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Review

Functional foods: Planning and development

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The discussion on functional foods among scientific communities and EC commissions is mainly focused on definitions and on legislative issues related to the presence on the market of this kind of products. Although many new products continuously appear, the functional food market is characterized by a high rate of failure. To realize a successful functional food, experts having different background should work together following a detailed workplan. In this paper, the problems related to planning and development of functional foods are considered using a step-by-step approach. The strategies for invention and development, formulation and validation of nutritional claims are regarded also illustrating practical examples of functional food development. The concept of food for special medical purposes, intended for individuals who are being treated under medical supervision, is also introduced.

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Contents

1 Ideas and planning

The health potential of foods is well perceived by European consumers. Particularly those having high education believe that a correct dietary regime together with physical exercise are the two fundamental parameters to maintain a satisfactory health status. Food marketing is following and pushing this trend and functional foods represent the direct answer that food companies could give to this request of "health by food" [1–3]. On the other side, public authorities look at functional foods as a possible tool to reduce social health costs as it happens in Japan where the FOSHU (Food for Specific Health Use) is promoted by the Japan Ministry of Health [4]. European consumers, particularly those of Mediterranean countries, are generally diffident towards new foods and they will not change their food choices only because they are marked as healthy. In these countries, the success of functional foods will depend on the degree of "confidence" that they will be able to acquire. For example, the acceptability of a food containing a functional ingredient is strictly dependent on the level of consumer recognition of that ingredient, *i. e.* vitamin, calcium, iron, or fiber, remain in the consumers mind much more than carotenoids, flavonoid, or omega-3 fatty acids [5, 6]. Urala and Lahteenmaki [7] pointed out that consumers did not see functional foods as one homogeneous group over different product categories. They perceive functional products as a member of the general product category, such as yoghurt or spread, and only secondarily as a functional food. The selection of the type of functional foods may be successfully guided by the market needs, however, consumer science studies have been carried out to understand how to transfer new scientific advances into new market products [8].

From the research and development point of view, functional foods represent a territory where the expertise of food technologists, nutritionists, medical doctors, and food chemists must be combined to obtain innovative products, at least maintaining the qualitative standard of the traditional foods. On the other hand, these foods must be able to modulate a physiological parameter related to the health status or disease prevention (Fig. 1). Planning and development of functional foods are strictly related to the safety

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Abbreviation: SFCA, Short-chain fatty acid

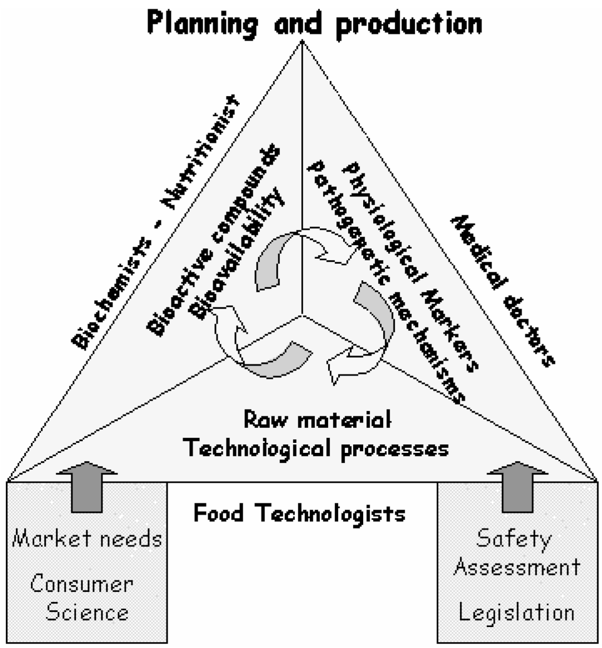

Figure 1. Disciplines and professional figures involved in functional food planning and development.

assessment and legislation aspects as well as to the market strategies and consumer science. Although legislation and consumer needs are not among the topics of this paper, they represent two key factors underlying the functional food development. In particular, it is expected that a more restrictive legislation on health claims will increase the quality of the research carried out by food companies. However, these problems are still under discussion and a complete regulation is still far from being established [9, 10]. Despite the uncertainty about rules, functional foods are continuously launched on EC markets and in some fields these products can be considered as the main innovative foods of the last years. The dairy market was profoundly changed by the presence of fermented probiotic milk. Also in the field of bakery, softdrinks, and baby foods a considerable number of new functional foods have been created [11]. However, the rate of failure is still very high and this is only partially due to the intrinsic risk associated with this kind of new products. In fact, in many cases it is possible to pick out mistakes in the research and development, which can be avoided by more accurate strategies. In this work, some indications on the procedure that should be adopted for the development of functional foods, are illustrated using a step-by-step approach.

