomato consumption, according to the Likert scale, showed that, in general, consumer choice for tomatoes was determined by taste, origin, certification and price (Table 3). This result confirms that the sample was attentive to the intrinsic quality of the tomato but that the price also required a certain consideration because it is a vegetable product that is part of the usual purchases. These results show, therefore, a certain linearity with the data in the Table 2 on factors that have an influence on the purchase of biofortified products.

With the following analyses, we tried to determine which techniques previously defined by the Codex Alimentarius could be the most suitable for the biofortification of the tomato, according to the preferences of the interviewees. The interviewees stated that they preferred to buy a product produced by means of organic farming, while showing that they accepted biofortification through agronomic techniques. The unacceptability of biofortified products produced by means of genetic modification was widespread. These responses confirmed that, for consumers, the term 'biofortified' is synonymous with 'organic'.

https://doi.org/10.17221/334/2020-AGRICECON

Table 3. Factors determining the purchase and consumption of biofortified tomatoes (%)

Question	%
Have you heard of biofortified tomatoes?	
Yes	52
No	48
Where do you buy tomatoes?	
Hypermarket	5
Supermarket	23
Hard discount	4
Traditional retail	18
Local market	29
Direct sale	21
What are the factors that affect tomato purchases?	
Flavour	18
Certifications	13
Seasonal product	9
Origin	16
Nutritional content	15
Produced by organic farming	12
Brand	3
Price	14
What limits the purchase of tomatoes (compared to the substitute)?	
Difficulty in finding	39
High prices	28
Low quality	33
What are the techniques used for the production of biofortified tomatoes?	
Traditional agronomic practices	37
Organic farming practices	59
Use and application of GMOs	4
How much would you be willing to pay for a fresh biofortified cherry tomato (EUR/kg)?	
Less than 2.0	18
From 2.0 to 2.6	23
From 2.6 to 3.0	41
From 3.0 to 4.0	13
Over 4.0	5
How much would you be willing to pay for a 33 cl pack of biofortified cherry tomato sauce (EUR/kg)?	
Less than 1.6	11
From 1.6 to 2.0	17
From 2.0 to 2.5	25
From 2.5 to 3.0	42
Over 3.0	5
What are the factors facilitating the purchase of biofortified products?	
Certification	19
Defined standards	32
Medical studies	49

Source: Elaboration on directly measured data

The consumers interviewed clearly expressed their disagreement with the use of GMOs, which they considered to be unhealthy and totally at odds with their idea of biofortified products, with which they associate the idea of safe products with positive health effects. This phenomenon was also found in some developing countries that use genetic modification only and exclusively for food enrichment for nutritional support purposes (González et al. 2009; Adeyeye and Idowu-Adebayo 2019). This finding highlights a misunderstanding of biofortified products, which must be overcome through legislation that defines the boundaries of the application of biofortification techniques.

The results show that 64% of those sampled were willing to pay more for a biofortified tomato, and respondents specifically identified the price range between EUR 2.6 and EUR 3.0 per kg. This willingness to pay is also confirmed for cherry tomato sauce, with 67% of those sampled willing to buy it and willing to pay between EUR 2.0 and EUR 3.0 for a pack of 33 cL of cherry tomato sauce, which in some cases is almost 100% more than the traditional product sold on average at EUR 1.50 per pack. The purchase price of biofortified products is therefore not considered to be a discriminating factor for the spread of these products, but a high price is often considered synonymous with quality.

With reference to the main obstacles that consumers encountered in purchasing biofortified products, three responses showed similar percentages: the difficulty of finding them (27%), the quality of the product not being very different from that of the substituted product (22%) and the high price (26%), which, although in contrast with what has been said, is always a fundamental discriminating element for a number of consumers. In the future, the marketing strategy must be based on the objective characteristics of the product and move away from price policies.

These data confirm that even though many biofortified products are present on the market, these products still show considerable shortcomings in terms

https://doi.org/10.17221/334/2020-AGRICECON

of regulation, quality, and distribution. In this sense, however, it seems important to reflect on the main obstacles, such as the difficulty of finding the products and little quality differentiation, because many times the consumer has the opportunity to buy biofortified products but cannot identify them because of the lack of appropriate differentiation.

In this context, a central role is obviously assumed by the issue of information, which, for products with particular characteristics, such as biofortified products, must be clear and complete, removing all doubt about the characteristics and method of production of the products. The results of this analysis show that although consumers show a certain propensity for and a good interest in biofortified products, together with a good willingness to pay a higher price for biofortified products, they still appear to be confused and definitely desirous of information from competent sources that can guide them to make the right choices.

CONCLUSION

The EU has validly objected that the term 'biofortification' could cause confusion in many European countries because of the widespread use of the word 'bio' as a synonym for 'organic' (Haas et al. 2011). Some countries within the EU have been very vocal and support the EU's position, arguing that the definition needs to be restrictive. Once again, the National Health Federation (NHF) agrees with the EU position. The term 'biofortification', at least within European countries, risks consumers' confusion as to whether they are purchasing organic products or something else entirely. The key question here is whether the definition of biofortification should be broad enough to include GMOs (Rousu et al. 2005).

The results of research carried out to try to understand consumer behaviour toward biofortified products show that at present the consumers of biofortified food products are generally confused and uninformed, even if they show a high willingness to pay for such products.

The results obtained in this study, which were then further investigated in another study (Timpanaro et al. 2020), made it possible to outline the profile of a consumer of biofortified products, which is different from that which emerges in other parts of the world where biofortification is understood mainly as the addition of elements necessary to increase the availability of micronutrients, regardless of the method by which the biofortification process takes place. This analysis, however, shows that consumers strongly linked biofortified products to organic production and totally disconnected biofortified products from GMO products.

The future of biofortified products will be determined by the creation of precise standards and definitions. Information could lead to higher demand and the placement of these foods among products that improve health, acknowledging that these are credence foods with nutritional characteristics and particular functions that could increasingly play an important role in developing and developed countries in the long-term (Diplock et al. 1999).

As already pointed out, one of the major problems related to biofortified products is the absence of a single, internationally accepted definition of the term 'biofortification'. Despite the lack of a globally accepted and recognised definition, biofortified products seem to be becoming increasingly widespread in Italy, and we have highlighted how consumers, if conscious and informed of the benefits, are willing to pay more for a product that they perceive as more 'functional' for their health.

In the long term, therefore, it would be useful to focus on the development of a globally agreed legislative framework that would clarify the limits and real characteristics of biofortified products, giving clear indications to all stakeholders in the chain as well as enhancing credibility and acceptance for consumers, who are still confused.

To this end, the role of intervention policies for biofortified products is central; clear strategies can promote the consolidation and dissemination of biofortified products.

The new frontier of biofortification, the tailor-made nutrition of plants to produce products for specific populations, with the creation of what is now known as 'tailored food', must be taken into account when drafting specific legislation.

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Received: August 19, 2020
Accepted: April 14, 2021