# Identifying objective quality attributes of functional foods

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**GENERAL REVIEW**

## Abstract

This study aims to identify objective quality attributes of functional foods based on literature reviews and proposing the future research agenda. There are not many articles that examined the objective quality of functional foods. This article aims to fill that gap: discussing objective quality attribute of functional foods based on the syntheses of previous studies. Previous research on objective quality of functional foods mostly came from the field of food science, and therefore applicable only to certain foods. Studies from the field of consumer behaviour/management mostly focused on perceived quality. This study used journals from three databases and utilised the term 'functional food' as the main keyword. Articles gathered were filtered based on their types and contents. There are two categories of objective quality found in literature. Firstly, objective quality related to the process, and secondly, objective quality related to the product itself. Both types are required to make accurate and marketable health claims of functional foods. Future research should try to empirically validate those objective quality attributes.

**Keywords:** health claim, safety, shelf-life, organoleptic, literature review

## 1. Introduction

The ancient recognition that foods provided health benefits encouraged the use of term 'functional food' (Sarkar, 2013). The term was first used in Japan in the late 1980s to represent additional nutrients that were detached from their recognised functions (Stanton *et al.*, 2001). It has been well recognised that functional foods have positive impacts on individuals and public health. Studies concerning functional foods have established connections between the reduction of risks of diseases and healthcare costs (Shahidi, 2009). The market for functional food has grown considerably and was projected to touch US$305.4 billion in 2020 (Bogue *et al.*, 2017). The powers behind this massive growth were the developed countries' fascination towards superior performance and longevity (Lawrence and Germov, 2004) and the developing countries' intention to rein the spread of diseases caused by malnutrition (Asian Development Bank, 2000). The growth of functional foods was also fuelled by the relentless efforts of food companies for gaining competitive advantage (Nestle, 2002).

The 'push' from governments and food companies were well-situated among consumers with growing concerns about food-related health (Dixon *et al.*, 2006). Current consumers perceive that functional foods provided an enhanced health benefit compared to traditional foods (e.g. Rojas-Rivas *et al.*, 2019; Schnettler *et al.*, 2015). This superiority was an objective characteristic demanded from all types of functional foods. However, it could not scientifically verify pre-purchase by consumers. They rely on *health claims* provided by the government, the marketers or both (Lu, 2015; Ovesen, 1999).

Regulators around the world have their own definitions of health claims. The European Union defined health claims as any claim that suggested or implied the relationship between a certain food substance and health (Lalor and Wall, 2011). The United States also used a similar definition. Japan, on the other hand, specified that any health claim made must be widely accepted by scientific experts and backed by sound evidence. In the management field, 'health claim' was known as one of the building blocks of quality (Gok and Ulu, 2018).

Every product or service has two types of quality, which are objective and subjective quality. Objective quality refers to product-related characteristics that can be measured using technical instruments (Giacalone *et al.*, 2016). Subjective quality, on the other hand, is consumers' perceptions (i.e. subjective for each person). A product would sell if consumers perceived its quality to be high. Perception or subjective quality has more weight than objective quality (Giacalone *et al.*, 2016). However, in the drug and functional food industry, this inequality was reduced by regulations that control the objective quality of functional foods. In order to build a perception of health-enhancing food, companies are legally required to base it on a set of proven objective quality attributes. The economics of objective quality could be achieved if those objective qualities were recognised and accepted by consumers.

Unfortunately, no study has explored the attributes of functional foods' objective quality in spite of its importance. Previous studies on functional foods were dominated by three streams. The first stream was consumer behaviour. They mostly dealt with perceived quality (e.g. Brečić *et al.*, 2014; Crofton *et al.*, 2013; Davčik, 2013). The second stream was food science. They mostly focused on a specific functional food or its ingredients (e.g. Bekers *et al.*, 2007, 2008; Busanello *et al.*, 2019; Sharma and Ghoshal, 2018). Public policy was the third stream (e.g. Dixon *et al.*, 2006; Lalor and Wall, 2011; Sadler, 1993). Previous articles predominantly discussed the regulations surrounding functional foods and health claims. Neither of the mentioned streams discussed the objective quality of functional foods in general. Therefore, this review aims to identify the objective quality of functional foods. It is expected that this review would be able to fill the gap in literature on the objective quality of functional foods. The findings could also be used in establishing regulations related to functional food by countries with a less developed functional food industry.

## 2. Functional food

Divergence in functional food's definitions has been often expressed in previous studies (e.g. Khan *et al.*, 2014; Sarkar, 2013; Schnettler *et al.*, 2015). The most referred definition was the one offered by Diplock *et al.* (1999):

> Foods are called functional if it [they] demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects in a way that is relevant to either improved state of health and well-being and/or reduction of risk of disease.

Compared with other descriptions regarding functional food, definition by Diplock *et al.* (1999) was somewhat general. For example, Bruce *et al.* (1999) stated the following:

> A functional food is (or appears similar to) a conventional food. It is a part of a standard diet and is consumed on a regular basis, in normal quantities. It has proven health benefits that reduce the risk of specific chronic disease or beneficially affect target functions beyond its basic nutritional functions.

Another type of definition has surfaced. Labrecque and Charlebois (2011) argued that 'functional foods are the results of supplementing foodstuffs with nutraceuticals or a bioactive ingredient to deliver health benefits'.

