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Yogurt: A Nature's Wonder for Mankind

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Abstract

Yogurt is a fermented dairy product, having several health benefits. Yogurt starter culture consists of a blend of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp *bulgaricus*. Today, there are more than 700 yogurt and cheese products found in Indian cuisine. Consumption of yogurt imparts various health beneficial effects to the host by promoting bone health, improving diet quality, reducing the incidence of chronic diseases such as obesity and cardio vascular disease. Yogurt also serves as a vehicle for fortification of several essential nutrients including protein, calcium, potassium, phosphorus and vitamins B2 and B12. Yogurt properties can be enhanced by the addition or treatment with various additives. Addition of minerals, herbs or their active components like oils could be an effective strategy to improve functionality of milk and milk products with respect to the health benefits, food safety and bio preservation. Recent developments in this regard have been thoroughly discussed.

Keywords: Yoghrt, fortification, functional food, health benefits

INTRODUCTION

Yogurt is an ancient fermented dairy product and has been consumed worldwide since the domestication of mammals (Tamime and Robisons, 2007a). For the production of Yogurt, the milk is commonly obtained from several domestic milk producing animals like cows, sheep, goat, even yaks, horses, buffalo and camels (Moreno *et al*., 2013). Yogurt is defined as the product of milk which is being manufactured with or without the addition of some natural derivative of milk, such as whey concentrates, skim milk powder, caseinates or cream with a gel structure that results from the coagulation of the milk proteins, due to lactic acid secreted by defined species of bacterial cultures and at the time of consumption these bacteria must be "alive or abundant". The given definition of Yogurt is part of the food legislation of many countries (Chandan, 2006). Chemically, Yogurt is a complex gel system its structure includes protein, polysaccharides and lipids (Marshall, 1993). Yogurt is also considered as the most natural and healthy probiotic. In fact, the beneficial probiotics are the live microorganisms which when taken in adequate amount offers various health improving effects. Investigations suggest that Yogurt have the ability to improve digestion, metabolic health and immunity, it might cease oncogenic reactions which results in reduction of chances of cancer occurrence (Sanders, 2000; Sanders, 2007; Holden *et al*., 2008). Consumption of Yogurt imparts various health beneficial effects to the host by promoting bone health, improving diet quality, reducing the incidence of chronic diseases such as obesity and cardio vascular disease (Donovan and Shamir, 2014). The lactic acid producing bacterial strains that have been used for the culturing of Yogurt are *Lactobacillus bulgaricus* and *Streptococcus*

thermophilus in combination with various optional dairy ingredients such as cream, milk and skim milk (FDA, 2013). Sometimes the other bacterial strains such as *Lactobacillus acidophilus* and *Bifidobacterium bifidus* are also added to introduce the more health beneficial effects. Daily consumption of Yogurt results in diminished growth of bacteria which helps in maintaining the micro flora of human gut (Moreno *et al*., 2013). Yogurt is assumed as healthy food due to its high digestibility and nutrient rich property, also it can be suggested to the persons having diseases like irritable bowel movement, inflammatory bowel syndrome and lactose intolerance (Hattingh and Viljoen, 2001; Mckinley, 2005). Yogurt also serves as a vehicle for fortification of several essential nutrients including protein, calcium, potassium, phosphorus and vitamins B2 and B12. Trends of fortification of natural fruits, fruit juice, pulp and dry fruits have been increasing these days (Ghadge *et al*., 2008).

HISTORY

Yogurt is also spelled as "Yoghurt " or "Yoghourt". Yogurt has been a part of the human diet for several thousands of years and known by various names throughout the world (Fisberg and Rachel, 2015). Yogurt is also named as katyk (Armenia), dahi (India), zabadi (Egypt), mast (Iran), lebenraib (Saudi Arabia), laban (Iraq and Lebanon), roba (Sudan), iogurte (Brazil), cuajada (Spain), coalhada (Portugal), dovga (Azerbaijan), and matsoni (Georgia, Russia and Japan) (Moreno *et al*., 2013). It is believed that the name "Yogurt" comes from Turkish word "Yogurmak" which means to thicken, coagulate or curdle (Fisbergand Rachel, 2015). As the Yogurt is a traditional milk product which was incorporated into the human diet around 10000–5000 BC (Moreno *et al*., 2013). In earlier times, due to the lack of technology and storage sources, milk spoiled easily, it was so difficult to preserve for long time (McGee, 2004). So at that time making Yogurt was only the option to preserve milk from spoilage, other than drying it (Batmanglij, 2007).

