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Scientific and Technical Aspects of Yogurt Aroma and Taste: A Review

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Abstract: Yogurt is a basic dairy product that has been consumed for centuries as a part of the diet, even when its beneficial effects were neither fully known nor scientifically proven. With time, yogurt has been continuously modified to obtain a product with better appeal and nutritional effects. The flavor components of yogurt are affected because of these modifications. The present review article is focused on the influence of the different parameters and modifications on aroma and taste components of yogurt. Extensive work has been done to explore the effect of chemical components as well as the microbial, processing, and storage aspects. The popularity of yogurt as a food component depends mainly on its sensory characteristics, of which aroma and taste are most important. This review also outlines the effects of the different modifications attempted in the composition of yogurt.

Introduction

With the development of processing technologies and the growing competition in the food market, the urge to provide nutritious food with appealing flavor properties has increased. Fermented food products have been around for thousands of years and have played an important part in human diet. Yogurt is one of the popular fermented milk products having different names and forms (Kurmann and others 1992; Tamime and Robinson 2007). It is a mixture of milk (whole, low-fat, or nonfat) and even cream fermented by a culture of lactic acid-producing bacteria, *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. Other bacteria may be added to the culture. The generalized process of yogurt production is summarized in Figure 1. Yogurt generally contains at least 3.25% milk fat and 8.25% solids not fat. Yogurt can be low fat (0.5% to 2% milk fat) or nonfat (less than 0.5% milk fat), which is more preferred because of health concerns. The popularity of yogurt is due to various health claims and therapeutic values. Along with these, the flavor of yogurt has played an important role in increasing its consumer demand, on which this review will concentrate. Sweeteners (for example, sugar, honey, and aspartame), flavorings (for example, vanilla and coffee), and other ingredients (for example, fruits, preserves, and stabilizers such as gelatine to improve the textural property) are added that modify the flavor of yogurt. Some of the fruits and fruit flavors currently used are summarized in Table 1. The aroma, body, and taste of yogurt and other cultured dairy products can vary depending on the type of culture and milk, amount of milk fat and nonfat milk solids, fermentation process, and temperature used.

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As there are many compounds and other factors affecting the overall yogurt aroma, the study of the effect of different factors on yogurt flavor can help food technologists to make desirable changes to maintain the popularity of yogurt as a diet food in the future.

Importance of Flavor in the Acceptance of Yogurts

Flavor perception is a complex phenomenon and traditionally flavor consists of odor, taste, and somatosenses, which has been discussed in detail by Reineccius (2006) in "Flavor chemistry and technology." The specialized taste receptor cells (collectively known as taste buds) located in the mouth lead to a combined complex sensation otherwise known as taste. The sensations can be expressed as sweet, sour, salty, bitter, and umami, which can be further divided into different categories of subsensations (Reineccius 2006). Odor is the complex sensation occurring because of the interaction of the volatile food components with the olfactory receptors, whose stimulus can be orthonasal (entrance of the odor stimulus is directly from the nose when one sniffs the food) or retronasal (entrance of the stimulus from the oral cavity when someone eats a food) (Reineccius 2006). Taste and odor are complex phenomena in themselves and the interaction of these with other sensory properties increases the complexity of human perception.

Flavor (taste plus odor) is not only a characteristic property of food that controls consumer acceptance but it is also associated with the feeling of wellbeing. Yogurt is a food that has its own peculiar and popular flavor, which is evident by its constant presence in the list of preferred foods worldwide. As a consequence of increasing consciousness about health and increasing competition in the food market, scientific studies are taking place around the world to obtain new products. Before trying any new food innovation in the market, sensory evaluation either by descriptive methods or methods using different sensory analyzers such as the electronic nose is increasingly encouraged. In this era of functional foods, of which yogurt is an important part, individuals' worries

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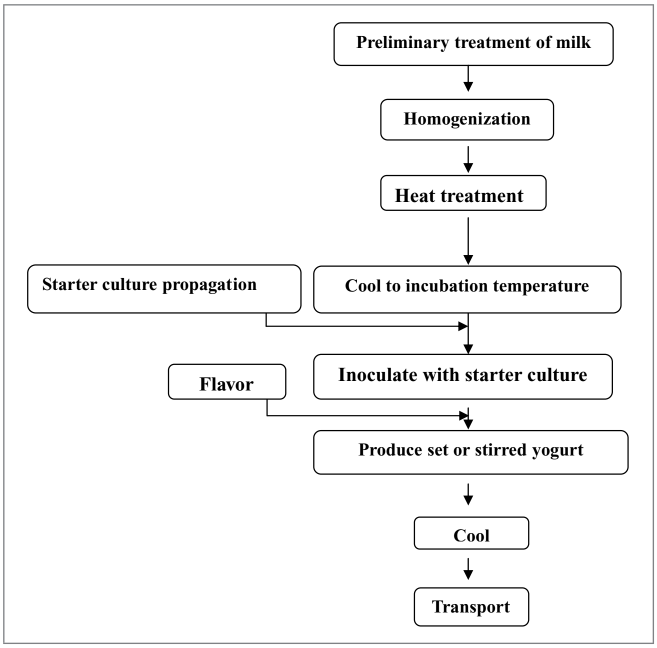

Figure 1–Generalized scheme illustrating the modern method for the production of yogurt.

regarding the new technologies used and the modernity of the processes might influence the acceptance of the food products (Devcich and others 2007). As will be discussed in later sections, there are many factors affecting flavor formation, flavor release, and perception, so mentioning the different constituents and treatments while marketing might have a significant effect on liking and purchase probability (Johansen and others 2010). In the case of yogurt, information regarding low fat content has been found to reduce consumer expectations regarding sensory qualities, but the presence of all types of yogurt in the market with varying fat contents implies that there are many types of consumers and there is demand for all types of products. However, there is one common point of concern on which all researchers concentrate, whenever they modify any food product they have in mind, the ultimate flavor and related sensory properties.

Table 1–Fruits and fruit flavors currently used in yogurt.

I	**Single**		
	Apricot	Apple	
	Black cherry	Bramble (artic)	
	Black currant	Cranberry	
	Mandarin	Damson	
	Peach	Elderberry	
	Pineapple	Grape	
	Raspberry	Guanabana	
	Strawberry	Guava	
	Banana	Kiwi	
	Bilberry	Kokum	
	Blackberry	Lime	
	Gooseberry	Loganberry	
	Grapefruit	Mango	
	Lemon	Papaya	
	Melon	Passion fruit	
	Orange	Pear	
	Plum	Pina colada	
	Prune	Quince	
	Rhubarb	Redcurrant	
	Tangerine	Sapota wortleberry	
II	**Mixed**		
	Fruit cocktail	Apple/raisin	Apple/wortleberry
	Fruit of the forest	Apple/orange	Cherry/elderberry
	Peach/raspberry	Cherry/orange	Grape/figs
	Peach/apricot	Cherry/pineapple	Kiwi/gooseberry
	Raspberry/redcurrant	Mixed citrus	Peach/passion fruit
	Strawberry/kiwi	Pear/banana	Pineapple/coconut
	Strawberry/coconut	Strawberry/blackberry	Raspberry/coconut

Source: Tamime and Robinson 2007.

Aroma Components of Yogurt

The odor and taste of soured milk products are characterized by numerous volatile bacterial metabolites, some of which are by-products of lactic acid fermentation or are produced by other reaction mechanisms. Lactic acid itself is suggested to be one of the major compounds significantly contributing to yogurt flavor (Beshkova and others 1998). More than 90 flavor compounds (Table 2) have been identified so far (Ott and others 1997; Lubbers and others 2004). It has been reported that the aroma and taste of yogurt are mainly because of the presence of nonvolatile or volatile acids and carbonyl compounds, and especially the group of carbonyl compounds is believed to have a significant influence on the final yogurt aroma due to their relatively higher concentrations (Imhof and others 1994; Kaminarides and others 2007). The most important aromatic components are acetaldehyde, acetone, acetoin, and diacetyl in addition to acetic, formic, butanoic, and propanoic acids (Figure 2).

