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# Accepted Manuscript

Title: **Concepts, benefits and perspectives of functional dairy food products**

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## Concepts, benefits and perspectives of functional dairy food products

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### Abstract

The rising awareness of the consumers towards the health benefits of food has resulted in the development of the so-called functional foods. These added value products which refer to prevention and/or therapeutic effects of food beyond its nutritional value, are especially useful for health improvement and reduction of medical care costs. The combination between health and nutrition and its potential to improve the quality of life has become one of the key attention points of consumers who are aware of and are seeking nutritional solutions to their health concerns.

Milk and dairy products have been used in human nutrition for thousands of years, providing important nutrients for the human body such as proteins, fats and calcium. It is now widely recognized that in addition to their basic nutritive role they also exert functional properties beneficial for human health, so the development of functional dairy products is one of the fastest growing areas in the dairy industry as well as one of the largest sectors in the global market of functional foods.

This review provides a brief overview of the health benefits and the natural functionality of dairy products as well as the challenges together with the future perspectives of their application as delivery vehicles for beneficial compounds to the human body.

**Keywords:** functional foods, milk, dairy products

### Introduction

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Functional foods (sometimes referred as physiologically functional foods, nutraceuticals, designer's foods or pharma foods) can be defined as those that provide the consumer with an identified health benefit above basic nutritional value (Bogue et al., 2017; Castillo et al., 2018; Playne et al., 2003). The concept of functional food was first introduced by Japanese scientists and later raised awareness for the need of such products in Europe and the United States. Today, there is much greater recognition that risk for disease development can be reduced and good health and well-being may be maintained through healthy lifestyle and diet. Ongoing support for the important role of foods such as fruits, vegetables, and whole grain cereals in disease prevention as well as dietary antioxidants and other phytoactive components from plants have helped the development of the functional food market, while the demographic and socioeconomic changes in population have raised the need for foods with added health benefits (Daliri and Lee, 2015). As a consequence, today's palette of functional products encompasses a wide variety of dairy-, confectionery-, soft-drinks-, bakery- and baby-food products (Kotilainen et al., 2006; Menrad, 2003; Ortiz et al., 2017; Syro et al., 2018).

Milk and dairy products have been used as part of the human diet for thousands of years, playing an important role in the nutrition and development of human populations throughout the world (Ortiz et al., 2017). Also, milk and dairy-based ingredients have been widely used as components of many food products because of their contribution to critical characteristics such as unique flavor, desirable texture and natural appeal of the product (Allen Foegeding et al., 2010).

The health benefits of milk and dairy products have been known since medieval times (Bhat & Bhat, 2011). These effects can be attributed to the numerous constituents of milk which exert favorable physiological functions and/or serve as precursors to biologically active substances in the human body (Fig. 1). Current scientific literature clearly indicates that dairy products consumption has positive influence on human health, reduces the risk of cardiovascular disease, atherosclerosis and improves the functions of the immune system as a whole (Davoodi et al., 2013; Elwood et al., 2010).

Fig. 1

Functional dairy products represent of the largest segments in the functional food market, with hundreds of new products being produced each year, due to their well-established natural appeal (Turkmen et al., 2019). The principles in the development encompass incorporation of different “functional” substances or microorganisms ranging from probiotics and prebiotics, phytosterols, minerals, vitamins to bioactive peptides (Ortiz et al., 2017). Also, the production of innovative functional dairy products has focused on incorporating food byproducts as source of bioactive compounds, thereby reducing the waste in the food chain and offering new ways to diversify the production of dairy foods (Iriundo-DeHond et al., 2018). Regardless of the carrier used, dairy or non-dairy, and bioactive compounds selected for the enrichment or fortification, the most important marker of consumer’s acceptance is the sensory profile of functional foods. Hence, the development of functional foods beyond functional properties of the foods have to consider primary health concerns, consumer’s familiarity with the concept of functional food and with the functional compounds, the nature of the carrier product, health effects, health claims helping consumers to make better-informed food choice and sensory appeal as an extremely influencing factor (taste being a factor that directs consumer’s choice and convenience as a basic requirement), packaging, shelf-life, and safety evaluation (Annunziata and Vecchio, 2013). Products with “natural” matches between carriers and functional compounds seem to have the highest level of acceptance among consumers. To avoid a mismatch between consumer’s needs and characteristics of new functional foods introduced in the market, great emphasis should be given in existing and future researches to consumer acceptance and preferences towards functional foods (Fig. 2). In this respect, acceptance for functional dairy products is increased due to certain bioactives which are naturally connected to these foods (probiotics, vitamins, minerals), especially among consumers with higher diet/health related knowledge, as well as with aging (Bimbo et al., 2017).