Yogurt Today

Today, there are more than 700 Yogurt and cheese products found in Indian cuisine (Batmanglij, 2007). These days Yogurt is typically milk that has been produced by fermentation and acidifying with viable and well-defined bacterial strains creating a thickened and flavored product with long shelf life. It contains several essential nutrients and also acts as a carrier of fortification of probiotics, fibers, vitamins and minerals. It is also easily modified according to taste by adding sweeteners, fruits and flavors as well as rice, soy or nuts to affect consistency and aroma (Fisberg and Rachel, 2015).Yogurt can be defined as the symbiosis of 2 strains of bacteria (*S. thermophilus* and *L. bulgaricus*) in a sterile environment at a very low temperature (36˚C - 42˚C) for 3 – 8 hours.

YOGURT TYPES

Various varieties of Yogurt are now available in the market to meet the nutritional requirements. Yogurt is available in various forms, according to texture (liquid, set and stirred Yogurt), fat content (high fat, moderate fat, low fat), flavors (natural, fruit, cereal, chocolate) (Mckinley, 2005). Yogurt can be categorized on the basis of its physical and chemical nature, added flavors and post incubational processes.

Yogurt consists of various types which are given below:

Based on chemical composition

According to the fat content, three major varieties of Yogurt are regular, low fat and non-fat Yogurt. Regular Yogurt is produced from full fat milk whereas low fat Yogurt is prepared from low fat or partially skim milk. For non-fat Yogurt skim milk is used (Weerathilake *et al*., 2014).

Based on the physical nature

On the basis of physical nature Yogurt can be divided into three categories: solid, semi-solid and fluid.

- **Set Yogurt**: Yogurts that are solid in nature (jelly-like texture) are known as set type Yogurt which is incubated and cooled down in the final packaging (Dairy Consultant, 2013). The procedure of manufacturing set Yogurt is explained in Fig. 2.

- **Stirred Yogurt**: Yogurt in semi-solid state are called as stirred Yogurt. Stirred Yogurts are prepared by incubating the mixture and breaking by stirring prior to cooling and packaging (Dairy Consultant, 2013). The texture of stirred Yogurt is less firm than set type Yogurt, it seems like very thick cream and a little reformation occurs after packaging (Aswal *et al.*, 2012). The procedure of manufacturing stirred Yogurt is explained in Fig. 1.

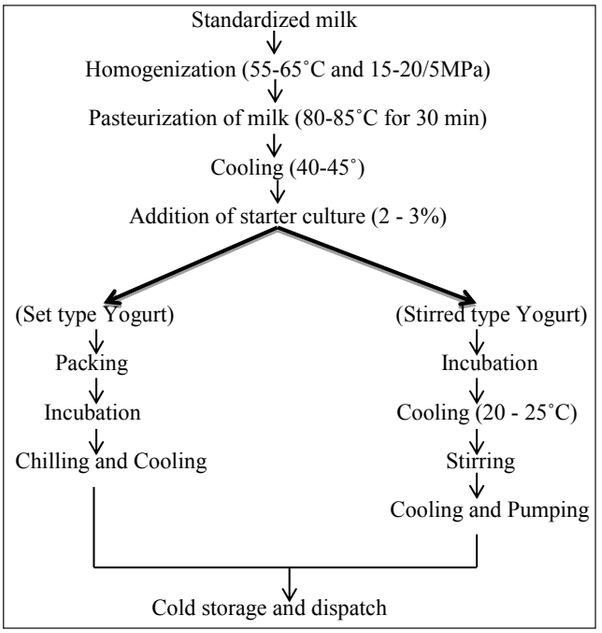

Fig. 1: Processing of set and stirred Yogurt

- **Drinking Yogurt**: Yogurt in fluid state is known as drinking Yogurt. Drinking Yogurt usually go under the process of homogenization to reduce the particle size which assured the hydro colloidal distribution and stabilization of protein suspension (Weerathilake *et al.*, 2014).
- **Processing of set and stirred Yogurt (**Lee and Lucey, 2010)

Based on the flavor of product

Addition of the flavor to Yogurt makes it more valuable and increase the consumers demand. Flavors can be added either after or before homogenization. This category involves two types of Yogurt, Plain/ Natural and flavored Yogurt.