The typical aroma of yogurt is characterized chiefly by acetaldehyde, so it is suggested as a major flavor compound. As reported by Hamdan and others (1971), "Pette and Lolkema (1950) were the first to suggest that acetaldehyde was the most important constituent of yogurt aroma." It was later suggested that "high concentrations of acetaldehyde are necessary to produce a desirable flavor in yogurt" (Hamdan and others 1971). The higher concentration of acetaldehyde (in the range of 5 to 21 ppm) is reported to be due to the low utilization rate of this compound. The lack of alcohol dehydrogenase enzyme in the bacteria, responsible for the conversion of acetaldehyde into ethanol, is suggested to be the reason of low utilization of acetaldehyde (Chaves and others 2002). Some investigators found that atypical and weak flavor resulted from less than 4.0 ppm acetaldehyde (which was considered to be the nonoptimal amount), whereas good flavor resulted when greater than 8.0 ppm of acetaldehyde was produced (Sandine and others 1972). Pathways of production of acetaldehyde have been summarized by Tamime and Robinson (2007), Zourari and others (1992), and Chaves and others (2002). Compounds such as glucose, catechol, glyceraldehydes, and acetylene, amino acids such as threonine and glycine, and DNA can act as the precursors of acetaldehyde. Zourari and others (1992) have emphasized the pathways based on glucose, threonine, and DNA components, whereas Tamime and Robinson (2007) and Chaves and others (2002) have illustrated the different pathways of synthesis of acetaldehyde from different possible precursors. The most important pathway of formation of acetaldehyde is reported to be the breakdown of threonine to acetaldehyde and glycine and the enzyme responsible for the catalysis, threonine aldolase, has been detected in both *Lb. bulgaricus* and *S. thermophilus*. Threonine aldolase activity in *S. thermophilus* is significantly decreased when the growth temperature is increased from 30 to 42 °C (Lees and Jago 1976; Wilkins and others 1986), but in *Lb. bulgaricus* it remains identical. As yogurt is manufactured at higher temperature, it is expected to be mainly produced by *Lb. bulgaricus* (Zourari and others 1992).

Later it was also found that "some yogurt products with low acetaldehyde still have a typical yogurt aroma, suggesting that

Table 2–Aroma components of yogurt.

Nr.	Aroma component	Nr.	Aroma component
1	Acetaldehyde	50	1,3-dimethylbenzene (1,4?)
2	Dimethyl sulfide	51	3-penten-2-one
3	Methylcyclohexane	52	1,3-dimethylbenzene (1,3?)
4	Propanal	53	1-Methylpyrrole
5	2-propanone	54	3-heptanone
6	Furan	55	1-butanol
7	Methyl acetate	56	1-ethyl-4-methylbenzene
8	2-methylfurane	57	1-penten-3-ol
9	Butanal	58	Limonene
10	Ethyl acetate	59	1,4-dimethylbenzene (1,2?)
11	2-butanone	60	2-heptanone
12	Methanol	61	Propylbenzene
13	3-methylbutanal	62	3-methyl-2-butenal
14	Dichloromethane	63	2-pentylfuran
15	Benzene	64	Pyrazine
16	2-propanol	65	Ethenylbenzene
17	Ethanol	66	1-pentanol
18	2-pentanone	67	3-octanone
19	2,3-butanedione	68	2-methyl tetrahydrofuran-3-one
20	Acetonitrile	69	Trimethylbenzene
21	Chloroform	70	Methylpyrazine
22	Toluene	71	Octanal
23	2-butanol	72	3-hydroxy-2-butanone
24	S-methyl thioacetate	73	1-methyl ethenylbenzene
25	1-propyl alcohol	74	3-methyl-2-butenol
26	2,3-pentanedione	75	2-nonanone
27	Dimethyl disulfide	76	2-hydroxy-3-pentanone
28	Butyl acetate	77	Furfural
29	Hexanal	78	1H-pyrrole
30	2-hexanone	79	Benzaldehyde
31	Dimethyl trisulfide	80	2-methylpropanoic acid
32	Acetic acid	81	Butyric acid
33	Propionic acid	82	3-methylbutanoic acid
34	2-methyltetrahydrothiophen-3-one	83	2-dodecanone
35	2-undecanone	84	Benzothiazole
36	2-furanmethanol	85	2-pentadecanone
37	Pentanoic acid	86	Nonanoic acid
38	Hexanoic acid	87	γ-dodecalactone
39	Heptanoic acid	88	Benzoic acid
40	Octanoic acid	89	Methional
41	Decanoic acid	90	(2E)-nonenal
42	δ-dodecalactone	91	Methyl 2-methyl butanoate
43	1-nonen-3-one	92	Ethyl hexanoate
44	2-methyltetrahydrothiophen-3-one	93	Hexyl acetate
45	Guaiacol	94	Diacetyl
46	2-methylthiophene	95	Acetone
47	2-methyl-1-propanyl alcohol	96	Acetoin
48	Ethylbenzene	97	Formic acid
49	Butanoic acid		

Source: Ott and others 1997; Lubbers and others 2004.

acetaldehyde is only one component of yogurt aroma and is not identical with the true yogurt aroma" (Hamdan and others 1971). Lindsay and others (1965) showed that the harsh flavors are caused by overproduction of acetaldehyde in relation to diacetyl.

Despite the controversies over the role of diacetyl in the overall aroma expression of yogurt, diacetyl is one of the other major aroma compounds (GuerraHernández and others 1995; Beshkova and others 1998). *Streptococcus thermophilus* is reported as exclusively responsible for the production of diacetyl by some researchers (Rasic and Kurmann 1978), but others support *Lb. bulgaricus* as the major source of production of diacetyl (Dutta and others 1973; Beshkova and others 1998). Lactose and citrate both act as the precursor of diacetyl which has been illustrated in detail by Nilsson (2008).

Many other compounds were found to contribute to the aroma of the end product, including 2, 3-butanedione, 2, 3-pentanedione, dimethyl sulfide, and benzaldehyde (Imhof and others 1994). Six compounds (1-octen-3-one, 1-nonen-3-one, methional, 2-methyltetrahydrothiophen-3-one, (2E)-nonenal, and guaiacol) with intense odor were found for the first time in yogurt flavor by Ott and others (1997). 1-Nonen-3-one was identified by spectral means for the first time during this study and its low odor threshold justified its impact role in yogurt in spite of its low concentration. It can be observed that acetaldehyde is an important contributor to yogurt aroma but not the sole contributor and the net aromatic effect is the result of the combination of all the aromatic components present.

During the characterization of the sensory properties of traditional acidic and mild, less-acidic yogurts in another study, by a trained panel using a descriptive approach, it was observed that the important flavor differences found between 2 samples of yogurt were mainly due to the differences in the acidity and not due to different concentrations of the 3 aroma compounds, which were acetaldehyde, 2, 3-butanedione, and 2, 3-pentanedione (Ott and others 2000). This observation emphasizes the importance of acidity in yogurt flavor.

Factors Affecting Yogurt Aroma

There are several factors, such as the microbial factors, processing parameters, source of milk, and chemicals and additives used which affect the aromatic properties of yogurt. Some of these important factors are discussed here as they affect the overall yogurt flavor.