Fig. 2

The purpose of this review is to give a brief overview of basic concepts of functional dairy products, to demonstrate their health benefits and to assess the trends in the development of novel dairy based functional products.

### **Functional dairy foods (products)**

### *Milk*

Milk derived from all mammalian species is known as the “nature’s best” food providing rich source of nutrients for the newborn, including protein, carbohydrate, lipids and minerals. Also, it is an available and rich source of these nutrients for the more mature consumer worldwide (Gantner et al., 2015; Haug et al., 2007; Playne et al., 2003; Visioli & Strata, 2014). The high content of important minerals (calcium, magnesium, phosphorus) and vitamins (riboflavin and  $\beta$ -carotene) as well the natural and bioavailable form in which these constituents are available to the human body puts milk in the category of physiologically functional foods (Erfanian et al., 2015; Playne et al., 2003).

The application of milk or dairy products as a vehicle for preparation of functional products is an excellent strategy that can lead to rapid improvement of the nutritional status of the population due to several advantages: milk is centrally processed and therefore quality control can be effectively implemented, it is widely consumed regularly in predictable amounts by people of different age groups and the cost is affordable by the target population. Milk is an excellent natural carrier for a wide range of added nutrients and their addition usually causes minimal changes in color, taste and appearance. Also, many studies have indicated that the stability and bioavailability of the added nutrients remains high (Alzate et al., 2010; Kaushik et al., 2014; Ocak & Rajendram, 2013).

Due to the numerous benefits, milk has been the subject of many studies dealing with the preparation of more “active” functional products using probiotics, vitamins and minerals or other bioactive compounds. Among many functional dairy products, probably the most famous example is the addition of prebiotic substances and probiotics to milk (Bakr, 2015). Probiotics are defined as living microorganisms that when consumed in adequate quantities provide health benefits to the host (Hill et al., 2014). Lactic acid bacteria (LAB) and bifidobacteria are the most studied and widely employed probiotics because they are normal constituents of intestinal microflora and have a long history of safe applications within the food industry. The use of milk is directly related to milk composition, which is a better matrix for probiotic bacteria growth than dietary supplements. Using probiotics in nutraceuticals, such as in capsules may lead to a reduction in functional efficacy due to the exclusion of the potential synergistic effect of the food. Originally, probiotic delivery was consistently associated with foods, particularly dairy foods help to buffer the probiotics through gastrointestinal tract and support their colonization (Ranadheera et al., 2010).

Further, the metabolic activity of the probiotics in milk can result in formation of another interesting group of bioactive compounds called probioactives. Such compounds, for example, are specifically released by the hydrolysis of milk's casein and appear only in fermented foods but not in dietary supplements. Therefore, milk and dairy products should be used as a vehicle for probiotics instead of supplements (Champagne et al., 2018).

The favorable effects of other types of functional milks, such as vitamin- and mineral enriched milk have been evaluated by researchers in different studies. These products include folic acid fortified milk for better absorption of folic acid (Mitsukutchi et al., 2017). Calcium and vitamin D fortified milk along with magnesium and zinc improves vitamin D status, lowers parathyroid hormone levels and reduces bone turn over (Bonjour et al., 2009; Kruger et al., 2010). Calcium in the form of calcium caseinate-phosphate complex in milk is readily released during digestion, making its bioavailability high. Since good bone health can be achieved through appropriate diet and active lifestyle, the usage of calcium-fortified milk in every day nutrition could protect from osteoporosis and bone fractures in later stages of life (Rajasekaran & Kalaivani, 2013).