2 Functional food design

Functional foods are primarily foods and any lowering of the organoleptic characteristics with respect to the conventional products is not acceptable. Therefore, whatever we plan to obtain the functional food, the sensorial properties of the final product must remain at the very center of the attention. The key issue in functional food design is the amount of active compounds that consumers should eat to receive a benefit from food intake. During the design phase calculations can show that the amount of food that one should eat to achieve a health effect is enormous. This can be both due to the impossibility to raise the concentration of the bioactive principle or to the use of food typologies that are usually consumed in low quantities, such as candies. As a general advice it would be recommended to use as base to develop a functional food one of the staple food that can be different for the various countries. In Italy pasta or tomatoes while in Northern European countries spreads and dairy products would be good selections.

There are three main strategies for functional food design.

(i) To modify the composition of raw material.

The macro- and micronutrient content of animal and vegetable raw material can be influenced by a lot of different parameters. For the animal-derived food there are many examples showing, by working on the composition of the animal diet, it is possible to obtain valuable dietary-improved food for humans. Omega-3-enriched eggs have been obtained from hens fed with an omega-3-rich diet, while conjugated linoleic (CLA)-rich milk is obtained from cows predominantly grazing green, thus cows on natural pastures. Genetical modification (GMO), both by molecular biology and by breeding techniques, is a powerful way to improve the nutritional quality of raw food material. Golden rice, the famous cultivar able to produce provitamin A, is only the most famous example of how GMO can represent an unexhaustible mine of opportunity to improve food nutritional quality.

(ii) To modify the technological process.

Many physical and chemical transformations occur during the industrial preparation of foods. In the functional food development it is possible to design a specific process allowing or enhancing the formation of compound(s) having specific biological activities.

- Fermentation is a very good example: soy-fermented sauces have an antioxidant activity much higher than the not-fermented ones because of the generation of *o*-dihydroxy phenols [12].
- Extrusion processes have been successfully used to improve the functional characteristics of many cereals [13]. The physical properties of the extrusion plant, as well as time and temperature of the process, have been shown to influence the soluble/insoluble fiber ratio and the antioxidant activity of the final product.

– Thermal treatment does not only cause the degradation of vitamins and other useful compunds. In some cases, it enhances the bioavailability as it happens for carotenoids, and it also generates compounds having antioxidant activity [14]. At present, the formation of new compounds during food thermal treatment can be regarded as a way to generate potentially healthy compounds. Somoza and co-workers [15, 16] have identified different Maillard reaction products which are formed in coffee and bread crust having potential healthy effects. In the near future, mathematical models able to predict the formation and the degradation of bioactive compounds from food in the different matrices will represent a useful tool for the functional food design [17].

(iii) To modify the formulation of the recipes.

The addition of a so-called functional ingredient to a traditional food matrix is the simplest and most common way to realize a functional food [18]. Many ingredients having more or less certified beneficial properties are available on the market. However, the simple addition of a functional ingredient should be performed taking into account many variables, such as the interaction with the food matrix, the stability to the process, and the bioavailability of the final product.

In many cases, the administration of a food spiked with a functional ingredient do not give the expected biological effect [19]. This is mainly due to the reduction of the bioavalability as a consequence of the interaction between functional ingredient and food matrix as well as to the lack of the appropriate condition for absorption. The addition of α-tocopherol to fruit juice can be poorly effective if it is not consumed together with fats. Another major problem is the alteration of the sensorial properties of the foods. Food enriched with soy-based ingredients, having tremendous beneficial health properties, are often disliked by the EU consumers because of the bean-like flavor in the final product. Finally, the added functional ingredient could undergo degradation or modification during the industrial process with conversion into a nonbioactive compound; this is often the case with antioxidant compounds added to foods that are successively kept in oxidizing environment.

3 Functional pasta

In the last years, scientific evidence exalting the physiological effects of dietary fiber (such as reduction of gut transit time, prevention of constipation, protection against colon cancer, production of short-chain fatty acids (SCFAs), promotion of colon functionality, increase of beneficial colonic microflora growth), has been shown convincing the food industry to use dietary fibers not only to improve the physical characteristics of their products but also to improve food nutritional properties (see Table 1).