Effect of microbial factors

Lactic fermentation is the most important process in the manufacture of sour milk products (including yogurt). The production time and properties of the end product depend on the qualities and activity of the starter culture. Production of some of the carbonyl compounds affecting yogurt flavor, by yogurt starter cultures, is summarized in Table 3. The traditional yogurt culture is comprised of *S. thermophilus* and *Lb. bulgaricus*. It was found by Courtin and Rul (2004) that these 2 microorganisms' association affects the production of volatile molecules involved in flavor development. The 2 microorganisms enter a symbiotic relationship, which means they are mutually beneficial during fermentation (Hamdan and others 1971; Kroger 1976). The optimum souring temperature of yogurt culture is between 42 °C and 44 °C, and incubation takes around 3 h until the desired acidity is achieved. Both microorganisms perform better in symbiosis than if grown separately. Initial pH of the milk favors the faster growth of *Streptococci*. Thereafter, increase in acidity favors the growth of *Lactobacilli* whose optimum pH is below 4.5. Initially, *Lb. bulgaricus* benefits the growth of the *Streptococci* by releasing the amino acids valine, leucine, histidine, and methionine from the milk proteins. For its part, *S. thermophilus* promotes the growth of *Lactobacilli* by creating minute amounts of formic acid. At least in the initial phase, the mutual stimulation of the 2 species in the mixed culture causes more lactic acid and aromatic compounds to be formed faster than would be the case with any of the 2 single cultures. A harsh acid flavor occurs when *Lb. bulgaricus* predominates or when excessive amounts of starter are used (Crawford 1962). Similar observations of higher concentrations of lactic acid and sourness in the presence of symbiotic interaction have been reported by another research group (Masato and others 2008). Additional microorganisms such as yeasts can also be included as probiotics (Lourens-Hattingh and Viljoen 2001) in the culture. For example, alcohol and carbon dioxide produced by yeasts contribute to the refreshing, frothy taste of kefir (Wang and others 2008), koumiss, and leben that

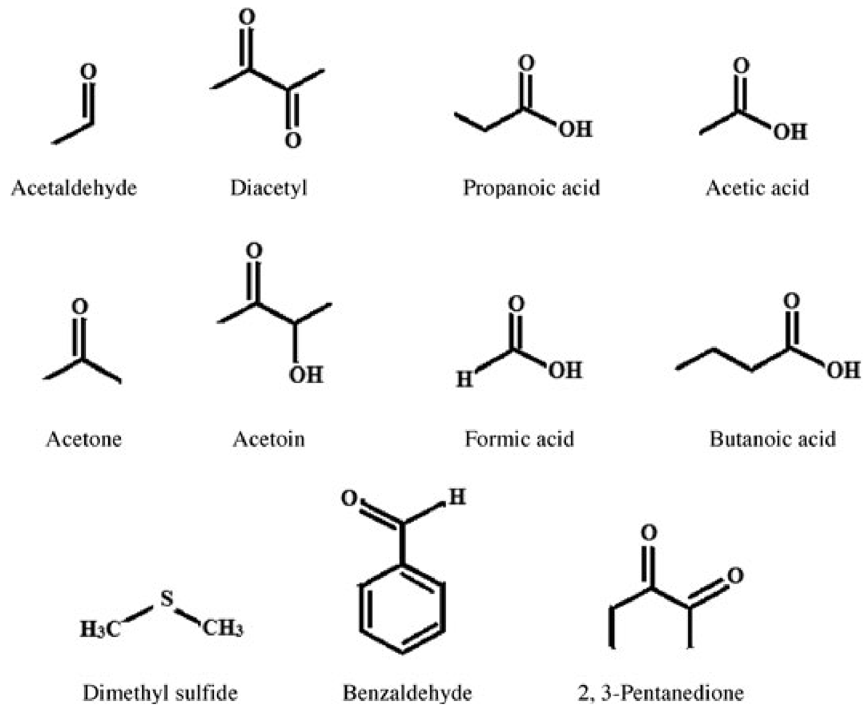

Figure 2–Major aroma compounds present in yogurt.

Table 3–Production of carbonyl compounds (μg/g) by yogurt starter cultures that affect the total overall aromatic property of yogurt.

Organism	Acetaldehyde	Acetone	Acetoin	Diacetyl
S. thermophilus	1.0 to 13.5	0.2 to 5.2	1.5 to 7.0	0.1 to 13.0
Lb. delbruekii subsp. *bulgaricus*	1.4 to 77.5	0.3 to 3.2	Trace to 2.0	0.5 to 13.0
Mixed cultures	2.0 to 41.0	1.3 to 4.0	2.2 to 5.7	0.4 to 0.9

Source: Tamime and Robinson 2007.

might be applied in case of yogurt by controlling optimized process conditions.

The efficiency of the symbiotic activity of *Lb. bulgaricus* and *S. thermophilus* was analyzed in the case of Bulgarian yogurt in terms of the "carbonyl compounds and saturated volatile-free fatty acids" produced. The highest activity of the yogurt cultures during the production process of carbonyl compounds was "during milk coagulation and cooling, up to 7 h." Maximum concentration was reported by 22 to 31 h. In the cooled sample of 22-h starter cultures, concentration of acetaldehyde was highest (1415.0 to 1734.2 μg per 100 g) followed by "diacetyl (165.0 to 202.0 μg per 100 g), acetoin (170.0 to 221.0 μg per 100 g), acetone (66.0 to 75.5 μg per 100 g), ethanol (58.0 μg per 100 g), and butanone-2 (3.6 to 3.8 μg per 100 g)." The thermophilic *Streptococcus* and *Lactobacillus* cultures, and the starter cultures mainly produced "acetic, butyric, and caproic acids" (Beshkova and others 1998).

To increase the production of yogurt aroma compounds, metabolic engineering has been very helpful, which is done by optimizing genetic and regulatory processes in the cells to increase their potential. Chaves and others (2002) studied the process of acetaldehyde production by *S. thermophilus* which was modified by metabolic engineering. There are many pathways of production of acetaldehyde by yogurt bacteria and in this case "reaction for acetaldehyde production catalyzed by serine hydroxymethyltransferase (SHMT)" was given special attention, which is "encoded by the *gly A* gene" and involves the "interconversion of threonine into glycine and acetaldehyde." An increase in acetaldehyde production was observed with supplementation of the growth medium with L-threonine. This implied that acetaldehyde production during fermentation could be correlated to the threonine aldose (TA) activity of SHMT. Inactivation of *glyA* leads to a severe decline of TA activity and subsequently absolute loss of acetaldehyde formation and vice versa. In another study by Ozer and others (2007), microbial transglutaminase (MTGase) was used at varying concentrations from 0 to 0.5 g/L for the treatment of nonfat set yogurt. It showed that the physical and sensory properties of nonfat set yogurt could be improved by incorporating MTGase up to a level of 0.3 g/L. These findings can be used to control and improve acetaldehyde production in fermented (dairy) products with *S. thermophilus* as starter culture. Higher levels of acetaldehyde production (Bongers and others 2005) and higher levels of diacetyl (Hugenholtz and others 2000) in the *Lactococcus lactis* cells can also be achieved by metabolic engineering.

Ozer and Atasoy (2002) studied the biochemical properties of yogurt samples produced by "nonviscous and viscous yogurt starter cultures and viscous cultures with methionine (10 and 30 mg/100 mL milk), threonine (5 and 10 mg/100 mL milk), and β-galactosidase (1 mg/100 mL milk), and with a heat-shocked culture." It was observed that the yogurts produced with the "viscous culture" contained least amounts of acetaldehyde, whereas the highest amount of acetaldehyde was observed in yogurts produced with "nonviscous culture." A significant increase of acetaldehyde level was observed because of the amino acid supplementation, lactose hydrolysis, and heat-shock treatments as compared to the samples inoculated with "viscous culture" only. These factors can be added to the list of other factors affecting the flavor of yogurt.