Iron-fortified milks have been designed to address the issue of anemia and studies have shown that this type of product improves anemic status thus it is a favorable approach in reducing micronutrient deficiencies in young and preschool children (Rajasekaran & Kalaivani, 2013; Sazaval et al., 2010). Selenium-enriched milk can be used to improve selenium status in humans and at the same time reduce the risk of developing cancer (Alzate et al., 2010; Hu et al., 2010).

Dairy proteins from milk and their properties have been intensively studied. They play important nutritional role and supply the body with essential amino acids and organic nitrogen and at the same time are rich source of biologically active peptides. They possess beneficial properties, but remain inactive within the sequence of the parent protein. Once released after enzyme hydrolysis, the peptides show radical scavenging, metal ion complexation properties and ability to inhibit lipid peroxidation. Lactoferrin from milk has been reported to inhibit intestinal tumors because of its apoptotic activity and the ability to modulate carcinogen- metabolizing enzymes (Pereira et al., 2016). On the other hand, intact milk proteins possess nutraceutical properties that enable their use as carriers of vitamins, minerals and fatty acids in addition to their immunomodulatory, anti-cancer, hypotensive and antibacterial properties (Mohanthly et al., 2014).

### *Fermented dairy products*

Fermented dairy products hold a long tradition and contribution to the nutrition of many societies and cultures worldwide and have been used to enhance intestinal health from ancient times. Even before scientific studies documented this benefit, fermented milk products were used to alleviate diarrhea caused by infection of pathogenic bacteria (Bashali et al., 2014).

The process of fermentation enables preservation of food as well as transformation of the raw material into a new product with unique sensorial properties (Bashali et al., 2014). During fermentation, the enzymatic activity of the raw material and the metabolic activity of the microorganisms can change the nutritive and bioactive properties of the food matrix resulting in beneficial effect for human health. Additionally, fermentation can result in removal of toxic or undesirable food constituents (Marco et al., 2017).

Fermented dairy products often contain compounds that are not present in regular milk such as exopolysaccharides (ex. kefiran in kefir) and natural enrichments including increased vitamin B<sub>12</sub>, K<sub>2</sub>, folate and riboflavin content (Hugenholz, 2013). Furthermore, they usually possess  $\beta$  – galactosidase activity and reduced lactose content compared to milk, making them potentially suitable for people suffering from lactose intolerance.

Many scientific studies have confirmed that natural fermented dairy products may possess antihypertensive effects, enhance systemic immunity and lower cholesterol and blood pressure. They may also serve as rich source of bioactive peptides released through fermentation by proteolytic cultures and have been linked to many potential health benefits to the endocrine, digestive, cardiovascular, and immune and nervous system (Marsh et al., 2014).

### *Yogurt*

Yogurt is a fermented dairy product usually obtained as a result of the fermentation process of milk by lactic acid bacteria such as *Streptococcus thermophyllus* and *Lactobacillus bulgaricus*. It possesses added health benefits over its parent product, milk and has provided the human body with nutrients and bioactive compounds long before the concept of functional food was known. The clear association between the consumption of yogurt and good health has resulted in an increased consumption of this product in recent years.

Yogurt, as nearly complete food, is an excellent source of protein, fat, essential vitamins and minerals such as calcium, magnesium, zinc, iodine and potassium. The fermentation process

may increase the bioavailability of vitamin B<sub>12</sub>, calcium and magnesium as well as proteins and peptides (especially in Greek style yogurt). In this manner, it can be considered as an ideal product for children and elderly who need to maintain their skeletal mass (Fernandez & Marette, 2017). Human studies have clinically demonstrated that yogurt consumption in lactose-intolerant individuals increases lactase activity in the small intestine, in addition to improved lactose tolerance, immune enhancement, and prevention of gastrointestinal disorders (Prentice, 2014; Savaiano, 2014).

As a probiotic carrier food, it can deliver significant amounts of probiotic bacteria in the body. Probiotics and prebiotics found in yogurt have been reported to have many beneficial effects such as weight reduction, cholesterol reduction and positive effects on overall cardiovascular health including hypertension (Gahruie et al., 2015).