- **Plain/Natural Yogurt:** This form of Yogurt is the simplest and least adulterated form which is prepared by lactic acid bacterial fermentation of pasteurized milk in order to produce its texture and flavor. It does not contain added color and additives, its plain and unsweetened fermented milk product. It contains pure Yogurt taste and rich amount of calcium among others (Dowden, 2013)
- **Flavored Yogurt:** Yogurt is present in the form of various flavors like fruit (apple, blue berry, apricot, lemon, black cherry, black currant, peach, strawberry), vegetables, cereal, chocolate, caramel, vanilla, etc. These additives itself contain 50% sugar whereas people prefers low fat and low sugar content products. Low or sugar less Yogurt is commonly sweetened by adding saccharin and aspartame. Flavor is added either at or just prior to filing into cups (Aswal *et al.*, 2012).

Others

- **Frozen Yogurt:** Initially, manufacturing of frozen Yogurt is somewhat similar to stirred Yogurt. Inoculation and incubation is carried out in the same manner as stirred Yogurt. It is prepared by freezing while stirring a pasteurized mix. Cooling is achieved in the same manner as ice-cream (Aswal *et al.*, 2012).
- **Concentrated Yogurt:** This type of Yogurt is inoculated and fermented in the same way as stirred Yogurt. It is followed by breaking of coagulum, and then the Yogurt is concentrated by boiling off some water under vaccum conditions to reduce the temperature required. Heating of low pH Yogurt leads to denaturation of protein and produces rough and gritty textures (Aswal *et al.*, 2012).
- **Pasteurized Yogurt:** These types of Yogurt are prepared after fermentation by heat treatment with different time-temperature combinations. These kinds of products are manufactured to

increase the shelf life of Yogurt or to decrease the natural tartness of Yogurt. But the disadvantage of pasteurized Yogurt is destruction of live and active cultures during heat treatment (Weerathilake *et al.*, 2014).

YOGURT MANUFACTURING PROCESS

The manufacturing process of simple Yogurt is explained in Fig. 2 (Aswal *et al.*, 2012).

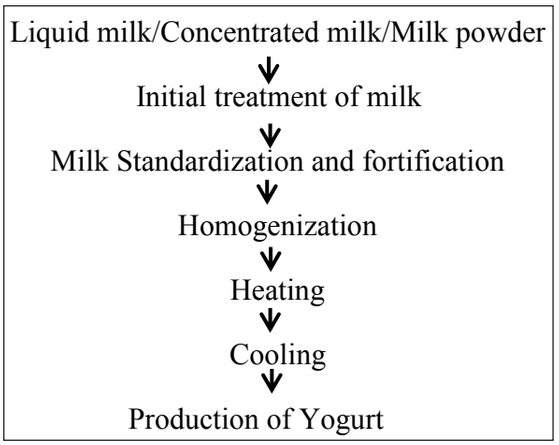

Fig. 2: Processing of Yogurt

Initial treatment of milk

For all types of Yogurt, the initial step is to prepare the Yogurt mix (milk fat, milk protein, nonfat milk solids, sugar, stabilizers, flavors and colors) and the heat treatment of this mix. Fat content of Yogurt may varies, it depends upon the type of milk added and it can be increased or decreased by adding skimmed milk powder, cream or butter fat and whey concentrates (Weerathilake *et al.*, 2014).

The Yogurt mix is heat treated for two reasons: first is to kill pathogens and spoilage microorganisms and second is to denature the milk proteins and to carry out the interactions between them which increase their water-binding capacity and firmness of Yogurt coagulum (Chandan and O'Rell, 2006).

Milk standardization and fortification

Milk standardization means standardization of fat and solid non-fat-content (SNF). Bovine milk fat content varies from 3.2% - 4.2% (w/w). For skim milk, fat content range from <0.5%, for semi- fat milk, fat content varies from 1.5% - 2% and for full fat milk, fat content is 3.5%. According to the consumer's demand, fat content of Yogurt varies from 0.1% - 10% (Tamime and Robisons, 2007b). In commercial Yogurt products milk solid content may varies from 14 -15% and the minimum milk solids non-fat content also varies from 8.2 – 8.6% according to the standards of various countries (Tamime and Robisons, 1999a). To attain the desired SNF content of milk, the milk mixture is fortified with milk powder (skimmed or full fat), whey protein concentrates or casein powder which results in increase in firmness and cohesiveness (Walstra, 2006c). Yogurt mixture should be standardize in such a way that the end product with not less than 2.7% protein content, milk fat content should be less than 15%. It is also important that the titrable acidity of Yogurt should not be less than 0.3% expressed as percentage of lactic acid. To achieve the characteristic properties of Yogurt like texture, mouth feel, viscosity appearance and to inhibit the whey separation, stabilizers such as pectin and gelatin are added to the Yogurt mix (Lee and Lucey, 2010)