Several other combinations of microorganisms have been tried for the preparation of drinking yogurt and related beverages that has been summarized by Tamime and Robinson (2007).

Effect of use of different sources of milk

Different sources of milk differ in composition, which after fermentation provide different types of flavored yogurt with different consistencies. The type of milk used in various parts of the world differs with the food habits and popularity of the kinds of milk products consumed. Combinations of many types of milk have been used to obtain different kinds of yogurt.

Sheep and goat milk have been used to prepare yogurt during different studies. Pure goat milk was found to be unsuitable for the production of yogurt as this milk is low in solids and the yogurt produced had "the lowest firmness and significantly inferior organoleptic characteristics" compared to others. However, yogurt prepared from mixtures of goat milk of an Alpine breed and local breeds with sheep milk of the Lacaune breed was of good quality, and with similar organoleptic characteristics (Stelios and Emmanuel 2004). In another set of experiments, microbiological quality and aroma components of yogurt samples produced from long-life goat and cow milk, and also from milk with 2% milk powder, were studied during 9 d of refrigerated storage. Initial acetaldehyde and diacetyl concentrations were higher in the case of yogurt prepared from goat milk than the one from cow milk. The concentration of acetaldehyde in the yogurt decreased during storage time. Control yogurt samples (samples without milk powder) had lower acetaldehyde concentrations than the supplemented samples, and during 9 d of storage; a significant increase in diacetyl content of yogurt samples was noticed (Božanić and others 2003). The yogurt prepared from goat milk was richer in glycine than yogurt prepared from cow milk, but the acetaldehyde content of the goat milk yogurt was found to be lower, which could be explained because of the inhibition of threonine aldolase by glycine (Rysstad and Abrahamsen 1987; Beshkova and others 1998). Buffalo milk is also a popular milk type used for the preparation of yogurt and several combinations of processing parameters have been applied by researchers to obtain desirable yogurt characteristics (Tamime and Robinson 2007). In another study, properties of yogurts prepared from sheep milk with different concentrations of fat (6.6%, 3.8%, 2.3%, or 0.9%, respectively) were analyzed (Kaminarides and others 2007), and it was observed that yogurt prepared with highest fat content received the highest appreciation for flavor and texture. Sixteen volatile compounds were identified and the important volatile flavor compounds on the 2nd day of study were "acetic acid, acetaldehyde, acetone, diacetyl, 2-butanone, 3-hydroxy-2-butanone, and 3-methyl-2-butanone." So to obtain the best flavor, a combination of different types of milk along with the starter culture is very important, but research is going on along with the continuing changes of consumer preferences.

Effect of processing techniques

As styles of yogurt have changed through the ages, processing techniques for yogurt have also changed. Processing techniques such as heat treatment, cooling, pasteurization, and homogenization are important steps in yogurt processing (Figure 1). The heat treatment of yogurt milk is intended primarily to kill pathogenic bacteria, at the same time reduce other microorganisms and inactivate enzymes such as lipase. So, it is advisable to heat the yogurt milk to between 85 and 95 °C. Some of the processing conditions for the manufacture of stirred-type pasteurized/ultra-high temperature yogurt have been summarized by Tamime and Robinson (2007), listing the different combinations of time and temperature of the heat treatments applied to obtain improved shelf life.

Mechanical treatment of yogurt has been found to influence aroma release and perception in the mouth more than the protein composition (Souchon and others 2006). High-pressure applications in yogurt technology can preserve milk intended for the production of yogurt and also preserve the final product. Yogurt preserved by means of high pressure can also be a good carrier of probiotic bacteria (Jankowska and others 2005), improve firmness, and reduce syneresis (Ancos and others 2000; Needs and others 2000). Sensory flavor analysis by Labropoulos and others (1982) of yogurt treated by ultra-high temperature and vat process systems revealed no significant differences, and gas chromatographic analysis of flavor isolates in the yogurts supported these observations of organoleptic analysis. Although in some of the cases, the high-pressure application has been detected to affect flavor. Pressurization at 100 to 300 MPa was found to cause slight changes in the flavor of the yogurts analyzed by Jankowska and his group, whereas pressure treatment at 400 to 1000 MPa resulted in negative changes in the flavor, consistency, and appearance of most of the yogurts under evaluation (Jankowska and others 2008). Similar results were obtained by Serra and others (2009), using ultra high-pressure homogenization at 200 or 300 MPa and at 30 °C or 40 °C to obtain homogenized milk to prepare yogurt, and during storage only slight differences in flavor compounds and yogurt bacteria counts were detected, except in those samples obtained from milk treated at 200 MPa.

Reps and others (2008) studied the effect of higher pressure levels on the properties of yogurt, prepared from milk mixed with stabilizer. It was observed that yogurt prepared from milk with MYO 752 stabilizer (starch, gelatin, pectin) gave the best results in terms of texture and pressurization, out of the 10 selected stabilizers. The number of *Lb. bulgaricus* lowered completely and the number of *S. thermophilus* lowered by 1 to 2 orders of magnitude without any effect on taste and aroma. So, the addition of stabilizers can also change the effect of application of high pressure.

Thermization is another method of treatment of milk, which is similar to pasteurization and uses lower temperature treatment and retains most of the original flavor of the milk. Alakali and others (2008) produced thermized yogurt by fermentation of pasteurized milk using yoghumet (a commercial yogurt culture containing *S. thermophilus* and *Lb. bulgaricus*) and thereafter heating at 65 °C, 75 °C, and 85 °C, for 20 min in each case. The study proved that heating at 85 °C produced acceptable yogurt with longer shelf life (6 wk) at an average room temperature of 35 ± 3 °C compared with those thermized at 75 °C (5 wk) and 65 °C (3 wk) similarly stored. The temperature of storage was room temperature (average 35 °C) and still the samples could be stored for 3 wk. Through storing at refrigeration temperature, storage life can be further increased. So, thermization can also be considered as an alternative for the treatment of the milk to obtain yogurt with longer shelf life, without significantly affecting the flavor.

The availability of fresh milk for the preparation of yogurt in the industry is not always possible. Refrigeration is the common method of storage of milk and CO_2 application can also be helpful. The suitability of milk preserved by refrigeration and CO_2 addition for the manufacture of plain yogurt was evaluated by Gueimonde and others (2003) using 2 commercial strains of *Lb. bulgaricus* and *S. thermophilus*. Yogurts manufactured, after milk pasteurization, from refrigerated CO_2-treated samples (pH 6.15) were compared with 2 different controls made from pasteurized milk, either fresh or refrigerated. The general processes taking place during the production of yogurt, such as multiplication and acidification capacity of the starter as well as the evolution of organic acids, were neither affected by the previous refrigeration and CO_2 treatment of raw milk nor by the residual CO_2 present in the pasteurized milk. However, refrigeration enhanced the production of ethanol and diacetyl and no difference in the sensory properties was detected between yogurts made from CO_2-treated milk and those made from refrigerated control milk throughout cold storage.

The new technologies such as application of high pressure, thermization, and CO_2 treatment can be used for the processing and preservation of the milk source and of yogurt. With proper combination of the different parameters, it can help improve the total processing technique and the shelf life. It also decreases food waste and food industry losses.