Table 1. Physiological effects and properties and/or mechanisms of action of some fibers useful as functional food ingredients

Fiber	Suggested physiological effects			Properties/mechanisms of action	Ref.
	Glccemic response	Lipid metabolism	Gut microflora		
Legume fiber	X			Low accessibility of α-amylase to the starch	[32]
Oat bran β-glucans	X	X		High viscosity Increase of bile acid excretion Reduction of cholesterol excretion Production of SCFAs by gut microflora	[33, 34]
Guar gums	X	X		High viscosity Delay in gastric emptying Delay in intestinal transit time Production of SCFAs by gut microflora	[35–37]
Pectins (citrus pectin)	X	X		High viscosity Ion-exchange ability Increase of bile acid excretion Reduction of cholesterol excretion Decrease of homocysteine	[38, 39]
Xanthan		X		Reduction of cholesterol excretion	[40]
Fructans (inulin)		X	X	Reduction of serum cholesterol Reduction of serum triglycerides Increase of beneficial microflora growth Increase of calcium absorption	[41–44]
Psyllium seed husk		X	X	Reduction of serum cholesterol Reduction of serum triglycerides Reduction of serum phospholipids Increase of beneficial microflora growth	[45–48]

Table 2. Comparison of some physico-chemical parameters relative to fiber-enriched pasta and traditional product [20]

Fiber	Consistence	Elasticity	Viscosity	Adhesivity	Cooking loss
Inulin	n. r.	–	–	+	+
Guar gum	+	–	+	+	–
Pea fiber	–	–	–	–	+

Symbols + and – represent an improvement or a worsening, respectively, of each parameter compared to traditional pasta.
n. r., hot recorded

The introduction of dietary fibers in a product like pasta provides many nutritional advantages. Conventional pasta has numerous physiological effects, first of all the reduction of postprandial glucose and insulin concentration, due to a glycemic index lower than bread [20]. Pasta is very popular and widely consumed due to its facility to be transported and stored as well as to be cooked and used in many recipes. In Italy, the daily pasta intake is about 100 g. Therefore, functional pasta, with 5% added dietary fiber, would allow most people to reach the recommended dietary intake of 25–30 g/d.

From the technological point of view, the major problem in dietary fiber addition to pasta is the possible modification of the physico-chemical and sensorial properties of both the added fiber and the final product. Technological treatments can modify fiber properties, such as the viscosity and ion-exchange capacity (which are the main contributors to the fiber effect on glucose and lipid metabolism), thus varying the physiological effects of the final functional pasta [21]. Also water absorption and viscosity as well as the ability to maintain a compact structure and the characteristic flavor and taste after cooking can be severely affected by dietary fiber addition [22].

Experimental tests in order to compare the properties of pasta fortified with inulin, pea fiber, and guar gum to the traditional product have been carried out by Tudorica and co-workers [20]. In particular, parameters, such as texture, elasticity, viscosity, adhesivity, and cooking losses, have been evaluated. As reported in Table 2, inulin-enriched pasta showed a compact but less elastic structure than the traditional product. This might be due to the interaction between the fiber and the proteins as well as to the competition between starch and proteins for water absorption. The entity of inulin loss in cooking water and thus the nutritional functionality of the inulin-rich pasta is still unclear. On the contrary, the addition of pea fiber determined the disruption of the pasta protein matrix, resulting in high starch losses in cooking water, while guar gum increased the consistence of pasta.

The studies on functional pasta are still at the beginning and trials on the efficiency of this product on health markers have not yet been published. The few dietary fiber-enriched pastas present on the EU market have very poor sensorial quality and a lot of work is necessary to obtain pasta products comparable with the conventional ones.

4 Implementation of health claims

Functional foods can be classified into two main categories according to the expected effects: those aiming to improve physiological functions and those aiming to reduce the risk of specific pathologies. In the first reports of the PASSCLAIM EC project (http://europe.ilsi.org/passclaim/), different intervention fields for functional foods have been selected. Among foods improving physiological functions, gut health, immune system activity, and also mental performance have been selected while cancer, cardiovascular disease, diabetes, and osteoporosis are the main targets of functional foods aiming at preventing specific pathologies [23].

A major problem in the functional food development is the verification of its efficiency. To verify specific physiological relevance of food consumption, a suitable and measurable marker must be indicated. This marker should be linked with certainty to the physiological effect(s) which can be measured using solid, well-known, and worldwide accepted procedure [24]. For example, to validate the efficiency of a food aiming to reduce the risk of cardiovascular disease, plasmatic low-density lipoprotein (LDL), cholesterol concentration, or simply blood pressure can be measured. On the other hand, the selection of a robust marker to verify the ability of a functional food to improve mental performance is a big challenge and the possible results will be easily criticized by the scientific community.