Homogenization

Homogenization is a process of breaking down of fat globules into smaller size so that its size becomes less than 1μm and in such a way it is uniformly distributed throughout the food matrix. Homogenization is considered as the most important processing step in case of Yogurt having high fat content. This process restricts the formation of distinct creamy layer on surface of the Yogurt (Chandan and Kilara, 2013). Homogenization is carried out using a homogenizer or viscolizer where the milk is introduced through small openings at high pressure which results in the breaking down of fat globules due to shear forces (Dairy Consultant, 2013). Usually, milk is homogenized for 10-17minute using pressure of 10-20 MPa in first stage and 5MPa in second stage (Lee and Lucey, 2010). Recently, to increase the firmness

and water holding capacity of commercial Yogurt than that of conventional, the ultra-high pressure homogenization has been introduced (Serra M., 2009; Serra M., 2008)

Pasteurization (Heat treatment)

Heat treatment of milk is also one of the most important process of Yogurt manufacturing that affects the microstructure and physical properties of Yogurt which ensures the safety of product. Heat treatment helps in the destruction of pathogenic microorganisms present in milk or Yogurt mixture as well as denatures the whey proteins to achieve a better body and texture of product. It also releases the compounds in milk that stimulates the growth of starter culture bacteria. (Dairy Consultant, 2013; Lee and Lucey, 2010). Pasteurization is a continuous or batch process which involves heating of milk to high temperature and holding for determined time period (Tamime and Robisons, 1999a). Various heat treatments can be applied on the basis of temperature and time which are listed below in Table 1:

Inoculation and Fermentation

During this stage Yogurt is formed its texture and flavor are developed (Tamime and Robisons, 2007b; Walstra, 2006c). After the pasteurization, the Yogurt mixture is cooled down to temperature 43-46°C (temperature range for thermophilic bacteria) and the 2% (v/v) of Yogurt starter culture bacteria is added (Dairy Consultant, 2013). Usually the standard Yogurt culture consists of *S. thermophilus* and *L. dulbrueckii subsp. bulgaricus* in 1:1 ratio and the inoculation of culture takes place in a sealed hygienic stainless steel vessel. In both set and stirred type Yogurt manufacture, the place of fermentation is different to each other. Individual containers and large hygienic stainless steel vats are used for Yogurt manufacturing process for set and stirred type Yogurt respectively. Incubation temperature of Yogurt is maintained and monitored throughout the manufacturing process (Weerathilake *et al.,* 2014). When the pH of Yogurt approaches 5.0, lowering of the activity of ST and LT initiates which gradually dominates the overall fermentation process until the desired level of pH and acidity reaches. Process is terminated, when the temperature reaches 4°C, at this temperature culture remains alive but its activity becomes limited (Walstra, 2006c; Vedamuthu, 2006). During the fermentation process, lactose converts into lactic acid due to the metabolic activity of the lactic acid bacteria which help in the coagulation of milk proteins and the production of volatile compound takes place which imparts flavor and aroma (Weerathilake *et al.,* 2014).

Table 1: Effect of temperature on Yogurt properties (Sfakianakis and Tzia, 2014)

Heat treatment	Temperature & Time	Effect on Yogurt
Thermalisation	60-69°C for 20-30s	No significant effect.
Low Pasteurization	63-65°C for 20 min/ 70-75°C for 15-20s	Characteristics affected by further processing (Walstra, 2006a). Slight increase in viscosity and firmness (Tamime and Robisons, 2007a).
High Pasteurization	85°C for 20-30 min/ 90-95°C for 5 min	Large increase in viscosity and firmness (Tamime and Robisons, 2007a).
Sterilization	110°C for 30 min/ 130°C for 40s	Very large increase in viscosity and firmness (Tamime and Robisons, 2007; Walstra, 2006a).
Ultra heat treatment	145°C for 1-2°C	Medium increase in viscosity and firmness (Tamime and Robisons, 2007a).

