Developing Yoghurt as Functional Food

Subjects: Agriculture, Dairy & Animal Science
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Edible coatings and films appear to be a very promising strategy for delivering bioactive compounds and probiotics in food systems when direct incorporation/inoculation is not an option. The production of dairy products has undergone radical modifications thanks to nanotechnology. Despite being a relatively new occurrence in the dairy sector, nanotechnology has quickly become a popular means of increasing the bioavailability and favorable health effects of a variety of bioactive components.

Keywords: probiotics ; nanotechnology ; yoghurt ; functional ; women health

1. New Strategy for Developing Yoghurt as Functional Food

1.1. Different Forms of Yoghurt

Yogurt is a fermented dairy product created by two types of lactic acid bacteria, primarily *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus.* Without the use of rennet, this fermentation causes acidification and coagulation, as well as an increase in shelf life due to the low pH. [1]. Many studies have looked into supplementing probiotic strains to yogurt in addition to the standard starter culture to boost the health benefits. Bio-yoghurt or functional yoghurt is the resultant yoghurt with probiotic bacteria [2]. Probiotic bacteria are defined as living microorganisms administered in a sufficient number to survive in the intestinal ecosystem, and must have a positive effect on the host [3].

Set-type or firm, frozen, sipping, stirred, powder, or concentrated, are texture classifications; natural, flavored, sweetened, or with added bits of fruits (fresh or dried) or honey are flavor classifications; fat and lactose residual content are shelf life and nutritional value classifications [4]. There's also a classification based on health advantages. Weerathilake et al. [5] have also reviewed the many varieties of yoghurt. It was based on physical and chemical properties, as well as added flavors and post-incubation treatments. El-Sayed et al. [6] recently used spray drying to make functional yoghurt powder and studied the survival of *Lactobacillus helveticus* CNRZ32.

1.2. Materials Used in the Manufacture of Yoghurt

A number of ingredients are needed to produce yoghurt, including starter, stabilizers, sweetener materials, fruits, and flavorings. In the yoghurt industry, yoghurt and yoghurt starters are among the most important ingredients, if not the most important. To obtain good sensory, chemical, and microbiological yoghurt, high-quality milk must be utilized. Different gums, e.g., alginate, xanthan gum, or gum arabic alone or in combination with maltodextrin, can be used as excellent coatings materials and can be proved as functional ingredients in yoghurts, not only as stabilizers or fat replacers, but as prebiotics as well. The type of milk used in yoghurt production is determined by the type of civet to be produced [5]. To fulfill the demands and expectations of some groups of customers in the community, yoghurt can also be manufactured from non-dairy milk or plant milk [7]. Coconut, soy or peanut milk, coconut with hemp milk, combined cow milk and coconut milk, barley milk, rice, guardar cereal, almonds, and other plant sources can be considered great functional components in the preparation of yoghurts.

1.3. Yoghurt Production

The principal methods of manufacturing yoghurt in traditional ways are by adding starter cultures (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*). Many additives can be added to yoghurt, especially if the purpose is to make a functional and healthy yoghurt. Desired additives are added to yoghurt throughout the manufacturing process in a very traditional way. Furthermore, Omega-3 polyunsaturated fatty acids (PUFA) are an important class of fatty acids, renowned for their health and nutritional benefits for people of all ages, and adding them to yoghurt amplifies those benefits [8]. Bello et al. [9] added *Camelina sativa*, *Echium plantagineum*, flaxseed, blackcurrant, and raspberry to milk prepared for the manufacturing of yoghurt before the fermentation process. However, the reports suggested that high content of α-linolenic acid in flaxseed and black currant oils can be capitalized through using it in yoghurt. Many other kind of fiber sources have been added, which has improved the texture, such as the addition of coconut flour [10][11][12], a great source of fiber, antioxidants, phenols, and probiotic bacteria for bio-yoghurt, with a distinct taste and smell and suitable for inclusion in a school meal for children. The yoghurt fortified with minerals to enhance the nutritional benefits, along with addition of the minerals in nanoparticles form, such as selenium, that is prepared by biological method using lactic acid bacteria as green nanotechnology may be a different class of yoghurt having maximum nutritional value [13].

The main starter culture used in yoghurt preparation are *Streptococcus thermophilus* and *Lactobacillus bulgaris*. Further, the main stabilizers used in yoghurt preparation are alginates (carageenan), gelatins, gums (locust bean, guar), pectins, and starch. However, plain yoghurts are not good in taste; therefore, in order to add taste in it, sweeteners, such as sucrose, saccharine, Acesulfame-K, and Aspartame, are added to it. In some cases, maple syrup is also added to the yoghurt. However, some are allergic to natural sweeteners, and, in such cases, artificial sweeteners are added to it. Moreover, a fact that should be taken care is of shelf life of yoghurt which is always less. As a result, preservatives must be added to extend the shelf life of the yoghurt. Sodium benzoate, potassium sorbate, and natamycin are examples of chemical preservatives. Natural preservatives, such as nisin and -polylysine, on the other hand, can be utilized to extend the shelf life of yoghurt. To increase the quality of the yoghurt, skimmed milk powder, whey powder, inulin, fruits, casein powder, and vitamins are sometimes added.