Effect of textural properties and stabilizing agents

In yogurt, higher fat content allows longer persistence of volatiles, whereas volatiles reach maximum inhaled air concentration much more quickly in low-fat yogurt. In food products, fats act as structuring materials and their elimination is impossible without finding replacement agents. Fats are also an excellent solvent for flavor compounds, which are mostly hydrophobic. The structure, texture, and flavor perception of food changes with the modification of fat content in food (Tuorila and others 1995; Hess and others 1997; Brauss and others 1999). Absence of fat therefore causes a complete change to the distribution of flavor molecules in a product. Fat replacers/thickeners and their amounts and storage time have been found to have a significant effect on physical, chemical, textural, and sensory properties of strained yogurts (Yazici and Akgun 2004). Fat replacers are first mixed with syrup or fruit preparation which are then mixed with yogurt. Rheological properties of fat-free yogurt are modified by the thickening effects of fat replacers, which has been well studied by many researchers (Ramaswamy and Basak 1992; Barrantes and others 1994). Modification of flavor release by the fat replacers is also well known (Pangborn and Szczesniak 1974); for example, with increasing pectin concentration and gel firmness, a decrease in aroma perception has been observed. Both viscosity and binding of flavor with the food matrix have been found to affect flavor release in case of various solutions with similar viscosity and different types of thickeners (Roberts and others 1996). Similar results were observed by Mälkki and others (1993) with oat gum, guar gum, and carboxymethylcellulose (CMC), and they showed that both the perceptions of flavor and sweeteners were modified by thickeners. In a pectin model gel with sugars, the 3-dimensional network of pectin chains was found to retain aroma compounds (Rega and others 2002; Lubbers and Guichard 2003). It was observed that the concentration of aroma compounds in the headspace of the samples was reduced by the presence of pectin in yogurts. Presence of starch in yogurt was found to induce a significant decrease of aroma compounds in the headspace as observed by Decourcelle and others (2004). It was found that, after swallowing, aroma release and intensity of olfactory perception were stronger in low-viscosity yogurts than in high-viscosity yogurts (Saint-Eve and others 2006b). However, a generalized statement regarding this is not possible, because a significant increase of flavor release was observed on addition of locust bean gum into fat-free stirred yogurt by Decourcelle and others (2004); but the sweeteners and guar gum appeared to have no effect. In this case, rheological parameters were not able to explain the difference of aroma release (which was contradictory to the other cases) and it appeared that, during shear conditions, the composition of fruit preparations has a major role in aroma release (Decourcelle and others 2004). The difference between the different stabilizers regarding the flavor release could be explained because of the difference of interaction of various types of thickeners with the yogurt matrix. So, some combinations of thickeners give a better performance than others. Among the 7 different stabilizers used by Mohammad (2004), which were pectin, guar gum, CMC, carrageenan, sodium alginate, corn starch, and gelatin, at 0.4% levels in buffalo milk with 16.6% total solids, cow milk with 13.5% total solids, and a mixture (1:1) of both having 15.0% total solids, the best result in terms of flavor was obtained with a combination of 0.4% corn starch and 16.6% total solids. The different concentrations of the same stabilizer differ in terms of the effect on the aromatic perception of yogurt also. In a study by Mumtaz and others (2008), it was observed that enrichment of yogurt with xylooligosaccharide (XO) at different levels had different effects. Addition of XO up to 3.5% did not influence taste and overall acceptability, but higher levels contributed to an aftertaste. The treatments, storage intervals, and total solids combined with the thickeners significantly affected the flavor and other properties such as syneresis, body/texture, acidity, and color of the yogurt samples investigated by Mohammad (2004).

As mentioned before, the overall aroma of yogurt is the result of the combined effect of many factors. When combined effects of the thickening agents and other factors such as mechanical treatment are considered, it was found that the final effect was different from the individual effects. The influence of thickening agents (modified starch/pectin mixture of 0 and 7 g/L) along with mechanical treatment (low, medium, and high) on the retention of esters (pentyl acetate and ethyl pentanoate), aldehydes (hexanal and (E)-2-hexenal), and a lactone (gamma-octalactone) in low-fat flavored stirred yogurts was investigated by Kora and others (2004) under equilibrium conditions. It was found that the thickening agent and mechanical treatment had little influence on aroma compound retention in this case. Increasing the dairy protein concentration was observed to have a decreasing effect on aldehyde retention and there was a "salting out" effect of carbohydrates on esters, in the treatment range studied. The sensory effect of thickening agents in this case was suspected to be due to sensory interactions between perceptions rather than physicochemical interactions.

Dairy foods contain a considerable amount of proteins, which not only acts as a nutritional source of protein for the body, but also affects textural properties and aroma perception. Depending on the physicochemical properties of the aroma compounds, olfactory properties may be influenced by protein changes in the matrices. It was demonstrated by Saint-Eve and others (2006a) that the protein composition influenced aroma release only when yogurt exhibited wide variations of complex viscosity. When the influence of flavored yogurt texture, induced by both protein composition and mechanical treatment, was considered, it was noticed that for the same matrix composition, the yogurt complex viscosity influenced both in-nose release and olfactory perception (Souchon and others 2006). The exchange area between yogurt and oral cavity was found to be the main physical mechanism responsible for in-nose release and perception. Another study was carried out by Saint-Eve and others (2006a) to investigate the impact of protein composition, at a constant protein level, on the physicochemical properties of 4% fat flavored stirred yogurt and, more specifically, on the rheological properties, the microstructure, and aroma release. It was shown that enriching yogurt with caseinate generally leads to changes in the microstructure network and caseinate-enriched yogurt has a higher complex viscosity than whey protein-enriched yogurt, which is another important protein additive in the dairy industry. Release of the majority of aroma compounds has been found to be lower in caseinate-enriched yogurt. Physicochemical interaction between aroma compounds and proteins was also quantified during that study. The flavor intensity and the fruity notes were found to be less intense in yogurts with a high caseinate ratio than in those with a low ratio (Saint-Eve and others 2006a). So, individual types of protein seem to have a certain effect, which also varies with the amount. The influence of gel structure on flavor release was also observed in this case and was found to be in agreement with sensory characteristics previously studied for these products. To improve the firmness of yogurts, enzymatic modification of milk proteins can also be applied (Kumar and others 2001). Enzymatic partial hydrolysis opens the protein structure producing hydrophobic and hydrophilic peptides, and when this process is controlled and is carried out prior to inoculation of the starter cultures, it can lead to faster growth of the organisms, and also improvement of yogurt flavor. Nutrease and trypsin immobilized on CM-Sephadex C-50 were used by Kumar and others (2001) to enzymatically modify milk proteins. The milk samples treated with nutrease and trypsin were used to prepare set yogurt. Yogurt prepared from milk treated with trypsin showed either a small or no improvement in textural and sensory properties, whereas yogurt prepared from nutrease-treated milk showed definite improvement (Kumar and others 2001).

To better understand aroma release in relation to yogurt structure and perception, Déléris and others (2007) determined the apparent diffusivity of aroma compounds within complex dairy gels using an experimental diffusion cell. Four aroma compounds (diacetyl, ethyl acetate, ethyl hexanoate, and linalool) were considered whose apparent diffusion coefficients were determined at 7 °C in yogurts, varying in composition and structure. It ranged from 0.07×10^{-10} to 8.91×10^{-10} m^2/s, depending on aroma compounds and on product structure. Yogurt fat content was revealed to have a strong effect on the apparent diffusivity of hydrophobic compounds. Fifteen-fold and 50-fold decreases in the apparent diffusion coefficient of linalool and ethyl hexanoate, respectively, were detected. Protein composition seemed to have a greater effect than that of mechanical treatment in this case. Differences in flavor release, and in perception observed previously, could not be explained completely, because variations in the apparent diffusion coefficient for the considered products were found to be limited. Physicochemical, physiological, and perceptual phenomena might be involved in the complex processes of aroma release and perception (Taylor 2002; Déléris and others 2007) and it can be observed that presence of stabilizers not only affects the total solids content but also the physicochemical properties of yogurt. The mechanical treatment required for each stabilizer varies from each other and higher levels may contribute an aftertaste (as mentioned before), which is also undesirable. Use of texturizing agents is a requirement of the food industry while replacing the fats in different foods, and that creates more challenges for food scientists.