In general, yogurt is the most preferring to be used as a base product for supplementation with a whole spectrum of bioactive compounds apart from the probiotics. Yogurts can be fortified/enriched with cereal grains, different seeds, fresh and dried fruits and their consumption is associated with numerous health and nutritional benefits (Guine & De Lemos, 2018). For example, the combination yogurt-fruit is offering nutrient dense and lower-energy alternatives in place of typical nutrient-poor snacks such as desserts and cakes; however, the beneficial effects should be confirmed in larger clinical studies (Sayon-Orea et al., 2015).

Studies comparing different food matrices showed that the matrix of yogurt is an appropriate carrier for plant sterols and stanols providing cholesterol-lowering efficiency (Algorta-Pineda et al., 2005; Clifton et al., 2004; Hyun et al., 2005; Mensink et al., 2002; Volpe et al., 2001). Based on the evidence, national and international guidelines recommend functional foods with added plant sterols and stanols as part of a dietary prevention strategy for promotion of cardiovascular health, in particular, management of hypercholesterolemia. It has been accepted that daily intake of 2 g plant sterols and stanols lowers plasma LDL-cholesterol concentrations by a median of 10% following a 4-week supplementation protocol. Therefore, plant sterols and stanols are granted a health claim regarding their beneficial effects, and functional foods supplied with these agents are offered to consumers in many countries. Since yogurt already has unique properties that make it an important component of a healthy and balanced diet, addition of plant sterols and stanols into yogurt provides the development of a new functional food that increases the benefit for consumers (Buyuktuncer, 2017).

Yogurt has shown great potential to be utilized as nutritional intervention for people living with HIV. It is a palatable product that contains good quality protein, essential micronutrients and can enhance a protective intestinal microbiome. Yogurt can significantly improve the protein and nutrient density of low-quality and low-quantity diets; this is required for optimal immune function. Yogurt can be locally produced in resource-poor regions and is accepted in regions most affected by the HIV epidemic. In addition, it can serve as a vector for additional micronutrient, probiotic, and prebiotic supplementation, which have been shown to reduce the sequelae of a pro-inflammatory state and microbial translocation in HIV (Hummelen & Hemsworth, 2017).

### *Kefir*

Kefir is a self-carbonated, slightly foamy viscous beverage, with a uniform elastic consistency and sour, acidic, and slightly alcoholic flavor. It is produced by the actions of the microflora encased in the kefir grain on the carbohydrates in the milk. This fermented milk beverage is regarded as an easily digested product and esteemed for its nutritional value (Bashali et al., 2014). Containing bacterial species known for probiotic properties, it has long been popular in Eastern Europe for its health benefits where it is routinely administered to patients in hospitals and recommended to infants (Nielsen et al., 2014). Kefir has been shown to positively influence GIT, stimulate the immune system and has anti-inflammatory and anti-carcinogenic effects, albeit not through clinical trials (Oliveira Leite et al., 2013).

The microbial profile of this beverage consists of around 30 species of LAB and yeast classifying kefir as major probiotic source (Ahmed et al., 2013; Kolakowski et al., 2012; Yang et al., 2010). The yeasts have been shown to enhance aggregation and adhesion of LAB to the epithelial cells and straighten their gastrointestinal tolerance. The reported probiotic activity of kefir also includes protection from toxins (Farnworth, 2003; Xie et al., 2012). The kefir component of kefir may also act as a prebiotic, supporting the growth and expression of known probiotic bacteria (Nielsen et al., 2014).

It affects the blood pressure through ACE-inhibition and exhibits immunomodulatory effects which may lead to reducing allergic responses in food allergy (Nielsen et al., 2014). However, studies on the benefits of kefir on cholesterol reduction have shown mixed effects (Vujicic et al., 1992).

Kefir and kefir fractions have been shown to be effective in killing cancer cells *in vitro* and in slowing cancer growth *in vivo* (Shiomi et al., 1982). According to one study, more than one third of patients with cancer use complementary and alternative medicine and the use of kefir by patients undergoing chemotherapy to help them alleviate GIT side effects have increased (Can et al., 2009).

Apart from preparation of functional kefir enriched with dietary fibers (Goncu et al., 2017; Simsek et al., 2017), the scientific literature is relatively poor in studies dealing with the preparation of other types of functional kefir drinks.