All definitions agreed on a few points. Firstly, functional food is not a pill or a drug, it is a type of food, and it is supposed to be consumed as a part of normal diet. This was where Health Canada drew the line between functional food and nutraceutical. The later was defined as a commodity (or commodities) extracted from foods being used in pills or capsules (Shahidi, 2009). Secondly, to be called 'functional', food must have proven health benefits beyond basic nutrition. Albeit there are differences on the type of health benefits demanded by each definition; some asked for its ability to prevent particular chronic diseases (e.g. Doyon and Labrecque, 2008; Lara *et al.*, 2018) and others required targeted functions, such as better performance or longevity (e.g. Dixon *et al.*, 2006; Goldberg, 1994; Gray *et al.*, 2003), but all insisted on functions beyond traditional foods.

The most prominent difference found in popular definitions was associated with the form of functional food. When the term was first coined in the 1980s, 'functional food' referred to foods that were added with nutraceuticals or bioactive component to improve health (Almeida *et al.*, 2013; Dixon *et al.*, 2006; Heasman and Mellentin, 2001). However, there have been articles stating that functional food could be both *fresh* and *processed* (e.g. Grajek *et al.*, 2005; Markovina *et al.*, 2011; Sarkar, 2007; Schreiner and Huykens-Keil, 2006; Verkerk *et al.*, 2009). Grajek *et al.* (2005) included conventional foods that contain 'naturally occurring bioactive' and Sarkar (2018) even added the phrase 'known or unknown biologically active compounds'. Consequently, if this definition was adopted, the term 'functional food' would have a very indistinct barrier from conventional foods, since conventional food might have a biologically active compounds that are not recognised by the scientific community. This study decided to define functional food as 'a modified food that provides health benefits beyond basic nutrition'.

The current functional foods are categorised into the following four types: fortified products, enhanced products, altered products and enhanced commodities (Bigliardi and Galati, 2013; Gok and Ulu, 2018; Kotilainen *et al.*, 2006; Sloan, 2000; Spence, 2006). Fortified products mean foods that have been fortified with extra nutrients such as fruit juice fortified with vitamins. An enhanced product, on the other hand, is a type of food that contained new components not normally found in certain foods, such as fermented milk with probiotics. Bigliardi and Galati (2013) stated that an altered product is a food from which harmful components have been *removed, reduced, or replaced by another with beneficial effects*. The last type, enhanced commodities, refers to a type of food in which its natural components have been enhanced.

## 3. Food quality

Although health claims were one of the most important inherent characteristics of a functional food, it was not the most important factor that affected consumers' acceptance. Studies on functional food-related innovations and marketing have found that 'proven health' claim was only one of the variables that influenced consumers' perception about food quality.

As mentioned above, there are two types of food quality: perceived (i.e. subjective) and objective quality. Perceived quality denotes subjective evaluations of foods (Cardello, 1995; Giacalone *et al.*, 2016; Lawless, 1995; Saenz-Navajas *et al.*, 2013). The perceptions were most likely to be unequal to objective characteristics. For example, objectively bananas contain vitamin, fibre, potassium and magnesium, regardless of their skin colours (Harvard T.H. Chan School of Public Health, n.d.). However, consumers still preferred bananas with no brown spots because they simply looked better.

Consumers' choice and behaviour were more affected by perceived rather than objective quality (La Barbera *et al.*, 2016). A study conducted in Australia and New Zealand has found that 90% of consumers read the nutrition labels of packaged foods (Mhurchu and Gorton, 2007). However, the deciding factor was not the label but the consumers' perceptions of the label. The benefits perceived for consuming functional food, not the actual-lab-tested-effects, were the most important factors in consumers' acceptance (Rezai *et al.*, 2017).

Even though the perceived quality has an outstanding effect, consumers still need to base their perceptions on something concrete (La Barbera *et al.*, 2016). For example, meat quality. Consumer A perceived a block of meat as a high-quality steak when he or she saw a dense marbling pattern on it. However, Consumer B might consider it as a health risk. They have different perceptions in terms of meat quality, but they based their judgement on something objective, the marbling pattern shown on the meat. Marbling was the intramuscular fat that appeared like a marble pattern (Gotoh and Joo, 2016; Smith, 2016). The marbling was an example of objective quality; a set of product-oriented characteristics, such as the nutritional components, the uniform ripening colour and the measured acidity.

Objective quality, in terms of foods, means inherent characteristics of certain foods that could be measured technically. Since currently, there is no study that has focused on the objective quality of functional foods, this study is drawing cases from other types of foods to explain the objective quality. The first example is pineapple slices. Their objective quality indicators included the level of decay, browning index and overall acceptability (Gonzalez-Aguilar *et al.*, 2004). Tristimulus reflectance colorimetry was used to assess the colour (Sapers and Douglas, 1998), and the firmness was measured using the maximum rupture force test (Gonzalez-Aguilar *et al.*, 2004). The second example is the broccoli. The objective quality of broccoli is determined based on its shelf-life, colour and chlorophyll content (Jin *et al.*, 2015). A 30% yellowing on a broccoli floret was used as the proxy of shelf-life. Colour was assessed using a chromameter, and chlorophyll content was measured using the following formula: 'Milligrams of chlorophyll mass per gram of fresh weight'. The third example is poultry meat. The quality assessment of chicken breast has a different approach. In a particular study performed by Petracci *et al.* (2015), the objective quality of chicken meat was assessed not based on the presence of good characteristics but on the absence of defective characteristics. The objective quality of poultry meat was evaluated based on the absence of deep pectoral disease, pale, soft, exudative (PSE)-like white striping, and wooden breast (Petracci *et al.*, 2015). In general, objective quality encompasses visual appearance, taste, texture and safety (free of diseases).