Recently, the "Virtual Food Component" (VFC) approach has been proposed by Monro [25] as a tool to evaluate the efficiency of functional food consumption. The author based his work on the observation that the simple presence of a specific ingredient in foods is not necessarily correlated to the desired biological function. For example, the bulk effect associated to fiber rich foods is not proportional to the amount of fiber reported in the nutrition fact table [26]. An application of the VCF approach is reported in Table 3: to evaluate the efficiency of fiber-rich foods, the increase in fecal mass was taken as functionality index. This index was used to evaluate the biological effect caused by the consumption of different foods taking the effect exerted by wheat fiber as reference. From data in Table 3 it can be noticed that peas, having an amount of fiber lower that oat (5.9% *vs.* 11.0% total fiber respectively), are almost equally effective in increasing feces weight. The different

Table 3. Amount of fibers of some foods and their efficiiency in increasing fecal mass

Food	Total fiber (%)	Fecal mass index[a)]
Oat flakes	11.0	7.7
Peas	5.9	6.5
Corn flakes	3.2	1.7
Dry apricots	3.2	3.1
White bread	2.6	1.4

a) Measured as wheat fiber equivalents for 100 g product (*i. e.*, that 5.9 g peas have the same effect like 6.5 g wheat fiber used as comparison) [26].

action is obviously related to the type of dietary fiber present in each food. The water-insoluble dietary fiber present in wheat bran is very efficient in increasing the feces weight, while the water-soluble β-glucans, which represent a great part of the oat dietary fiber, are not. In other words, using the fecal mass index it is possible to illustrate the different functionality of the products overcoming the information present in the food compositional tables.

The information on the package and the claims used in the advertisement campaign strongly influence the consumers' choices of food products. In the field of functional foods the nutritional and physiological claims obviously have an outstanding importance. The general message given in these claims is that the regular consumption of the product, combined with a balanced diet, could prevent some pathologies or to improve a physiological function [9].

The health and nutrition claims that can be used for functional foods are not yet strictly regulated. A recent EC document gives some recommendations underlying the need to release health claims only upon severe conditions and after independent scientific evaluation of the real health benefits [27]. The actual situation allows the presence on food packaging of many different and appealing claims. They are in many cases quite generic like: "increase body strength" or "help to maintain fitness" and in many cases they are not supported by any scientific evidence. The general behavior is to attribute food the properties that can be found in scientific literature for the single component or for the functional ingredient and only in a few cases a trial using the specific product has been performed. When, in the near future, more restrictive rules on functional food health claims will be approved, the availability of scientific evidence on the product will become the real bottleneck to launch functional food on the market. On the other hand, consumer associations strongly support the concept that health claims should be used only when data on the efficiency of the product are available and finally also the food industry would take advantage from more reliable health claims.

5 Food intended for special medical purposes (FSMP)

In clinical practice, dietary recommendations in the management of chronic diseases rely on denying patients certain foods, an approach which results in a severe reduction of quality of life. The concept of food intended for specific medical purposes (FSMP) has been introduced to indicate food specifically developed for consumers having specific pathologies or at risk to develop some diseases [28]. In the approach using FSMP, the consumers' sensorial satisfaction and the medical efficiency will be both taken into account. FSMP can be regarded as a subcategory of functional foods which have a primary target disease where a dietary impact has been demonstrated, such as noninsulin-dependent diabetes mellitus or cardiovascular diseases. Recently, also the use of FSMP as coadjuvant of pharmacological therapies received great attention in the scientific literature. Probiotics in the treatment of transplantations [29] and liver diseases [30] as well as the use of antioxidant-rich foods to counteract antiviral drug oxidative stress [31] represent some interesting examples of the advantage that patients could take from the use of FSMP. Patient associations recommend the development of this kind of foods as their use is perceived as more natural and better tolerated than pills. Moreover, it has been estimated that savings for the public healthcare will result from a widespread use of FSMP.

6 Conclusions

European consumers are well aware of the correlation between food and health. This fact, together with the increase in food quality and safety knowledge, offer an important opportunity to food industries to develop a wide range of new functional ingredients and foods. A widespread consumption of these foods may significantly influence the consumers' health status, thus representing an easy-to-use tool to reduce social health costs. Moreover, functional foods represent an important challenge for the cultural growth of food companies. In fact, to develop functional foods, from design to production, a total qualification of the whole factory, including staff training and refreshing, is needed.

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