### Ayran

Ayran (drinking yogurt) is a fermented traditional product prepared by addition of water to homemade yogurt or by addition of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* to industrially produced milk, according to the Turkish Food Codex (TFC, 2009). It is an easily digestible and highly valued drink with high vitamin and calcium content, especially used as cold refreshment during the summer. The ayran has been subjected to many investigations in order to make this product more “functional”, healthier or with greater antioxidant capacity. However, the main technological problem is ayran’s instability during storage. Thus, the addition of stabilizers must be considered (Yilmaz et al., 2015). The incorporation of inulin or pectin in the ayran has produced a functional drink with higher content of aroma components and higher antioxidant activity (Najgebauer-Lejko & Sady, 2015; Kök-Taş & Güzel-Seydim, 2010). Ayran has been successfully used as a vehicle for delivery of cocoa hull waste phenolics in the form of liposomes (Altin et al., 2018). Also, efforts have been made to add probiotic and prebiotics to make a more functional drink. In the study performed by Petreska Ivanovska et al. (2018), new probiotic/synbiotic drink enriched with *Lacobacillus casei* 01 and oligofructose – enriched inulin was developed. The obtained samples enriched with synbiotic microparticles containing *L. casei* 01 and oligofructose-enriched inulin had the main advantage in terms of probiotic survival and increased production of lactic, acetic and propionic acid. The newly developed product gained functional properties, while retaining the quality of conventional ayran with the possibility to be offered to consumers as a part of a healthy diet. Ayran supplied with the same symbiotic microparticles has provided anti-inflammatory activity in trinitrobenzene sulfonic acid-induced

model of rat colitis indicating one potential approach in prevention and treatment of inflammatory bowel diseases (Petreska Ivanovska et al., 2017).

### *Cheese*

Cheese is a dairy product rich in nutrients such as proteins, peptides, different types of fatty acids, several vitamins and essential minerals such as calcium. Being very nutritious it has a long history in the human diet. The high content of fat and protein makes cheese energy-rich and nutritious food for all age groups. Nowadays, a wide variety of cheese products from Cheddar to Mozzarella are produced worldwide and the trend is continuously increasing (Exposito et al., 2016).

Cheese is a rich source of dairy fat. Kratz et al. (2013), reviewing the effects of food rich in fat on human health, summarized various studies demonstrating that dairy fat consumption can provide better metabolic health and may protect against metabolic dysfunction. In addition, cheese is an excellent source of minerals, especially calcium and phosphorus. The casein – calcium phosphate of cheese shows high mineralization potential on teeth enamel, so the EFSA has supported the consumption of cheese as an anti-carries measure (EFSA, 2008). Cheese proteins are one of the most important nutrients, responsible for nutritional, physicochemical, functional and sensory aspects of cheese. The bioactive peptides exhibit different physiological effects such as anti-oxidative action, modulation of gastric function as well as lowering the blood pressure (Exposito et al., 2016). Lactoferrin, a biologically active peptide which undergoes denaturation in sterilized milk or yogurt, is abundant in cheese a detectable range and represents an alternative source of biologically active lactoferrin. An interesting example are the Italian hard cooked cheese types such as Parmigiano Reggiano and Grana Padano because according to their composition they can be considered as “functional foods”. During cheese ripening (enzyme-modified cheese process) bioactive peptides of physiological importance may be produced, such as opioid peptides, ACE-inhibitory peptides, casein peptides with immunomodulatory action or caseinophosphopeptides which may function as mineral carriers (Summer et al., 2017).