The above-mentioned examples showed that those foods have a set of clear objective quality indicators and measurements which could be used to separate or rank products based on their inherent characteristics. In the functional food category, there has not been a study that collected objective quality attributes or indicators which could be used to evaluate and compare products. Therefore, the current study's main purpose was to identify those objective quality attributes by conducting reviews of previous literature on functional foods.

## 4. Methodology

This study aimed to identify the attributes of objective quality of functional foods by reviewing previous literature. The inclusion/exclusion criteria are shown in Table 1. The ideal keywords would be 'functional foods' and 'objective quality', 'intrinsic quality', or 'objective cues'. However, based on research using three databases (Emerald Insight, ScienceDirect and Taylor & Francis), the

**Table 1. Articles inclusion criteria.**

| | Rationale | Included | Excluded |
|---|---|---|---|
| **Publication type** | The aim of this study is to review research on functional foods. Thus, articles chosen were research articles only. | Research article, case study, conceptual paper/literature review. | Technical paper, secondary article, chapter items, commentary/review of other articles. |
| **Peer-review** | Peer-reviewed process ensures the validity and reliability of articles. | Peer-reviewed. | Non-peer-reviewed. |
| **Quality of journals** | Journal quality ensures the validity and reliability of articles. Journals were only taken from three publishers because of the authors' access limitation. | Journals from three publishers: Emerald Insight, ScienceDirect, and Taylor & Francis. | Journals outside Emerald Insight, ScienceDirect, and Taylor & Francis. |
| **Language** | The author(s) can only comprehend texts in English. | Articles written or translated to English. | Articles written in languages other than English. |
| **Time frame** | The time frame was not defined because this study aims to create a broad comprehension of the topic and not only the latest. | NA | NA |
| **Content** | This study aims to identify the objective quality of functional food. Thus, the article chosen were the ones that focused on functional foods. | (1) Articles on how to create or process certain functional foods/ the production side of functional food industry (2) Articles on how to assess or evaluate certain functional foods (3) Articles concerning the consumers' side of functional food industry (4) Articles on functional food industry in general (5) Articles concerning the governments' side of functional food industry | (1) Articles that did not draw boundaries between functional foods and nutraceuticals (2) Articles that explored the potential functional food properties contained in certain foods (deciding whether certain food could or could not be categorised as a functional food) (3) Articles that discussed the advantages or disadvantages of certain methods to characterise certain functional foods |

results were thin. Therefore, two broad terms were used, 'functional food' and 'quality'. The articles were filtered further based on their types. The search on the three databases did not use year limitation, because we did not want to miss any groundwork that might be conducted decades ago but highly cited until now.

Using the Emerald Insight database, single terminology was used, 'functional foods' in 'anywhere' (any part of the text). This process yielded 230 unfiltered articles. Using the ScienceDirect database, the authors used 'functional food' as the keyword in 'title', and 'quality' as the keyword in 'title, abstract, keywords'. The result listed 35 research articles. Using Taylor & Francis Online, the authors utilised the same method as the one used in for ScienceDirect. In all 92 articles were found. This study manually excluded secondary papers, technical papers, chapter items and commentary, and solely used research papers (including literature reviews). After manually filtering the articles based on their categories, the remaining were read to determine their relevance. This study excluded articles that did not focus on functional foods.

## 5. Results and discussions

### Articles' demographics

This study gathered 357 articles from three databases (see Table 2), but after the filtering process based on publication type and content relevancy, the total number of research articles used in this study came down to 146. From selected 146 articles, this study identified several topics, such as consumer behaviour (marketing management), public policy, food science, health and medicine and others (i.e. biomedical and functional food industry) (see Figure 1). The three most popular topics are further elaborated in the next section.

Previous studies on functional foods are divided into three broad topics. The first topic is 'consumer behaviour and marketing management'. This is the most popular topic. In fact, consumer behaviour, in general, has always been a dominant area of social sciences (MacInnis and Folkes, 2009) because the society is continuously shifting and there have been observable differences based on

**Table 2. Total number of articles.**

| | The number of initial articles | Filtered based on publication type | Filtered based on relevancy |
|---|---|---|---|
| Emerald Insight | 230 | 193 | 96 |
| ScienceDirect | 77 | 35 | 18 |
| Taylor & Francis | 92 | 92 | 32 |
| The total number of articles used in this study | | | 146 |

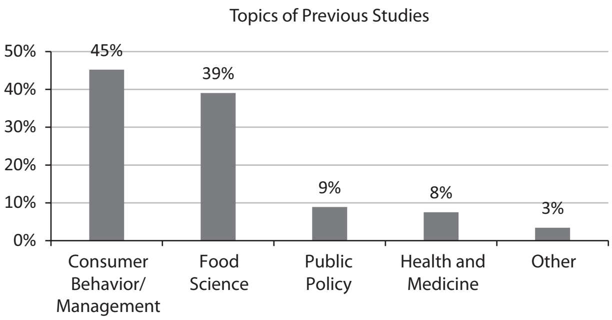


**Figure 1. The categorisation of research topics in previous studies.**

context which demanded a myriad of studies in the area. In the context of functional food industry, the interest on consumer behaviour might be built because even though the governments and the businesses were participating, consumer acceptance and growth of the functional food industry still heavily rely on consumers (Childs, 1997).