Cooling

After the pH of Yogurt reaches to 4.5-4.6 Yogurt is cooled down to 5°C in order to stop the fermentation process and further acid development (Tamime and Robisons, 1999a; Tamime and Robisons, 2007b; Walstra, 2006b).Cooling of Yogurt involves two phases: First phase involves the rapid decrease in coagulum temperature less to than 10°C which results in the inhibition of fermentation process leads to Yogurt with low viscosity, second phase of cooling involves the initiation of rapid decrease in coagulum temperature less than to 20°C. Then the temperature of Yogurt lowers down to 5°C (storage temperature) with an increased viscosity (Tamime and Robisons, 2007b; Walstra, 2006b). After manufacturing set-Yogurts are directly transferred to cold stores or chilled in cooling tunnels, whereas coagulum of stirred-Yogurts are firstly cooled down by agitation in order to smoothened the product before filling to containers (Lee and Lucey, 2010)

COMPOSITION OF YOGURT

Composition of Yogurt is almost similar to the composition of milk from where it is derived but it only varies if other ingredients such as fruit, cereal or other components are added to the Yogurt. Yogurt contains protein, carbohydrates, calcium, phosphorus, vitamins and minerals (Mckinley, 2005). Composition of Yogurt varies according to the variety of Yogurt. The average composition of bovine milk includes 3.5% fat, 4.5% lactose, 3.3% protein, 0.7% mineral matter.

- **Vitamins and minerals**: Yogurt is a rich source of riboflavin (Vitamin B2), thiamin (Vitamin B1), vitamin B12, folate, niacin, magnesium and zinc (Mckinley, 2005). Yogurt generally contains Vitamin B1, Vitamin B2 and Vitamin B12. Vitamins have high risk of loss during processing of Yogurt because Vitamins are more sensitive to changes in environmental factors than minerals. Some factors that negatively affect Vitamin content are heat treatment, pasteurization, agitation, ultrafiltration and oxidative conditions even sometime bacterial culture may influence the vitamin content (Buttriss, 1997)
- **Proteins:** Proteins are naturally present in milk in high quality due to its high biological value as well as it contains all the necessary amino acids to maintain good health. Milk proteins available in Yogurt contain higher content of proline and glycine than in regular milk (Mckinley, 2005).
- **Carbohydrates:** Lactose is the major carbohydrate found in Yogurt in comparative to others. In total, raw milk contains about 4.6% lactose content. However, the amount of lactose is lowered by 20-30% during the fermentation process, as the lactose converts into its simpler form of glucose and galactose due to the metabolic activity of lactic acid bacteria (USDA, 2001).
- **Fat content:** Fat content of Yogurt depends on the fat content of original Yogurt mixture. According to the USDA specifications of Yogurt, fat content of low fat and non-fat Yogurt varies from 0.5-3.25% (USDA, 2001). In case of Yogurt, homogenization and fermentation breakdowns the fat into easily digestible absorbable fatty acids (Mckinley, 2005).

Ingredients of Yogurt

Yogurt is a mixture of variety of components including milk, sweeteners, stabilizers, fruits, flavors and bacterial cultures. Milk is the most important ingredient of Yogurt. Selection of the milk depends upon the type of the Yogurt to be manufactured. For full fat or regular Yogurt whole milk is used, for low fat partially skimmed milk is preferred and for fat free Yogurt skim milk is used. To adjust the fat content, cream or butter fat is added whereas to enhance the total solid content of Yogurt mix, skim milk powder and whey protein concentrate are used. Usually, stabilizers are added to the mixture, which improves the texture of Yogurt such as body and firmness as well as prevents whey separation. It also helps in the uniform distribution of ingredients. Sweeteners are just added to enhance the flavor and aroma (Weerathilake *et al*., 2014) (Table 2).

Table 2: Nutritional information of Yogurt (Aswal *et al.,* 2012)

Components	Value (per100g)
Carbohydrates	4.7 g
Calcium	—
Energy	257 KJ
Fat	3.3 g
Protein	3.5 g
Riboflavin	0.14 mg
Vitamin	27µg

YOGURT STARTER CULTURES

To achieve the desirable characteristics of the product various combinations of starter cultures are used for manufacturing of Yogurt which also provides therapeutic benefits to the consumer. Usually manufacturer adds 2–4% Yogurt starter culture according to its activity (Ghadge *et al*., 2008). Yogurt is commonly prepared by fermenting milk using a symbiotic culture of bacteria *Lactobacillus delbruikii ssp. bulgaricus* (LB) and *Streptococcus thermophiles* (ST) under controlled conditions such as temperature and environment (Sanders, 2000; Marshall, 1993). *Streptococcus thermophilus subsp. thermophilus* (ST) is only the species of streptococcus genus which is being used in dairy starter cultures. However Yogurt starter culture may include strains like *Lactobacillus acidophilus, Lactobacillus casei, Lactobacillus lactis, Lactobacillus jugurti, Lactobacillus helveticus, Bifidobacterium longum, Bifidobacterium bifidus* and *Bifidobacterium infantis.* ST is a gram positive and thermophilic bacteria (temp 35-53˚C). It can be also considered as thermo-tolerant bacteria. According to morphology, its cells are in spherical shape, forming chains, during the early stage of their life as it matures, it acquires rod like shape whereas LB is a rod shaped, gram positive and anaerobic bacteria which grows at temperature 40-44˚C. LB also has the ability to produce very high amounts of lactic acid bacteria by metabolizing lactose (Walstra *et al.,* 2006c; Vedamuthu, 2006).