Cheese has been used as a suitable platform for delivery of probiotics. According to certain studies the combination of hypocaloric diet and probiotic cheese could help reduce body mass index, arterial blood pressure and the risk of metabolic syndrome in obese patients with hypertension (Castro et al., 2015; Sharafedinov et al., 2013). In order to increase mineral intake,

cheese has been fortified with iron-enriched yeast and the study conducted in 32 young women indicated that these type of functional product shows similar iron bioavailability when compared to the iron bioavailability from ferrous sulphate (Sabatier et al., 2017). Also, cheese was fortified with vitamin D using protein emulsions as delivery systems and increased retention of this vitamin was achieved in cheddar cheese (Tippets et al., 2012). Cheese can be relatively easily fortified with vitamin D<sub>3</sub> to provide up to 100% daily value in the diet, as it has a higher milk fat content than liquid milk, which aids inclusion of fat-soluble vitamins (Ganesan et al., 2011). Standardized cow's milk (fat 3 g/100 g) was used to manufacture Feta cheese fortified with 40, 60 and 80 mg of iron/kg cheese using ferrous sulphate (FeSO<sub>4</sub>), ferric chloride (FeCl<sub>3</sub>), ferric pyrophosphate (Fe<sub>4</sub> (P<sub>2</sub>O<sub>7</sub>)<sub>3</sub>) and microencapsulated ferrous sulphate. Chemical composition and sensory characteristics of fortified cheeses were determined after 60 days of ripening and the best quality was found in cheeses fortified with 40 mg/kg of microencapsulated ferrous sulphate. Cheese has been used as a matrix for incorporating natural and synthetic antioxidants (Alenisan et al., 2017).

### *Ice cream*

Ice cream can be defined as frozen complex dairy food system containing ice crystals, air cells, polysaccharides, proteins and minerals, especially calcium, but also sodium and potassium (Goff, 2008). Frozen dairy desserts such as ice cream, adapt most readily to nutrient fortification and inclusion of nutraceuticals, thus they can be used as adequate carriers of nutraceuticals because of their low storage temperature, ability to stabilize ingredients as well as the popularity among consumers (Goraya and Bajwa, 2015). Current advances in the development of the ice cream technology have resulted in preparation of functional ice cream, product enriched with bioactive compounds or probiotics.

The nutrient composition and energy value of ice cream is related to the food value of the products from which it is made, but regardless of the mix, ice cream is an excellent source of energy and an ideal substrate for the proliferation of probiotics (Etarevi Evive et al., 2017; Soukulis et al., 2014). In order to provide health benefits, ice cream has been enriched with insoluble dietary fiber, natural antioxidants and fruits and fruit-based products which represent an alternative strategy for increase of the phenolic content of the product. As for milk and milk products, ice cream and other frozen dairy desserts can be used as excellent sources of inorganic minerals and water-soluble vitamins (Marshall et al., 2003). Ice cream is considered a good source of calcium

(836 mg/kg) and as an excellent vehicle for calcium administration to different target groups (van der Hee et al., 2009; Ferrar et al., 2011).

Despite the development of several types of functional ice cream products, there is scarce evidence for the health benefits from clinical trials. Also, the potential of novel strategies for incorporation of different bioactive compounds to ice cream should be thoroughly investigated.

## Conclusion

The development and usage of functional dairy products offers numerous benefits to the consumers and represents an important strategy to improve the health and nutritional status of millions of people. These products should be consumed as a part of the healthy diet throughout all life periods especially during childhood and adolescence and in elderly people. In future, their efficacy and health promoting effects must be confirmed in larger clinical studies and collaboration between food producers and scientists must be accomplished. In addition, further understanding of the functional properties of many dairy ingredients would allow food technologists to utilize their potential contribution to product characteristics in order to develop novel functional products. General interest in health and increased consumer awareness as well as perceived self-efficacy has to contribute to shaping the acceptance of functional food products, while the creativity of food technology should further advance the development of food products that can support optimum health.

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## Резиме

### Концепти, придобивки и идни трендови на функционални млечни производи

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**Клучни зборови:** функционална храна, млеко, млечни производи

Зголемениот интерес на потрошувачите за здравствените придобивки поврзани со храната доведе до развој на таканаречените функционални прехранбени производи што овозможуваат подобрување на здравствената состојба на луѓето и намалување на трошоците за лекување.

Млекото и млечните производи се користат во исхраната илјадници години наназад и претставуваат извор на значајни хранливи состојки како што се протеини, масти и калциум. Покрај високата хранлива вредност, тие покажуваат и поволни физиолошки својства, па развојот на функционални млечни производи претставува еден од најбрзо растечките сегменти во млечната индустрија, како и еден од најголемите сектори на глобалниот пазар на функционални производи.