The four major topics in the consumer behaviour of functional foods were consumer awareness (e.g. Armstrong *et al.*, 2005; Bazhan *et al.*, 2017; Gok and Ulu, 2018), knowledge (e.g. Arens, 2018; Hasnah Hassan, 2011; Kljusuric *et al.*, 2015; Lalor *et al.*, 2011; Lu, 2015), perception (e.g. Badrie *et al.*, 2007; Bazhan *et al.*, 2017; Crofton *et al.*, 2013) and consumer attitude (e.g. Kljusuric *et al.*, 2015; Markovina *et al.*, 2011; Rezai *et al.*, 2017; Schnettler *et al.*, 2015). The purposes of those studies are similar. However, those studies' underlying purposes were basically connate, to understand consumers' decisions regarding functional foods, and it was not uncommon for studies to coalesce those topics in a single article. This finding is aligned with a previous literaturere view on the topic of consumer behaviour in general by Peighambari *et al.* (2016).

Several notable findings were derived from previous studies. Firstly, there were many variables (i.e. independent, mediating and moderating) that have been proven to affect consumers' decision to either purchase or consume functional foods: perception, attitude, knowledge, trust, health-consciousness, to name a few. Secondly, people in countries such as Greece, Iran, Trinidad and Croatia, were found to be generally unfamiliar with the terms 'functional food' (or 'nutraceuticals' and 'designer foods'; Badrie *et al.*, 2007; Bazhan *et al.*, 2017; Christidis *et al.*, 2011; Markovina *et al.*, 2011). There were indications that consumers were confused, even though they have consumed functional foods before. The term was considered as a '*techno-jargon*' that has not reached consumers (Bazhan *et al.*, 2017). Thirdly, the intention or the decision-making process in terms of consuming or buying functional foods varied across age and gender. Females were more health-conscious and more likely to buy or consume functional foods compared to men (Armstrong *et al.*, 2005; Bogue *et al.*, 2017; Lalor *et al.*, 2011) as well as early middle-aged people (Bhaskaran and Hardley, 2002; Čukelj *et al.*, 2016; Krystallis *et al.*, 2008; Schnettler *et al.*, 2015).

The second most popular topic was food science (Figure 1; see also Table 3). Studies on this topic were dominated by the following three streams. Firstly, studies on the effect of a certain process towards a functional food's active compounds (e.g. Bekers *et al.*, 2007, 2008; Ivanović *et al.*, 2018; Lalel *et al.*, 2017). Scientists generally question as to how production processes, storage and even fertilisation processes of certain functional foods' raw material could affect the efficacy and the shelf-life of functional foods. Secondly, studies on how to develop (or modify) a functional food (Agrahar-Murugkar *et al.*, 2018; Ismail *et al.*, 2018; Kia *et al.*, 2018; Lara *et al.*, 2018; Sanzana *et al.*, 2011). Thirdly, studies on the health-related characteristics of functional foods. Different types of foods were investigated under this stream (Bouderbala and Bouchenak, 2016; Celiktas *et al.*, 2010; Malav *et al.*, 2015; Yousefi *et al.*, 2018). Previous researchers either investigated active compounds or conducted trials on animals and humans.

The third broad topic is public policy. It has two major concerns, which were the effect of certain policy on functional food industry and regulations comparison between several countries (i.e. usually developed countries such as the United States, Japan, Australia, New Zealand and the European Union). The oldest publications (used in this study) on functional food regulation called for consumer protection so that the 'market does not run ahead of the science' (Sadler, 1993). The next batch of articles in the late 1990s argued that the concept of functional food at that moment was 'vague and malleable' and especially

**Table 3. Examples of foods examined in the previous studies.**

| Category | Types of food (or its derivatives) | Author(s) |
|---|---|---|
| Fruits | *Mangifera pajang* and *Artocarpus odoratissimus* | Bakar *et al.* (2010) |
| | Palmyrah | Lalel *et al.* (2017) |
| | Pomegranate | Ferrari *et al.* (2010) |
| | | Çam *et al.* (2014) |
| | Strawberry | Basu *et al.* (2014) |
| | Carrot and watermelon | Mestry *et al.* (2011) |
| Vegetables | Artichoke | Bekers *et al.* (2007, 2008) |
| | Vegetable gourd | Devaki *et al.* (2015) |
| | Swiss chard | Ivanović *et al.* (2018) |
| | Microalgae | Sahni *et al.* (2019) |
| | Aloe vera | Sanzana *et al.* (2011) |
| Poultry and meat | Chicken egg | Applegate (2000); Bhat *et al.* (2015); Surai and Sparks (2001); Yousefi *et al.* (2018) |
| | Quail egg | Sahin *et al.* (2008) |
| | Meat | Olmedilla-Alonso *et al.* (2006) |
| Fish | Fish | Tahergorabi *et al.* (2015) |
| Grains, beans and nuts | Chickpea | Amaral *et al.* (2014) |
| | Mung bean | Amaral *et al.* (2017) |
| | Oat, maize, and soybean | Kaur *et al.* (2017) |
| | Flaxseed | Hassan-Zadeh *et al.* (2008); Kumar *et al.* (2017) |
| | Cereal | Lara *et al.* (2018) |
| | Grains | Pasha *et al.* (2015) |
| | Peanut | Bishi *et al.* (2015) |
| | Nuts | Olmedilla-Alonso *et al.* (2006) |
| Dairy food | Milk and yogurt | Ismail *et al.* (2018); Kia *et al.* (2018) |
| | | Busanello *et al.* (2019); Saeed *et al.* (2013); Sarkar (2013, 2018) |