Effect of different added flavors

Different fruit flavors have been used for a long time to increase the flavor characteristics of yogurt (Table 1). Addition of flavors also increases options for consumers, and it helps in marketing yogurt and retaining consumer interest even with changing food habits. Several flavors used in the food industry have been summarized by Tamime and Robinson (2007). The addition of flavor generally increases the sensory acceptance of the yogurt. Honey and apple are some of the flavors that are quite acceptable. During a study by Ghadge and others (2008), addition of various proportions of apple fruit pulp or honey separately to buffalo milk yogurt (prepared with a mixed starter culture containing a 1:1 ratio of *S. thermophilus* and *Lb. bulgaricus*) led to higher sensory effects and in this case yogurt with superior sensory quality was obtained with 10% apple fruit pulp and 5% honey. Similar results showing acceptability have been obtained for strawberry, cherry fruit powder (Kim and others 2009), peach flavor (Santana and others 2006), and soursop (*Annona muricata* L.) flavor (Lutchmedial and others 2004) and for many others.

Strawberry flavor is probably the most popular fruit flavor used in the yogurt industry and several studies have been conducted regarding its effect on the flavor of other compounds and also aroma release. Mei and others (2004) studied how yogurt ingredients affect aroma release in the mouth during eating, and it was observed that aroma release of the ethyl butanoate, (Z)-hex-3-enol, and ethyl 3-methylbutanoate (components of strawberry flavor) was suppressed by sweeteners, with 55 DE high-fructose corn syrup having the greatest effect. Simulation of yogurt with fruit preparation syrup was done to study the discharge of "strawberry flavor compounds at vapor/matrix interfaces in model food systems" (Nongonierma and others 2006). The effects of various parameters including "physicochemical characteristics of the flavor compound, the structure and composition of the matrix, and temperature (4 and 10 °C)" on the release of the flavor compounds were studied. As observed in other cases, "the composition and structure of the matrix" were having an effect on the partitioning of the flavor compounds. In this case, physicochemical interactions with pectin and sucrose slightly increased the retention of the flavor compounds and in the presence of 5% fat, release of flavor was unaffected by "the composition of the dispersing medium." An increase from 4 to 10 °C, which was one of the factors observed led to "increase in the overall amount of flavor released" in this case, which implied that temperature could be an additional factor.

Addition of fruity flavors such as strawberry also helps to overcome many undesired flavors. However, in the case of supplementation of a strawberry-flavored yogurt with an algal oil emulsion by Chee and others (2005), the trained panel could discern a strong fishy flavor in supplemented yogurts even after 22 d of storage. Addition of fruit flavor enhances the popularity of yogurt in general, but the other components present in yogurt affect the effect of the flavor additive also very much. The other fortified components may dominate over the flavor additive and give a different taste and also change the overall acceptability of the product.

Effect of the storage parameters

The concentrations of the flavor compounds acetaldehyde, ethanol, and diacetyl change during storage depending on duration and temperature of storage (Vahčič and Hruškar 2000). Acetaldehyde content was found to decrease at temperature levels of 4 °C, 20 °C, and 37 °C during 25 d of storage and diacetyl and ethanol contents were found to have increased during the study by Vahčič and Hruškar (2000). Sensory quality decreased with duration and was found to be closely related to changes in the contents of aroma compounds that were more pronounced at higher temperatures. No significant change was detected during refrigerated storage at 4 °C and samples were found unsuitable for consumption after 15 d at 37 °C, which implies storage at lower temperature might retard the deterioration process.

There have been studies to find out the reasons of decrease of the acetaldehyde content with an increase of time of storage also. Bills and Day (1966) demonstrated dehydrogenase activity at low storage temperatures by some lactic *Streptococci* and found these organisms reduce acetaldehyde and propionaldehyde but not acetone or butanone. Keenan and Lindsay (1967) reported dehydrogenase activity by *Lactobacillus* species. Since differences as low as 1 ppm acetaldehyde can be detected in milk products, the differences noted in acetaldehyde during storage between cultures are important and must be taken into consideration when selecting yogurt cultures, and those organisms which produce the most acetaldehyde and utilize it slowly during storage should evidently be selected. Hamdan and others (1971) found that acetaldehyde decreased during storage when obtained by Cultures R1 (Hansen's) and 405 (Moseley's), whereas acetaldehyde from Culture 403 (Moseley's) remained constant during 2 wk of storage. When a single strain of *Lb. bulgaricus* and *S. thermophilus* was used, reduction of acetaldehyde was higher as compared to that produced by commercial cultures together. Results from another study using probiotic and plain yogurt purchased from Croatian and Slovenian markets have shown equal changes in the aroma of both types of yogurt, after storing for 25 d at 4 °C and 20 °C, which was so because of the same microorganisms present in both yogurt types (*Lb. bulgaricus* and *S. thermophilus*) having the greatest influence on the aroma, while the addition of other microorganisms had mostly probiotic effects (Hruškar and others 2005).

Storage at 20 °C for 21 d was compared with storage at 30 °C for 3 d (accelerated) during a study of refrigerated storage (10 °C for 91 d) of whole and skimmed flavored set-type yogurt (Salvador and Fiszman 2004). A trained panel and a consumer panel assessed the refrigerated yogurts where trained-panel scores were correlated to instrumental data, and the acceptability data for long storage were studied using consumer criteria. According to the logistic regression of the data from a 50-consumer sensory evaluation, the probability of the whole yogurt being accepted after 91 d at 10 °C was around 40%, whereas for the skimmed yogurt it was only 15%, largely because the skimmed yogurt developed certain negative attributes at an earlier stage of storage than the whole yogurt. Lack of fat seems to affect both the preservation and expression of the flavor compounds, which can make the storage of skimmed yogurt a potential challenge.

Packaging material is also an important criterion that influences food properties. They not only affect the food components, but also the flavor of many food materials. Saint-Eve and others (2008) studied variation of sensory and physicochemical properties of stirred flavored yogurt with varying percentage of fat content (0% and 4%) and packaging material (polystyrene, polypropylene, and glass). They observed that with decreasing fat percentages (0%), the effect of packaging material increased and packaging effect was least for 4% fat yogurt, which implies that a higher percentage of fat in yogurt also helps in resistance against the influence of the packaging material. Low-fat yogurt when stored in glass container displayed least decrease of aroma. Although in terms of least loss of aroma compounds and minimum development of aroma defects, polystyrene seemed preferable for yogurt.

As mentioned before, strawberry is a popular flavor and it has been used by food scientists quite often to analyze aroma release. Lubbers and others (2004) studied the influence of storage on aroma release in headspace gas and also some rheological properties in strawberry-flavored fat-free stirred yogurts. The quantity of flavors in the headspace of products at 28 d of aging was found to be significantly weaker for some flavor compounds (methyl 2-methyl butanoate, ethyl hexanoate, and hexyl acetate) that were chosen for the study. The apparent viscosity of the products significantly increased during the 3 observed periods (7, 14, and 28 d at 10 °C). The composition of the flavored yogurt, proteins, exopolysaccharides, and fruit preparation had a great impact on the release of aroma compounds, which supports the previously observed results. The aroma compound amount in the headspace decreased when the matrix changed from water to yogurt, and with the fruit preparation, the headspace amounts for esters were significantly lower than in water alone, respectively, 23, 27, 29, and 17% less for methyl 2-methylbutanoate, ethyl hexanoate, hexyl acetate, and benzyl acetate. In flavored yogurt, the amount of aroma compounds in the headspace decreased again in comparison with the result obtained with the fruit preparation. Ethyl hexanoate and hexyl acetate presented the higher decreases of 48% and 53%, respectively. It shows that addition of fruit to the yogurts has a different effect on the flavor release than the addition of fruit flavor. The observed difference can be correlated to the change of rheological properties of the yogurt with the addition of fruits and fruit flavors. A decrease in the viscosity of yogurt has been observed with the addition of fruits, which affects the aroma release as well (Lubbers and others 2004). So, yogurts with fruit preparation are generally provided with a thickener which modifies the aroma expression further, because each thickener has its own role in aroma release (Wendin and others 1997;Lubbers and others 2004).