Во овој труд е даден краток осврт на здравствените придобивки, природната функционалност на млечните производи, како и предизвиците и идните трендови во развојот на функционалните млечни производи како системи за испорака на биоактивни супстанции.

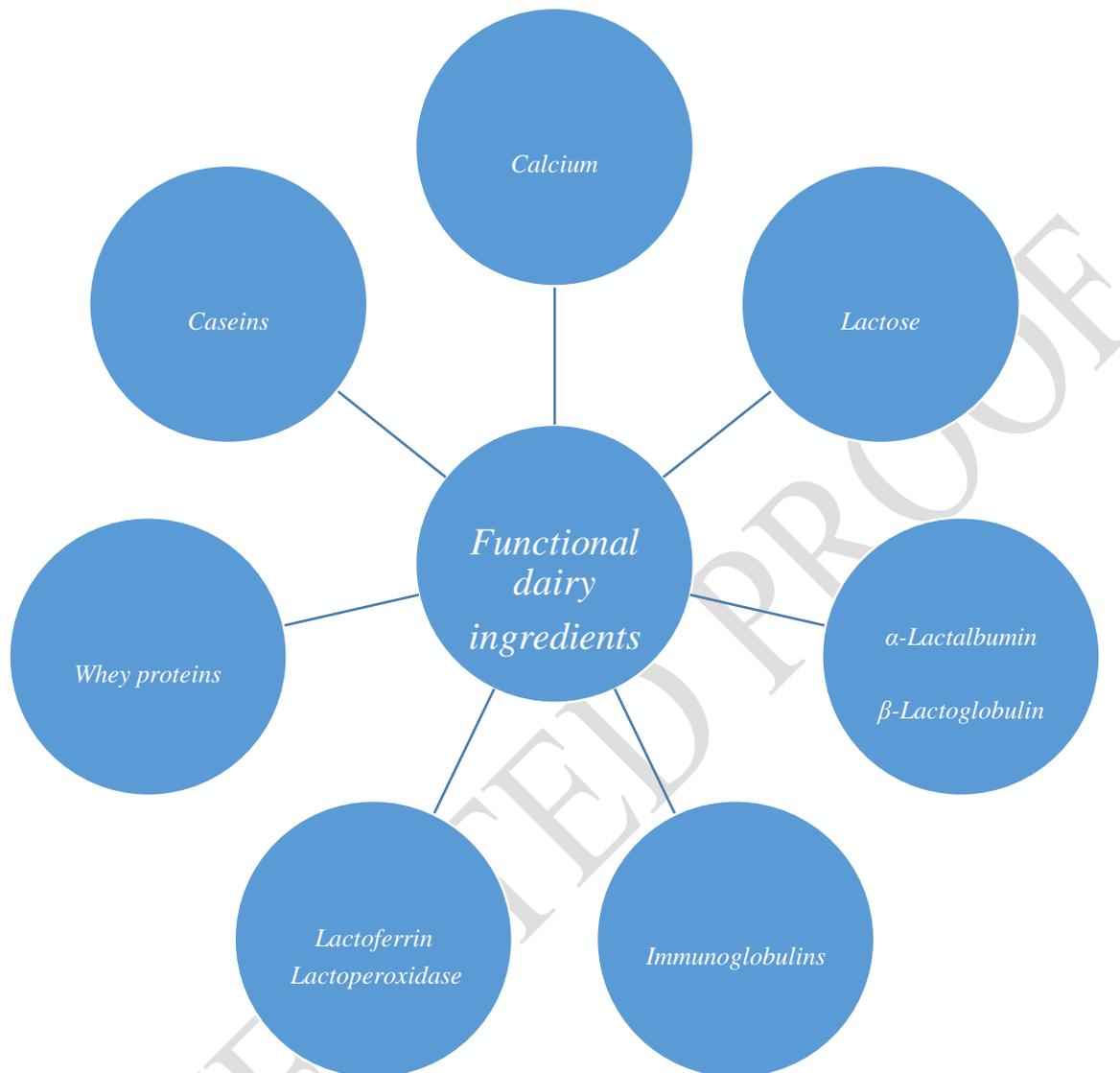