unspecific for establishing any regulation (Glinsmann, 1997). In a 1998 study done by Childs (1997), it was found that Japan was the only country that had a set of regulations. Australia was reviewing it under the standardisation code, while Canada, the European Union and New Zealand had no regulation in place. The absence of specific and agreeable definition was probably the reason why up to this point, the 'functional food regulation' does not exist. Instead, countries formulated regulation on 'food with health claims'. The European Union's regulation regarding foods with health claims has been a popular research topic (e.g. Arens, 2018; Khedkar *et al.*, 2016; Martinez and Siani, 2017). Previous studies have found that despite European Food Safety Authority's (EFSA) available guidelines (Pravst *et al.*, 2018), translating regulatory requirements into scientific requirements remained a challenge for the functional food industry (Khedkar *et al.*, 2017). Other countries were not free of confusion either.

## Functional foods' objective quality attributes

One particular thing to be noted is that functional food is essentially a food (Bazhan *et al.*, 2017; Diplock *et al.*, 1999) that stands as a part of daily diet. Hence, the objective quality of functional food cannot be separated from the food type. A functional food carries the objective quality indicators of the vehicle, both sensory and non-sensory (see Table 4). For example, an enriched egg. Aside from assessing its functional properties, such as selenium, vitamin E, lutein and docosahexaenoic acid (DHA), evaluation of an egg's quality should also include albumen height, egg weight, yolk height, yolk diameter and the level of acidity. Functional foods' objective quality attributes are provided in Table 5.

### *Product-oriented quality*

*Has a proven health claim*: The most cited functional food's objective quality is 'proven health claim'. The claim ranges from reducing the risk of certain diseases (e.g. Doyon and Labrecque, 2008; Goetzke and Spiller, 2014), curing certain diseases (e.g. Bhaskaran and Hardley, 2002; Hunt, 1994), improving performance (e.g. Badrie *et al.*, 2007; Dixon *et al.*, 2006) and maintaining longevity (e.g. Aiello *et al.*, 2016; Dixon *et al.*, 2006). There were also claims on different types of nutrition contents.

Consumers cannot confirm this quality on their own; hence, they rely on two things. Firstly, the label provided by

**Table 4. Examples of foods' objective quality indicators.**

| Types of food | Carrier/ vehicle | Quality indicators of the carrier in general (A) | | Additional indicators of food as a functional food (B) | |
|---|---|---|---|---|---|
| | | Non-Sensory | Sensory | Non-Sensory | Sensory |
| **Fresh** | Egg | Albumen height<br>Egg weight<br>Yolk height<br>Yolk diameter<br>Level of acidity | Appearance<br>Smell<br>Yolk shape<br>Yolk consistency | Safe and potent dosage of:<br>Selenium<br>Vitamin E<br>Lutein<br>DHA | Appearance<br>Smell<br>Yolk shape<br>Yolk consistency |
| | Fish | Adenosine triphosphate(ATP) breakdown compounds<br>Trimethylamine (TMA), total volatile base nitrogen (TVB-N), thiobarbituric acid (TBA) and formaldehyde<br>Ammonia<br>Volatiles<br>Biogenic amines<br>Total viable count | Skin colour<br>Presence of bloodspots on gill cover<br>Stiffness<br>Firmness of the belly<br>Smell<br>Eye's shape and clarity<br>Gills' colour and smell | Safe and potent dosage of:<br>Eicosapentaenoic acid<br>Docosahexaenoic acid<br>Angiotensin-converting enzyme (ACE) inhibitors<br>Phosphoenol pyruvate (PEP) inhibitors<br>Taurine<br>(Antioxidants)<br>Selenium | Skin colour<br>Presence of bloodspots on gill cover<br>Stiffness<br>Firmness of the belly<br>Smell<br>Eye's shape and clarity<br>Gills' colour and smell |
| **Processed** | Cereal | Available cereal grains and carbohydrates (CHO)<br>Energy<br>Vitamins (thiamin, riboflavin, niacin)<br>Amino acids (lysine, threonine, tryptophan)<br>Protein quality (true digestibility, biological value, net protein, utilisation protein) | Moisture content<br>Shape<br>Colour<br>Flavour<br>Taste<br>Consistency | High fiber<br>Omega 3<br>Cholesterol-reducing properties<br>Antioxidant | Moisture content<br>Shape<br>Colour<br>Flavour<br>Taste<br>Consistency |
| | Cookies | Dough texture<br>Stickiness, adhesion and dough strength<br>Cookies texture<br>Moisture<br>Fat (proximate analysis)<br>Protein | Colour<br>Appearance<br>Aroma<br>Hardness<br>Flavour<br>Mouth feel<br>After-taste | Safe and potent dosage of:<br>Phenolic<br>Flavonoid<br>Antioxidant activity | Colour<br>Appearance<br>Aroma<br>Hardness<br>Flavour<br>Mouth feel<br>After-taste |