1.4. Yoghurt as Functional Food

Apart from vitamins and minerals-based supplements, probiotic yoghurts are also frequently used as functional foods by wellness-oriented people. In addition, supplementation of dairy products with selenium after preparing it in the form of nano using biological methods or green nanotechnology [14] is important. Furthermore, incorporation of suitable fatty acids on milk proteins can lead to developing a complex protein very similar to HAMLT (Human α-lactalbumin Made Lethal to Kill Tumor Cell), which has the ability to kill cancer cells selectively without damaging healthy cells [15][16][17][18]. Nano-emulsions are also used for delivery of important bioactive compounds that have important health and therapeutic effects, such as beta-carotene and omega-3 [14][19]. Carotenes normally only dissolve in fat and not in water. In the production of the nanoscale dye, the color particles are coated/surrounded by a shell of starch. Thus, they can also be used in watery foods and color the beverage yellow-orange. As innovations, nanoproducts to color food or filter materials would be conceivable in principle. In addition, the encapsulation of aroma particles in nanoparticles, for example, can enable the aroma to develop at the desired time [20].

Health properties can be increased, as well as many important ingredients, such as dietary fiber lacking in dairy products, antioxidants, phenols, and residual fatty acids by incorporating coconut flour. The frozen yoghurt supplemented with coconut flour nanoparticles has been prepared with green nanotechnology and probiotic bacteria. Coconut flour nanoparticles operate as a prebiotic and boost the activity of the starting culture as well as probiotic bacteria strains. It was discovered that adding it to frozen yoghurt combinations in various proportions with probiotic bacteria present increases its activity and improves the sensory and technological aspects of the final product [21]. Yogurt was added to ethanol sage extract as a good source of phenols after encapsulating phenols in the form of liposomes, and this addition significantly influenced the yoghurt's chemical and rheological properties, as well as the growth of the starter culture and probiotic bacteria [22]. Sprout nano-powdered have been used in the production of yoghurt to boost health benefits. According to Ahn et al. [21], this resulted in a decrease in pH compared to peanut powder, and a yoghurt with an increase antioxidant content [23]. The concentration of less than 0.1% was sensorily acceptable to the consumer and also suitable for microbial growth. Chitosan nanoparticles powder yoghurt had been proven to have no effect on chemical, sensory, or rheological properties [24]. Chitosan nanoparticle powder added to yoghurt is aimed to increase features and properties that are beneficial in the treatment of certain diseases, as evidenced by much research [24][25]. An enhanced qualities of ginseng have been obtained when it was synthesized as a nanopowder and yoghurt was produced using it as supplement, which has functional properties and represents an active ingredient in the production of functional yoghurt [25]. Egg shells are an unusual calcium booster that has been shown to be beneficial to dental and bone Various researchers have observed that preparing eggshell in nano-form enhances calcium bioavailability in clinical trials [25]. However, as compared to the control (regular—not in nanoform) yoghurt, the nutritional representation of calcium discovered in the form of nanopowder performed better in terms of chemical and sensory qualities [26][27]. Santillan-Urquiza et al. [28] used a set-type yoghurt to add two different quantities of iron oxide, zinc oxide, and calcium phosphate nanoparticles.

Yoghurt is one of the most important dairy products that can be eaten for different age groups and available in different forms in the markets whether it is plain or flavored with different form such as stirred drink (drinkable) or set [29][30]. Due to the high cost of medical treatment, particularly for chronic conditions, those have become more prevalent in recent years. Foods that have the ability to improve health status and prevent diseases such as cancer, Alzheimer's, and other disorders affecting women's health have recently piqued researchers' interest [31][32][33][34]. Probiotics are referred to as 'live microorganisms, which, when administered in inadequate amounts, confer a health benefit on the host [35]. The majority of commercial probiotics are *Lactobacillus* and *Bifidobacterium* species used in products such as yoghurt and fermented products, milk powder, and frozen desserts [36][37][38]. *Lactobacillus acidophilus* is a type of beneficial bacteria that can be found in the body naturally, most commonly in the intestines, mouth, and female genitals, and it is recommended that women who suffer yeast and bacterial infections eat yoghurt with this probiotic. Moreover, *L. acidophilus* produces lactase, and vitamin K, which is important for bone strength and blood clotting. [39][40]

It has been known that probiotics have many health benefits, such as antimicrobial activity, alleviating diarrhea, anticarcinogenic properties, high serum cholesterol, allergic, HIV diseases, and improving lactose intolerance and immune system [41][42]. Furthermore, the medical applications of nano-toothpastes, have demonstrated antimicrobial and remineralization effectiveness [43][44].