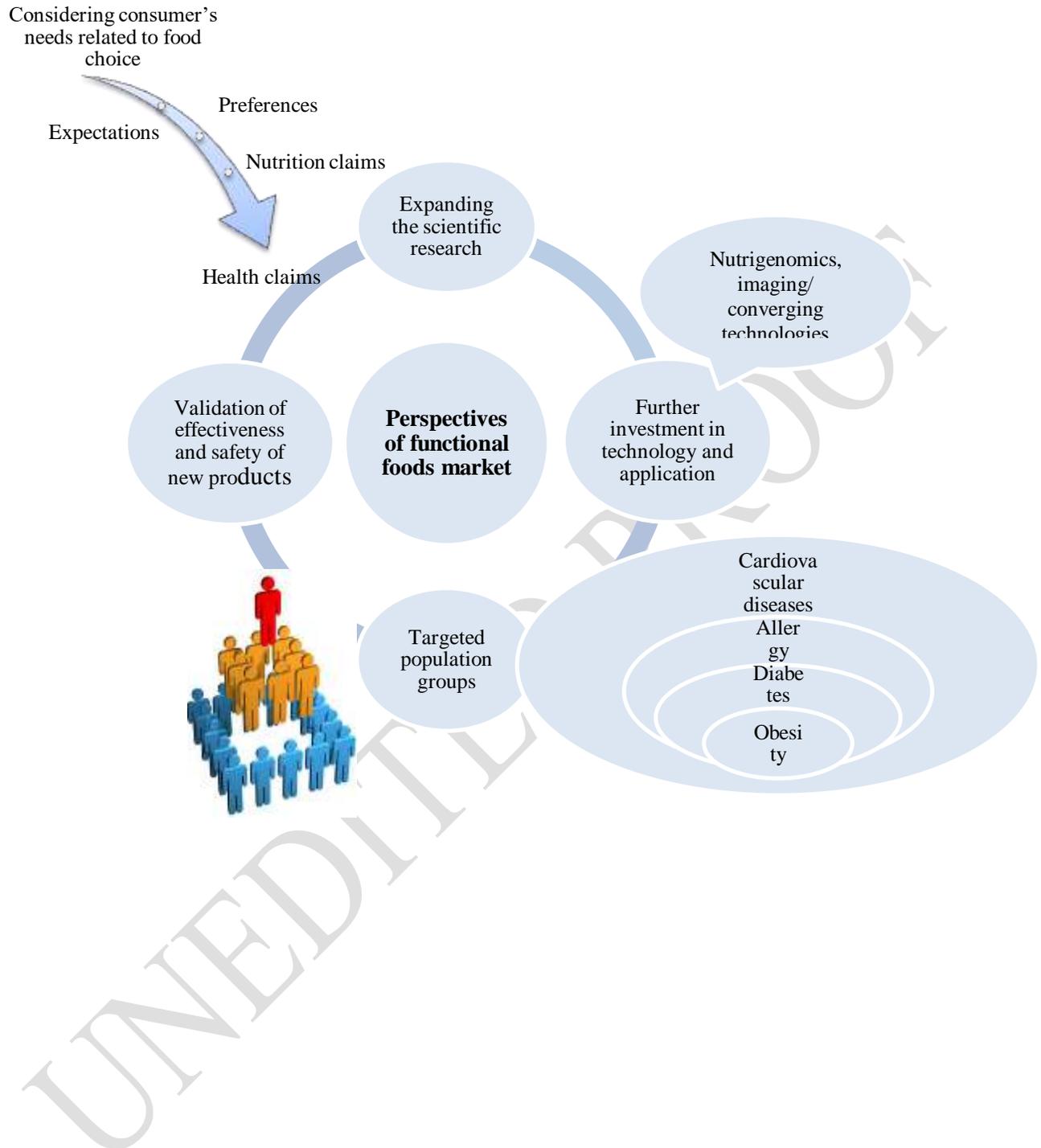


Fig. 1. Bioactive ingredients often used for enrichment/fortification of dairy products.

Fig. 2. Concepts for future trends in functional food market.



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