*Source*: Agrahar-Murugkar *et al.* (2018); Alasalvar *et al.* (2002); Crofton *et al.* (2013); Food and Agricultural Organisation (2017); Ribeiro *et al.* (2019); Sahin *et al.* (2008); Surai and Sparks (2001); Haard *et al.* (1999); Lara *et al.* (2018).
*Note*: The indicators listed in the table are by no means complete. Because the aim of this study is to capture the objective quality of functional foods in general, this article is not going to discuss the objective quality of each food in detail.
DHA, Docosahexaenoic acid.

functional food's producer (Armstrong *et al.*, 2005; Bimbo *et al.*, 2018; Childs, 1997; Shamal and Mohan, 2017). It is a general practice in the food industry to provide nutritional information on food packaging. At some places, it is mandatory to list sugar, salt and fat contents, the recommended intake, and the calories. The second factor on which a consumer relies upon is the information provided by the government (Foo *et al.*, 2013; Hamlin and McNeill, 2016) such as the Health Star Rating (Australasian), Healthier Choice Symbol (Singapore) and FOSHU Symbol (Japan). Even though the effectiveness of these ratings or symbols was debatable, previous research has agreed that, to an extent, consumers considered these ratings as a proxy of proven health claims in their decision-making process.

In the functional food industry, businesses never made health claim categorisation and definition. Instead, different governments regulated it and each country has its own definition and categorisations (see for example Figure 2). Governments tend to shy away from the term 'functional food' and chose to call it 'foods with health claims'. Health claims are heavily regulated in developed countries. Generally, a health claim was a claim that 'expressly, or by implication characterizes, the relationship of any

**Table 5. Functional foods objective quality.**

| Quality category | Quality attributes | Examples |
|---|---|---|
| Product-related quality | Proven health claim | Aiello *et al.* (2016); Badrie *et al.* (2007); Bhaskaran and Hardley (2002); Dixon *et al.* (2006); Doyon and Labrecque (2008) |
| | Organoleptically acceptable | Gray *et al.* (2003); Kljusuric *et al.* (2015); Kumar *et al.* (2017) |
| | Safe | Almeida *et al.* (2013); Anninou and Foxall (2017); Bazhan *et al.* (2017); Hasler *et al.* (2001) |
| | Suitable vehicle/carrier | Kraus (2015); Lalor *et al.* (2011); Uauy *et al.* (2002) |
| | Reasonable shelf-life | Ferrari *et al.* (2010); Gaudette and Pickering (2013); Singh *et al.* (2015) |
| Process-related quality | Scientific-based production process (proxies: the production process adhered to scientific findings) | Ferrari *et al.* (2010); Ismail *et al.* (2018); Zhao *et al.* (2005) |
| | Commercially viable production process (proxies: price and availability) | Bazhan *et al.* (2017); Brečić *et al.* (2014); Gok and Ulu (2018); Kljusuric *et al.* (2015); Urala and Liisa (2003) |
| | Standardised production process | Food Standards Australia New Zealand, 2007; The Ministry of Agriculture Nature and Food Quality of the Netherlands, 2005 |

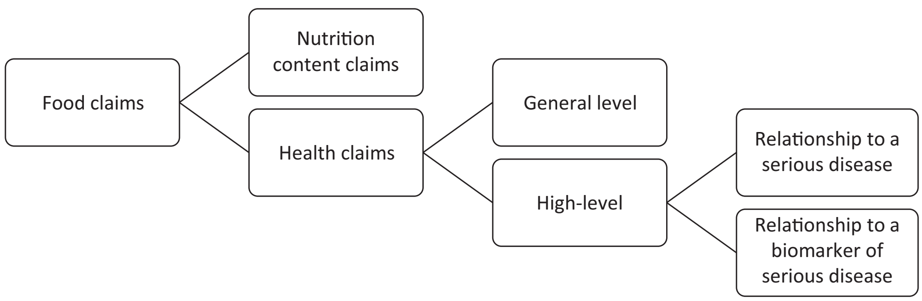


**Figure 2. Health claims categorisation (Food Standards Australia New Zealand, 2016).**

substance to a disease or health-related condition' (Lalor and Wall, 2011).

When it comes to product marketing and consumer acceptance, regulating health claims is essential because of consumer safety, which is very important. Governments must ensure that fear of certain diseases or degenerative conditions is not exploited commercially by functional food manufacturers using health claim labels. A health claim is something that consumers could not verify on their own. They might accept it, refuse it, or, very likely, misinterpret it (Markovina *et al.*, 2011). Thus, the key here is not the type of claim but product's demand to be proved scientifically *before* it reaches consumers.