Fermented milk products have gone through various developments and stages. The manufacture of fermented dairy was primarily intended to increase the conservation period and then to discover its benefits in relation to increasing its nutritional value for improving human health [45]. Various fruits, herbs, and plant sources rich in fibers, antioxidants, phenols, and other compounds, either free or coated, are sometimes added to yoghurt to make up for a lack of milk, or to improve the quality of food matrix for the development of edible coatings or films, so that the consumer can consume an integrated diet rich in all elements [46][47][48][49]. With technological developments, ultra-filtration technology has added new products to the yoghurt market, especially pre- and post-COVID-19; probiotics were considered by consumers to be a booster to the immune system, yoghurt fortified with added nutrition [50][51][52]. For probiotic bacteria and bioactive compounds which are affected by the environmental conditions through the digestive tract and during the various product manufacturing steps, the microencapsulation technology represents a good solution for that [53][54]. Coating materials are selected based on the specific functional component features as well as the type of application final products. In the case of yoghurt, as a perfect medium for functional ingredients supplementation, different gums (e.g., xanthan gum, guar gum, and gum arabic), alone or in combination with maltodextrin, seem to be excellent coatings materials to encapsulate functional ingredients. The coating material protects the microorganism by controlling stress response mechanisms against the gastric environment, which include gas exchange, moisture, oxidative reaction rates, solute migration, and so on. However, it does provide some protection from harmful external conditions such as UV light and heat. Many technical approaches based on physical and chemical principles have been investigated for probiotic microorganism microencapsulation. Nanotechnology and its different forms have begun to be used to obtain products with functional health properties that have no effect on taste, composition, or other final product properties [55]. Continuous progress on much technologies research is ongoing, the most important of which is human health and satisfying consumer needs to find various products that meet desired needs and interests, along with having distinctive qualities that reflect on health and activity and protect from chronic diseases. Lately, many studies have focused on clinical investigations of fermented dairy products, particularly yoghurt, in recent years due to its features as a pleasant, healthy drink that is popular and acceptable to people of all ages in various societies [56][57].

Probiotics are meant to play crucial role in human health. In this regard, microencapsulation and nanoencapsulation for edible packaging techniques offer efficient strategy in protecting and at the same time increasing the quality of the probiotic species. Probiotic microencapsulation stands out as a promising alternative for replacing antibiotics through beneficial microorganisms. However, such a process would be providing an option of gradual release of compounds of interest for preserving food [58][59].

One of the most popular materials for storing bacteria is alginate. If one brings a solution of alginic acid in water with a solution that contains calcium ions, this leads to cross-linking of the alginic acid and the formation of a hydrogel. In this context, many works deal with the immobilization of probiotic bacteria, such as *Lactobacillus acidophilus* and *Bifidobacterium* spp. These bacteria are those found in yoghurt. The reason is to improve the survival of the bacteria in the human digestive tract, in order to increase the positive effects of these bacteria. *L. plantarum* and *L. rhamnosus* have been entrapped in an optimized hydrogel Ca-alginate system [60].

Researchers have also exploited the potential of utilizing modified starches along with mixture of probiotic cultures (*Lactobacillus reuteri* ATCC 55730, *Lactobacillus rhamnosus* GG ATCC 53103, and *L. acidophilus* DSM 20079) at an initial concentration of 12.9 log·CFUmL-1 [61]. Further, probiotics incorporated with natural products have emerged as an effective edible packaging material which have the potential to replace the chemical preservatives for food preservation.

There has been a rise in health and food awareness as a result of the spread of social media and the availability of internet networks that have turned the world into a tiny village [34]. The majority of consumers who are concerned about having a healthy lifestyle prefer to drink milk and dairy products, with yoghurt being the most popular [33]. However, advantages of consuming yoghurt continually include evading the bad side effects of antibiotics; supplementing vitamins as vitamin B (B-2, B-12) [62]; balancing sugar in blood [63]; cancer prevention, digestive diseases and infections; preventing diarrhea; and maintaining a healthy intestinal environment; high in conjugated linoleic acid [64]. Moreover, yoghurt is beneficial to women's health. *Lactobacillus* spp. found in yoghurt helps to prevent candida and vaginitis in the vaginal area. According to studies, women who take yoghurt on a regular basis have improved vaginal health. Yogurt should be consumed on a daily basis, based on the benefits listed above [65][66].