THE ROLE OF STARTER CULTURE ON YOGURT

These two starter bacteria in Yogurt manufacturing have two major functions one is milk acidification which denatures casein micelles resulting in the formation of coagulated gel and the other is synthesis of aromatic compounds (Guler and Park, 2011). Smooth texture, suitable viscosity, good flavor and low post fermentation acidification are the properties of high quality Yogurt product. Recently, it has been found that the weak post acidification property is an important factor for Yogurt starter selection (Donkor *et al*., 2006; Vinderola *et al*., 2000; De Ancos *et al*., 2000)

Lactobacillus delbruikii ssp. bulgaricus (LB) and *Streptococcus thermophiles* (ST) shows synergic effect in the milk environment metabolizes lactose into lactic acid and results in the reduction of milk pH. When together grow in milk, ST grows very fast as LT grows slowly. When the pH of Yogurt reaches about 5.0, activity of ST lowers whereas LB dominates the overall fermentation process until the target pH reaches and fermentation process ceases (Walstra, 2006c; Vedamuthu, 2006). The growth of the symbiotic bacteria enhances changes in the native components of milk which are responsible for sensory and physiochemical characteristics of Yogurt (Vedamuthu, 2006).

The addition of symbiotic cultures (*Bifidobacterium animalis* ssp. *lactis*) and fortification of whey protein concentrate results in a stronger coagulum, increases firmness and adhesiveness values for the Yogurt (Hekmat and Reid, 2006).

STARTER CULTURE SYSTEMS USED FOR YOGURT PRODUCTION IN DAIRY INDUSTRY

In some countries, *Lactobacillus bulgaricus* is legally required in starter cultures for the production of Yogurt, because it provides a typical Yogurt flavor. Sometimes *Lactobacillus helveticus* and *Lactobacillus lactis* are sometime mixed with the starter culture Mckinley, 2005).

Production of Yogurt on industrial scale includes common systems of starter culture used for Yogurt in dairy industry are:

- For the starter culture, it is necessary to produce a sterile and conductive environment for growth.

- To enhance the viscosity and texture, denaturation and coagulation of proteins is required (Gandhi, 2006)
- Milk or whey based media, corn syrup and molasses, as a basal are used for commercial production of Yogurt.
- Some vitamins like vitamin B and specific amino acids are used for the optimum growth of starter cultures.
- To maintain the cell viability cryoprotectants like glycerol, lactose, ascorbate, glutamate and sucrose are used for both frozen and lyophilized cultures.
- pH is controlled by the addition of alkaline compounds like gaseous NH_3, NH_4OH, Na_2CO_3 and KOH (Durso and Hutkins, 2003)
- Use of direct-vat-set (DVS) reduces the chances of phage contamination during Yogurt production as well as maintains the strain balance in case of mixed stain cultures (Surono and Hosono, 2002).

THE ASSOCIATIVE GROWTH OF YOGURT STARTER BACTERIA AFFECTS THE YOGURT QUALITY

Protocoorperation is a process in which Yogurt bacteria enhance each other's growth by the exchange of metabolites (Sieutwerts *et al.,* 2010). Protocoorperation and symbiosis are the most important factors of Yogurt bacteria (*Streptococcus thermophillus* and *Lactobacillus delbrueckii subsp. bulgaricus*) for their growth. During the production of Yogurt both the cultures mutually benefits each other (Courtin and Rul, 2003). The combination of these two strains results in the higher lactic acid and flavor production than from single strain (Hui, 2004.). The *S. thermophillus* forms acid much slower than *L. bulgaricus* which liberates small peptides and amino acids as well enhances the growth of *S. thermophillus* (Wong *et al.,* 1983). After three hours of post incubation, relative amount of bacteria becomes equal. At pH values between 4.2-4.4 as *S. thermophilus* is inhibited whereas *L. bulgaricus* is tolerant to pH values as low as 3.5-3.8 (Hattingh and Viljoen, 2001). Due to acid tolerant capability of *L. bulgaricus*, Yogurt becomes soft (Pastink *et al.,* 2008). Weak interactions lead to decreased fermentation rate and unbalanced growth (Hanemaaijer *et al.,* 2015). To achieve the same ratio of two bacteria, the concentration of inoculum incubation, time and temperature must be in controlled manner (Hui, 2004). Exopolysaccharides are produced by *S .thermophillus* which helps in the formation of matrix with the milk proteins resulting in the final Yogurt structure (Cheirslip *et al.,* 2003).