Health claims in the European Union were assessed by EFSA based on a high-standard scientific evaluation (Martinez and Siani, 2017). To prove health claims, EFSA mandated at least the following three things (Lensen *et al.*, 2018):

1. Sufficient characterisation of bioactive substance
2. There must be a beneficial physiological effect
3. There must be an established, scientifically causal relationship between the substance and the physiological benefit

In Australia and New Zealand, the food standards are managed by the Food Standards Australia New Zealand (FSANZ). They have set the rules on how the food industry could make general health claims (e.g. maintain brain health) or high-level health claims (e.g. reduce the risk of heart attack; Tapsell, 2008). The substantiation of claims must be backed by scientific evidence, its relevance for the health of population, and worded correctly (Tapsell, 2008; Wellard-Cole *et al.*, 2019). A previous study showed a 52% rate of successful substantiation of food health claims (Wellard-Cole *et al.*, 2019).

In general, the scientific documentation needed to generate the most important objective quality indicator of functional foods (i.e. health claims) is classified into three categories: epidemiology, biological mechanisms and intervention trials (Ovesen, 1999). Epidemiological data used statistics to create an association between intake and certain diseases. Biological data were gathered using animal models that mimic the plausible mechanism of interaction between intake and the disease. The intervention trial was the highest form of documentation. It recorded data from 'human population intervention' (Ovesen, 1999, p. 811).

*Organoleptically acceptable*: In spite of functional food's projected high growth rate (Gineikiene *et al.*, 2017; Global Industry Analysts: Functional Food and Drinks, 2012), customers' acceptance, as a result of marketing process, has been extremely varied. Functional foods were highly accepted in the United States, European Union and Japan. However, previous studies have found that some market segments voiced concerns over the health claims and distrust towards manufacturers (Bazhan *et al.*, 2017), and compared with organic foods, the health benefits of functional foods were often discounted (Gineikiene *et al.*, 2017). Some consumers opined that alterations to foods had compromised their taste (Gray *et al.*, 2003; Kljusuric *et al.*, 2015; Kumar *et al.*, 2017).

As mentioned before, functional food is essentially a food. For it to be digested properly, it must be good organoleptically, which means that human senses can accept and enjoy it. Consumers generally understood and even expected that the taste of functional foods would somehow be inferior compared to their traditional counterparts (Gray *et al.*, 2003; Kljusuric *et al.*, 2015; Kumar *et al.*, 2017). However, at the very least, it must be decent.

There are two ways to assess organoleptic attributes. Firstly, by sensory analysis by panellists. For example, in a 2017 study by Lalel *et al.* (2017), they used 30 semi-trained panellists to assess the appearance, crispiness, odour and flavour of five functional chips made out of cassava, wheat and *palmyrah* pulp. Another example is the analysis of colour, appearance, body and texture of goat milk mixed with *tamr* and honey (*Rayeb* milk). The product was organoleptically tested by 10 trained staff (Ismail *et al.*, 2018). Sensory analysis was also done of omega-3 polyunsaturated fatty acid (PUFA)-fortified surimi seafood. The test was done by 79 panellists in terms of visual appeal, colour, aroma, texture, flavour and acceptability (Tahergorabi *et al.*, 2015). The second way to evaluate an organoleptic attribute was through technical measurement. For example, assessing the firmness of butter using a cone penetrometer (Dixon and Parekh, 1980), evaluating food colours using a colorimeter (Agrahar-Murugkar *et al.*, 2018; Biron *et al.*, 2011; Çam *et al.*, 2014; Ferrari *et al.*, 2010; Lekshmi *et al.*, 2019; Nunes *et al.*, 2016; Zhao *et al.*, 2005), calculating dough stickiness using Chen–Hosney stickiness cell, or cookies' brittleness with a three-point bending rig (Agrahar-Murugkar *et al.*, 2018). Both ways to assess organoleptic attributes were considered as objective measures.

*Suitable base-carrier/vehicle*: The vehicle is the base food used to deliver additional functional properties. From the consumers' standpoint, it is about taste preferences (Kraus, 2015; Lalor *et al.*, 2011). Preferences of certain products, such as milk or yogurt, could be exploited as effective delivery of health-enhancing compounds. From the governments' perspective, the delivery of functional food must consider coverage. The aim of governments, especially in developing countries, was to provide healthy food for as many people as possible. So, they tended to choose staple foods as the vehicles of functional ingredients (Mannar and Hurrell, 2018). From the scientists' perspective, it is about optimum delivery or the best vehicle for certain micro- or macronutrients and the inherent/naturally occurring functionality. The choice of food matrix and the source of bioactive compounds were extremely important because the biological impact of functional food is dependent on both. For example, iron fortification; it must consider the bioavailability of iron, the food matrix, and 'the balance of inhibitors and enhancers and total iron intake' (Uauy *et al.*, 2002). Wheat has a higher percentage of iron absorption compared to maize-masa, making the former (in this context) a better carrier.

*Safety*: The issue of safety in terms of functional foods was the main concern (e.g. Almeida *et al.*, 2013; Anninou and Foxall, 2017; Bazhan *et al.*, 2017). Functional food is exhibited between food and medicine (Sarkar, 2007, 2018), and this fact has made the safety issue all the more important. Previous studies associated 'safety' with minimum (or no) side effects, but potent recommended daily intake. One of the previous articles argued another detail that the consumption of a particular functional food should not create significant interactions with prescription drugs (Hasler *et al.*, 2001). Most of the articles in the Food Science category dedicated their studies to either characterising a potential functional food (e.g. Bhat *et al.*, 2015; Saeed *et al.*, 2013) or examining the level of certain compounds in functional foods to ensure its effectiveness in producing physiological benefits for consumers by testing them with live subjects (Ballali and Lanciai, 2012; Maringaneli and Jones, 2010). The se studies were conducted to ensure that functional foods were safe to consume in certain 'dosage', effective, and did not create an adverse effect.