2. Effect of Yoghurt Manufacture Technology on Health

Yogurt has a number of beneficial effects on human health, particularly when consumed on a daily and consistent basis, as shown in **Figure 1** [67]. Probiotics are living and active bacteria found in fermented dairy products, particularly yogurt. These bacteria have been demonstrated to promote gut health by favoring the growth of "preferred" bacteria over "undesirable" bacteria. One of the most significant technological advancements in the production of yoghurt has been the development of healthy yoghurt that has a clear influence on the diseases of the time, either by preventing injury or by improving the condition and lowering the symptoms associated with injury. Alzheimer's disease is one of the most common age-related diseases, and the most important and recent studies on the condition will be discussed, with yoghurt content on probiotics as a beneficial form of disease protection and treatment.

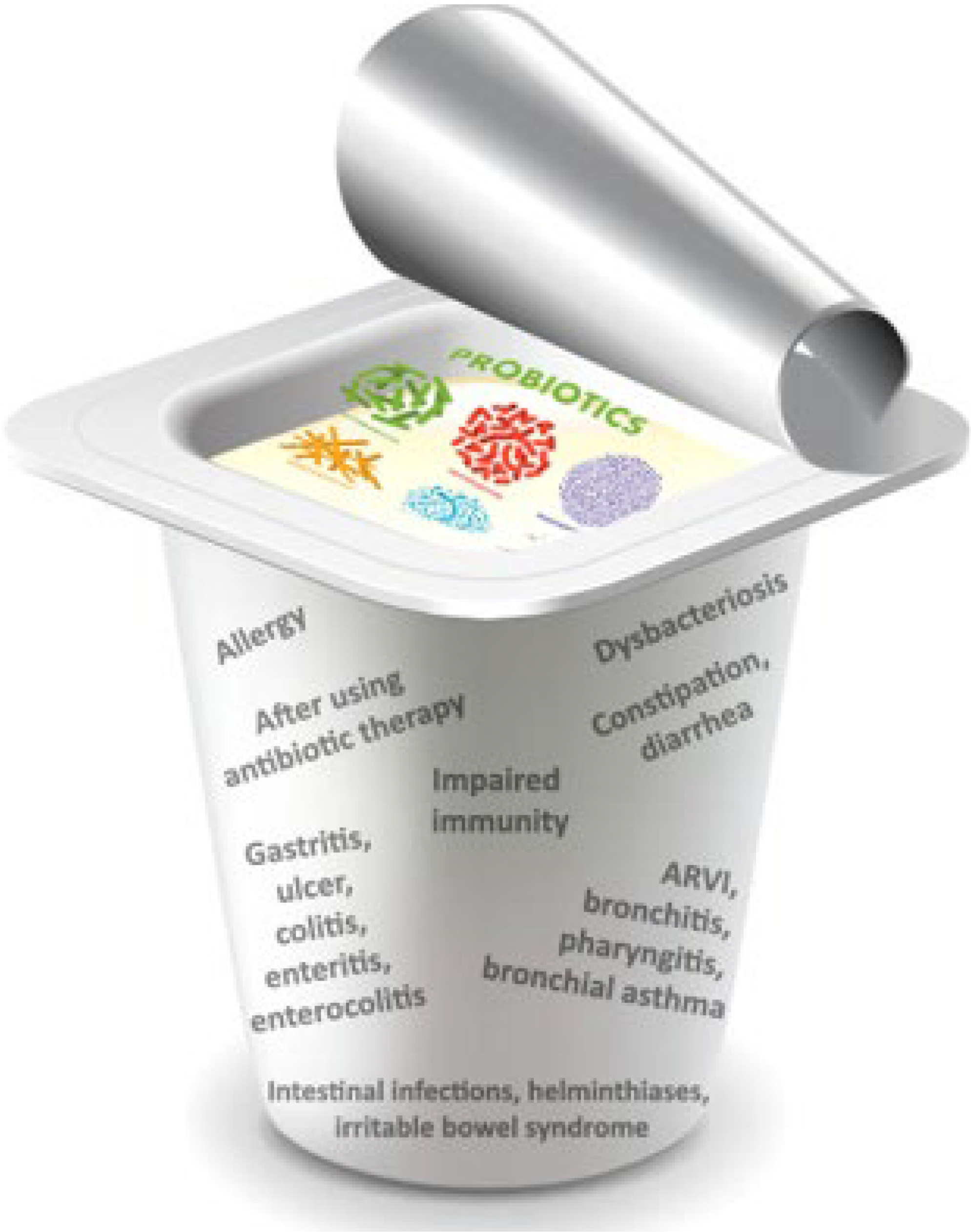

Figure 1. Health benefits of probiotic bacteria (adapted from Linares et al. [67]).

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