FACTORS LEADING TO INHIBITION OF YOGURT STARTERS

Yogurt starters are used to fermentation of milk by producing lactic acid. Yogurt starter performances may be inhibited due to the following reasons:

- Raw milk should be free from pathogenic microorganism, because starter culture is susceptible to the harmful phages (Josephsen *et al.,* 2004).
- Residues of the sanitation chemicals such as quaternary ammonium compounds, idophors, hypochlorite and hydrogen peroxide used during cleaning of dairy equipment can also effect the growth of Yogurt culture (Surono *et al.,* 2002).
- Natural inhibitors secreted in milk such as lactins and agglutins, but generally destroyed by the heat treatment.
- Environmental pollutants like insecticides have also critical effect on Yogurt starter (Teixeira *et al.,* 1999).
- Both strains have different characteristics, so their incompatibility cause some changes like production of acid, flavor, aroma during fermentation (Robinson *et al.,*2002).
- Pasteurization, incubation and cooling temperature are also significant factors leading to inhibition of Yogurt starters (Gandhi, 2006).

BENEFICIAL EFFECTS AND USES OF LAB

Lactic acid bacteria are one of the different species of bacteria which helps in the production of lactic

acid during fermentation of carbohydrates. These bacteria are used for the production of Yogurt and responsible for the taste, colour, and texture due to the production of various compounds. Bacteriocins are the antimicrobial substances which are produces by lactic acid bacteria, have the ability to cease the pathogens and food spoiling bacteria (Rattanachikunsopon and Phumkhachorn, 2010). Lactic acid bacteria have been known for beneficial effect on human being, such as it helps in prevention of various diseases. Sufficient quantity of Yogurt in daily diet can improve the following diseases (Aswal, *et al*., 2012) like:

- It prevents from *Heliconbeter pylori* and strengthens the immunity.
- It improves the digestibility especially stomach, reduce the blood pressure, bad cholesterol, risk of heart attack.
- It protect from vaginal infection, osteoporosis and arthritis.
- It is good for skin.
- Protect from colon cancer.
- Production of antimicrobial substances by lactic acid like organic acids, bacteriocins, diacetyl and hydrogen peroxide act as preservative and also cease the growth of harmful putrefactive microorganisms (Noordiana, *et al*., 2013).
- It is good for lactose mal-absorber, due to removal of toxic or anti-nutritive factors (lactose and galactose) by LAB (Wouters *et al*., 2002)

HEALTH BENEFITS OF YOGURT

Globally, Yogurt is very popular fermented product. Nutritionally, Yogurt provides sufficient amount of calcium in bio-available form. As Yogurt plays a significant role in improving the human health, consumption and demand for Yogurt has been increased (Weerathilake *et al*., 2014). Yogurt preferred due to abundant nutritional value like essential amino acids, vitamin D, vitamin B6, and vitamin B12, riboflavin, calcium (Farnworth, 2008; Kolars, 1984). Yogurt reduces the blood pressure and protect from osteoporosis (Park, 2013). Findings suggested that the Yogurt considered as probiotic, which enhances digestion, metabolic health, immunity and might stop the oncogenic reaction or delays occurrence of cancer in the body (Sanders, 2000; Sanders, 2007; Holden. *et al*., 2008). Yogurt is good source of natural protein so it is tolerated by lactose mal-absorber. It helps in burning fat and act against colon cancer. Vaginal infection also reduces and strengthens the collagen in the skin (Aswal *et al*., 2012).

TEXTURE OF YOGURT

As Yogurt is the healthiest fermented product, texture is one of the most important components of Yogurt quality. Texture is latin word 'texura' (cloth), used to represent the cross-linking style of wavy threads. Texture represents all the rheological and structural attributes (Ramaswamy and Basak, 1991; Borwankar, 1992; Foegeding *et al*., 2011; Fisher and Windhad, 2011). Texture of Yogurt can be affected by milk composition, dry matter content, heating, homogenization, type of bacterial culture, incubation temperature, cooling, storage time etc. (Kucukcetin, 2009). Heat treatment affects the textural properties of produced Yogurt include characteristics (firmness and cohesiveness), viscosity, flavor, microbial content and milk protein. Texture of Yogurt can be enhanced by adding different ingredients like nonfat dry milk or whey (Harvey and McNeil, 1998). Texture and taste of Yogurt can also be improved by the addition of insulin (Kip *et al*., 2006). By the addition of lacto peroxidase, texture of Yogurt is improved, but its apparent viscosity decreased (Hirano *et al*., 1998).