*Reasonable shelf-life*: The case of shelf-life was somehow similar to the case of organoleptic attributes. Ideally, a long shelf-life is a desirable attribute when it comes to processed foods, but on the other hand, functional foods were at points required to be free of dangerous chemicals. A long shelf-life was hard to achieve naturally and both consumers and producers understood that in the context of functional foods or healthy foods, the lengths of shelf-life might be compromised. Previous studies also discussed natural ways to preserve or prolong the shelf-life of functional foods without adding dangerous chemicals or processing functional foods in a way that would significantly reduce its efficacy (Ferrari *et al.*, 2010; Gaudette and Pickering, 2013; Singh *et al.*, 2015). For example, a study done by Singh *et al.* (2015) focused on using *Moringa Oleifera* (drumstick tree) to preserve livestock-based functional foods. Another example was a high-pressure treatment to preserve natural anthocyanins in pomegranate juice (Ferrari *et al.*, 2010).

### *Process-oriented quality attributes*

The process-oriented quality was not mentioned explicitly or discussed in previous studies. However, their existence was countlessly implied in every article. There were three important process-oriented quality, which are the scientific-based production process, commercially viable process, and standardised food production process. All articles in the Food Science category were trying to find the health benefits of certain foods scientifically or to prove the causal relationship between functional ingredients or foods and physiological benefits. The production process must consider those studies to make sure that they generate products that possess sufficient beneficial compounds, confirming that the production process does not alter or diminish the efficacy of compound. On articles in the Public Policy category policy (e.g. Childs, 1997; Lalor and Wall, 2011), the scientific-based production process was also emphasised.

The second process-oriented quality attribute is a commercially viable process. This attribute was inferred from the rationale that functional foods must be accessible to the majority of people in a country. From the consumers' standpoint, this rationale necessitates affordable prices and easy access (i.e. available in many places). The quality indicators were often mentioned in articles in the Consumer Behaviour category (e.g. Bazhan *et al.*, 2017; Brečić *et al.*, 2014; Gok and Ulu, 2018; Kljusuric *et al.*, 2015; Urala and Liisa, 2003). From the producers' perspective, this means that a quality product is the one that could be mass-produced at reasonable costs.

The third process-oriented quality attribute is a standardised food production process. This attribute was not specific for functional foods, but for processed foods in general. It was also not mentioned in the articles used in this study. However, to legally produce and distribute functional foods in a country or internationally, adherence to a specific standardised food production process is mandatory. The European Union's General Food Law, and Australia and New Zealand, for example, mandated the implementation of Hazard Analysis and Critical Control Points (HACCP) (Food Standards Australia New Zealand, 2007; The Ministry of Agriculture Nature and Food Quality of the Netherlands, 2005). A derivative of HACCP, ISO 22000 is also widely accepted as a norm for processed food production.

## Conclusions and the future research

Functional food is a growing industry. Many studies have investigated almost every aspect of this industry, upstream (i.e. development of functional foods) until downstream (i.e. acceptance of functional foods by consumers). Studies on functional foods were dominated by three broad topics, which were consumer behaviour, food science and public policy. Articles on consumer behaviours encompassed subtopics, such as awareness, knowledge, perception and attitude, while articles on food science generally focused on the development or characterisation of certain functional foods. Articles on public policy discussed the effect of policy on the functional food industry as well as regulations' comparison across countries.

From the selected articles, this study found product- and process-related quality attributes, which were inherent characteristics of functional foods; variables which the absence of one of these attributes would make a food unqualified to be called functional food. Product-related quality attributes include the following: (1) Food has an enhanced health benefit, (2) it must be organoleptically acceptable, (3) safe, (4) delivered with suitable vehicle/carrier, and (5) has a reasonable shelf-life. Process-related quality attributes are (1) a scientific-based production process, (2) a commercially viable production process, and (3) a standardised production process.

This study has identified the objective quality attributes of functional foods through a literature review using articles from three databases. However, the attributes are not validated empirically. Therefore, *the first future research agenda* is to validate the accuracy of those attributes from the perspective of governments, businesses and consumers as the major drivers of the functional food industry. Other objective quality attributes that have not been mentioned in this article could also be identified through validation process. This study has not determined detailed indicators from those objective quality attributes. Quality indicators are important to enable quality assessment of certain products or processes. Hence, the *second future research agenda* is to build more detailed indicators from attributes and create levels or ranks that could be used to measure the quality of functional foods objectively. As mentioned before, the growth of the functional food industry depends on consumers' acceptance, and subjective or perceived quality carries more weight than objective quality. Therefore, for the next consumer behaviour study, the *third future research agenda* is to pinpoint the objective quality that could best serve as a quality stimulus to persuade consumers.

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### Compliance with Ethical Standards

This article followed all ethical standards for a research without direct contact with human or animal subjects.

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