To increase the storage quality of a product, the reduction of water content can be helpful. One of the methods used these days is osmo-dehydro-freezing, which is applied to a variety of fruits and vegetables (Robbers and others 1997; Dermesonlouoglou and others 2007, 2008) where water is removed by osmotic pretreatment without any phase change (Barbanti and others 1994; Dermesonlouoglou and others 2007) and then the product is frozen. The amount of water to be frozen then is less, which helps in minimizing the refrigeration load during freezing (Huxsoll 1982; Dermesonlouoglou and others 2007). Osmo-dehydro-frozen fruits have a lesser water content which when added to yogurt also decreases the comparative amount of water which could be added while adding the fresh fruits. This can make a difference in the final viscosity of the product (as is evident in the previous case), which is related to aroma release and also to storage quality. Vahedi and others (2008) assessed the effect of osmo-dehydro-frozen fruits on various properties of yogurt such as sensory, physical, chemical, and microbiological properties in 2 stages. Its quality during storage was also evaluated. In the 1st stage, the type, percentage, and time of addition (before and after fermentation) of fruit were determined which indicated that "yogurts containing 10% apple or 13% strawberry, and added after fermentation, had better quality as the taste value was higher in strawberry yogurt and texture and mouth feel values were higher in the yogurt with high percentages of fruit." In the 2nd stage, quality evaluation during storage was done. Similar to other cases, storage was found to have "a significant effect on pH, acidity, syneresis, taste, and texture ($P < 0.05$)."

Fortification of Yogurt with Health-Promoting Additives, Benefits, and Their Organoleptic Effect

Yogurt is a popular food product and it can help as a medium to supply nutritive component such as calcium, generally deficient in certain segments of the human population. This idea has been used by many food scientists to fortify yogurt with certain essential nutrients. This part of the review presents some of the cases of fortification of yogurt along with their benefits and drawbacks.

Yogurt is an excellent source of calcium and high-quality protein. But it contains very little iron, which is common among all dairy products (Blanc 1981). The practice of fortification of yogurt with iron is gaining popularity and is expected to help fulfill nutritional needs. An advantage of using dairy foods as the vehicle for supplementing the diet with iron is that people who consume diets of low iron density typically consume more dairy products and those with diets high in iron consume the fewest dairy products. Furthermore, iron-fortified dairy foods have a relatively high iron bioavailability. Lactic acid bacteria do not require iron for growth (Neilands 1974), and iron addition to yogurt may change the balance between lactic acid bacteria and other bacteria that do require iron for growth (Jackson and Lee 1992). According to a study by Hekmat and McMahon (1997), it was found that the oxidized flavor scores of iron-fortified yogurts were slightly higher than control yogurt, and there was no enhancement in metallic, bitter, or other off-flavors. There was no detectable significant difference in the appearance, mouth feel, flavor, or overall quality of fortified and unfortified flavored yogurts, as observed by the consumer panel. It implies that all yogurt samples were appreciated by the consumer panelists signifying yogurt as an appropriate medium for iron fortification.

Along with fortification of yogurt with iron, the addition of calcium to yogurt has also been done. As reported before "plain whole yogurt contains about 120 mg calcium per 100 g" (Pirkul and others 1997). Fortification of yogurt with calcium is expected to be able to address individuals' requirements who are at risk of calcium deficiency related disorders. Even when individuals do not consume large amounts of dairy products to meet their calcium requirements, fortification will supply required amount of calcium in 1 or 2 servings. Fortification of plain low-fat yogurt with calcium gluconate (Fligner and others 1988) is reported to be possible with minor physical and chemical changes and no effect on organoleptic properties of the yogurt (Pirkul and others 1997).

The increasing emphasis on use of natural food additives in diet has promoted the use of honey, which has been gaining interest as a substitute sweetener because of its wholesome image (Chick and others 2001; Ustunol and Gandhi 2001). Low pH (approximately 3.9) and ability to decrease sourness of solutions make it an attractive additive for acidic products such as yogurt. However, combinations of honey with yogurt are comparatively rare (Brown and Kosikowski 1970; Roumyan and others 1996) because it is reported to have "inhibitory effects on lactic starter cultures" (Čurda and Plocková 1995; Roumyan and others 1996). Factors related to antibacterial nature of honey are not completely understood (Taormina and others 2001), and are expected to be because of "high sugar content" limiting water available for proper growth of microorganisms, the "relatively high acidity, the presence of organic acids, and the presence, at low concentrations, of hydrogen peroxide" (Mundo and others 2004). Floral source of the honey is an important factor influencing its antimicrobial characteristics (Molan 1992). Studies have shown that during storage at 4 °C, the characteristic microorganisms (that is, *S. thermophilus* and *Lb. bulgaricus*) in yogurt are not significantly affected by the presence of honey at 1.0% to 5.0% (w/v) (Varga 2006). pH and lactic acid levels of the final products were found unaffected by honey, and it highly improved the sensory characteristics of the final product, with approximately 3.0% (w/v) of honey, without having a negative effect on the lactic acid bacteria.

By-products, rich in fiber and bioactive compounds, contribute about 50% of the total weight in the asparagus processing industry, which emphasizes their potential contribution in human nutrition. In a recent study, yogurts were enriched with fiber obtained from the nonedible part of asparagus shoots and fiber obtained from all methods of processing was found equally prospective for yogurt enrichment (Sanz and others 2008).

Fortification of nonfat yogurt with whey protein isolate (WPI) has also been tried (Isleten and Karagul-Yuceer 2006) and fortification of yogurt with sodium caseinate (NaCn) and yogurt texture improver (TI) has been done. It was observed that yogurt with WPI did not have desirable sensory properties and the descriptive panel indicated that yogurt with WPI had the lowest fermented flavor attribute. In general, yogurt fortified with NaCn and TI displayed better physical and sensory properties than did the control (nonfat yogurt made from reconstituted skim milk powder [SMP] fortified with SMP) and WPI-fortified yogurt and consumer acceptability for the flavor was the same for all. Mistry and Hassan (1992) studied the effects of high milk protein powder (containing 84% milk protein) addition on the quality of nonfat yogurts and it was found that supplementing skim milk up to 5.6% protein content could produce good-quality nonfat yogurt with the added benefit of extra protein content in the yogurt.

For the last several decades, marine lipids have received growing interest because of their valuable health effects (Nielsen and others 2007). Many studies have demonstrated that eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) have a positive effect on myocardial infarction and on immune and eye functions (Schmidt and others 1992; Werkman and Carlson 1996; Marchioli and others 1999) and in neurological diseases, for instance depression and Alzheimer's disease (Morris and others 2003). The healthy image of EPA and DHA and the wide consumption of dairy products such as yogurt support the possibilility of use of yogurt as a vehicle for increasing consumption of fish oil. However, due to the presence of high content of polyunsaturated fatty acids, foods with fish oil are prone to oxidation that might lead to the development of undesirable fishy and rancid off-flavors and may even promote cardiovascular diseases (Das 1993; Jacobsen 1999; Let and others 2003; Shimoni and others 2003). In a separate study (Chee and others 2005), an algal oil emulsion was added to yogurt mix flavored with a strawberry fruit base, to supply 500 mg ω-3 fatty acids per 272-g serving of yogurt. The hydroperoxide content was found to increase during storage and was unaffected by the stage of addition of algal oil emulsion. Even after 22 d of storage, the trained panel could recognize a stronger fishy flavor in supplemented yogurts, but both control and supplemented samples were rated as "moderately liked" by the consumer panel, which supports the option of further analysis in this regard.