FORTIFICATION OF MICRONUTRIENTS THROUGH YOGURT

Recently Yogurt enriched with different micronutrients to meet the human beings requirement. Fortification is another method to enhance the quality and quantity of Yogurt with several nutrients such as minerals, vitamins and functional ingredients. In addition, fortified Yogurt correct the inadequate nutritional value as well as prevent diseases due to malnutrition (Gahruie, *et al*., 2015).

Fortification of minerals

- **Iron:** Fortification of iron can be important to control the occurrence of deficiency diseases like anemia, alter mental development, poor immunity and impair cognitive score in kids and leads to poor pregnancy (Gaucheron, 2001; Martinez *et al.*, 2002). As Iron is pro-oxidant so, it initiates lipid oxidation and iron compounds does not affects the nutritional and sensory properties (taste, flavor) of food during processing (El-Kholy, *et al.*,2011).
- **Calcium:** Yogurt is fortified with tri-calcium citrate which contains 1 g/L of calcium (Gerhart, 2013). Deficiency of calcium results in fracture of bones in adult female and also in males. It is right way to increase the level of calcium in Yogurt. Moreover, organoleptic properties are not affected by calcium fortification and also reduce the risk of bone fracture (Ocak and Ranjendram, 2013).
- **Magnesium and zinc:** These minerals can be important and effective on individual health as calcium. Tri-magnesium and zinc citrate can be used to fortify dairy products (Gerhart, 2013). Deficiency of magnesium causes serious biochemical and symptomatic changes and zinc deficiency cause growth retardation, behavioral disturbances, night blindness, delayed healing of wounds and impaired taste (King and Keen, 1994).

Fortification of vitamins

Vitamins are compounds, which play significant role as cofactors in the human body. Diseases occurred due to the deficiency of vitamin D are childhood rickets, osteoporosis and osteomalacia. It has been found that the risk of developing cancer, osteoporotic fractures and autoimmune diseases also increased due to the vitamin D deficiency (Holick, 2002). It might also reason for type 1 diabetes, hypertension, multiple sclerosis and various other cancers (Holick, 2004). Different researches have been conducted on the stability of vitamin D in milk and other dairy products (Renken, 1993; Upreti, 2002; Kazmi, 2007; Wagner, 2008; Hanson, 2010).

STORAGE AND PACKAGING CONDITION

Packaging

Packaging plays an important role. It provide protection from the external force and also attractive, convenient for distribution. A good oxygen barrier will help the product from oxidation (Mattila-Sandholm *et al.*, 2002; Vasiljevic and Shah, 2008). For th packaging of Yogurt, different types of packaging material used (Brody, 2006; Nilsen *et al.*, 2002; Tamime and Robinson, 1999b). Commonly, packaging material used is thermoformed HIPS (High Impact Polystyrene) in the form of small cups or larger tubs with either an aluminum foil/plastic laminate or a paper/plastic laminate heat-seal lid or closure. These containers may be packed in form-fill-seal machines or be delivered performed from packaging materials suppliers. A pigment (TiO_2) is added to HIPS to enhance the appearance or protect the package from light. This also helps in heating and softening the HIPS sheet for thermoforming when radiant heating is used (Robertson, 2006). Rectangular paperboard cartons or cups (with or without an aluminum foil layer), glass containers, PP (polypropylene), HDPE (high density polyethylene) containers are also popular. PET (polyethylene terephthalate), PVC (polyvinyl chloride), PVdC (Polyvinylidene chloride copolymer), PLA (polylactate), ceramic containers have also been used in many markets for some specialty products (Faderiksen *et al.*, 2003, Tamime and Robnison, 1999b).

Storage

Cow milk, dried milk, and soy milk Yogurt could be stored for two weeks in refrigerator or freezer and for a week or less at room temperature without any effects on the physio-chemical, microbial and sensory properties (Muhammad *et al.*, 2009). After lyophilization and gamma irradiation treatment Yogurt is packed in polymer packing – three-layer aluminum folio, under vacuum and stored at temperature 0°C - 5°C (Ivanova *et al.*, 2011)

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