Cashew apple serve as a rich source of vitamin C and has been rated as one of the leading indigenous fruits and huge amounts are seen in local markets during harvest season in several countries of South America and Africa (Akinwale 2000). It was used as a nutritional additive in the production of yogurt during a study (Aroyeun 2004), which led to higher vitamin C content than yogurt without the cashew apple additive and commercial plain nonfat yogurt The results obtained from sensory evaluation indicated that the yogurt into which cashew apple had been added "compared favourably" with the reference sample (commercially available Fan Milk yogurt) in terms of all the attributes evaluated, and there was no significant difference. In another study Bartoo and Badrie (2005) analyzed the physicochemical and sensory quality of stirred yogurts prepared from cow milk with added dwarf golden apple (*Spondias cytherea* Sonn.) nectar. Yogurts with golden apple nectar were more appreciated than the control (0% nectar) yogurt in terms of all sensory attributes and were found to develop a buttery odor by 4 wk of storage. A 226-g serving of this yogurt provided a good source of phosphorus and was found rich in protein. As evident fortification with all these valuable and easily available sources has the potential of changing the preference of yogurt market further.

Probiotics, Prebiotics, and Yogurt Aroma

The term probiotic refers to live microorganisms which when administered in sufficient quantities confer a health benefit on the host (FAO/WHO 2001). Yogurt is rich in probiotics which is one of its other beneficial characteristics and some of the food scientists have observed that the presence of probiotics does not affect yogurt flavor or consumer acceptance (Hekmat and Reid 2006). Other than *Lb. bulgaricus* and *S. thermophilus*, several other microorganisms might be added to the yogurt such as *Lb. acidophilus*, *Bifidobacterium lactis*, and *Lb. casei* (Aryana and others 2007a), *Lb. reuteri* and *Lb. rhamnosus* (Hekmat and others 2009). A survey (Krasaekoopt and Tandhanskul 2008) regarding consumer acceptance of yogurt containing probiotics encapsulated in alginate beads coated with chitosan was carried out in Thailand where the acceptance assessment of this product was performed by consumers and the sensory characteristics of products were evaluated using descriptive analysis which indicated that a potential market exists for yogurts containing probiotic beads.

The term prebiotics refers to the nondigestible components present in food that help in the growth of beneficial microorganisms (probiotics) in the digestive system. One of the prebiotic compounds which has been widely used is inulin (Aryana and McGrew 2007; Aryana and others 2007b; Allgeyer and others 2010). Inulin has been found to affect the taste (Guggisberg and others 2009) and sensory property, and consumers have been found to prefer yogurt with inulin more than low-fat yogurt without it (Spiegel and others 1994). Inulin's effect on starter culture fermentation rates, survivability, organic acid concentrations, and degree of proteolysis can also be used to explain its effect on sensory properties (Allgeyer and others 2010). Similar results regarding the positive acceptability of many other prebiotic components have been reported which include fructooligosaccharide (Gonzalez and others 2011) soluble corn fiber, polydextrose (Allgeyer and others 2010), and inulin of different sources.

The interaction effect of prebiotics and probiotics on the final yogurt product is still an unresolved and controversial topic. In some cases, a prebiotic is reported to have a positive effect on the probiotics in terms of growth and survivability (Ozer and others 2005; Aryana and McGrew 2007; Aryana and others 2007b), but in other cases, it does not show any remarkable positive effect (Daniel 2009; Allgeyer and others 2010). But the effects of the probiotics and prebiotics on human health are having a strong impact on the yogurt market and addition of prebiotics and probiotics in proper ways and amounts can increase consumer preference for these products (Allgeyer and others 2010).

Expected Future Trends in Yogurt Sales

Yogurt can be made available in different forms such as drinking yogurt, lactose-hydrolyzed yogurt, strained yogurt, frozen yogurt (with categories soft, hard, or mousse), dried yogurt, bio-yogurt (yogurt made with different live cultures other than the 2 most widely used ones), vegetable oil yogurt, soy yogurt, and chemically acidified yogurt (Tamime and Robinson 2007) and yogurt has always been successful in making people enjoy the products. Ever-growing consumer demand for convenience, combined with a wholesome diet and preference for natural ingredients, has led to growth in the functional beverage market. Current trends and changing consumer needs indicate a great opportunity for innovations and developments in fermented milks. While scientific and clinical evidence is mounting to corroborate the consumer perception of health from fermented milks, the probiotics, prebiotics, synbiotics, and associated ingredients are able to add an attractive dimension to cultured dairy products. The compounds responsible for yogurt aroma can be used as additives. It has been concluded in one study that in the prescribed range, 1-nonen-3-one can be added to food, pharmaceutical, cosmetic, and perfume compositions to flavor the products and to impart aroma, particularly to dairy products and coffee extract. The 1-nonen-3-one can also be combined with other compounds that provide taste and aroma, and the combined compounds can be added to the compositions (Ott and others 2001). The application of yogurt to prepare baked goods such as bread has been patented, which are reported to have improved flavor and other properties that can be obtained by incorporating yogurt in the dough (Hill 1974). Owing to expanding market size of dairy companies, there has been a merging of dairy products and fruit beverage markets with the introduction of "juiceceuticals" such as fruit-yogurt beverages that are typical examples of hybrid dairy products which are able to offer health, flavor, and convenience at the same time. Another potential growth area for fermented milks includes value-added products such as low-calorie, reduced-fat varieties, and those fortified with physiologically active ingredients, including fibers, phytosterols, omega-3-fatty acids, whey-based ingredients, antioxidant vitamins, and isoflavones that provide specific health benefits beyond basic nutrition. Continuous efforts are being made to develop fermented milks containing certain nonconventional food sources such as soybeans and millet and convert them to more acceptable and palatable forms thus producing low-cost, nutritious fermented foods. Use of biopreservatives and certain innovative technologies such as membrane processing, high-pressure processing, and carbonation can lead to milk fermentation under predictable, controllable, and precise conditions to yield hygienic fermented milks of high nutritive value (Khurana and Kanawjia 2007), which can help to further improve the industry and add value.

Conclusion

Yogurt has been present in the human diet in many parts of the world because of acceptance of its taste (along with remarkable beneficial effects). In the case of yogurt, strawberry is known to be the most popular added flavor. With the advancement of technology, it is now common to find different types of flavors such as peach, red fruits, lemon, apple, and so forth. Aroma additions provide various flavor possibilities in the dairy market that has increased the popularity of products such as yogurt, milk drinks, desserts, and others. To satisfy consumer demands, manufactures increasingly propose yogurts with reduced fat content. In order to maintain the same texture, fat is replaced by thickeners and gelling agents. The decrease in fat content and its replacement by texturizing agents can lead to change in the distribution of flavor molecules within the product and to differences in flavor perception. Care should be taken while modifying the aroma components because yogurt is a major source of nutrients for both vegetarians and nonvegetarians. We can deduce from the studies conducted up to now that to have acceptable modifications in yogurt, much work is still to be done, which will be able to maintain the originality of the product, at the same time satisfy ever-changing consumer demands.

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