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Addition of buttermilk improves the flavor and volatile compound profiles of low-fat yogurt

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ABSTRACT

We investigated the sensory properties and volatile compounds of full-fat yogurt, low-fat yogurt, and low-fat yogurt with addition of buttermilk at different concentrations. Full-fat yogurt exhibited higher sensory scores than the others. Addition of buttermilk improved the sensory of low-fat yogurt, but an excessive addition (> 4%) decreased its acceptability with respect to flavor. Low-fat yogurt with addition of 1% buttermilk (1% LF-BMY) exhibited similar flavor as full-fat yogurt by the analysis of sensory and electronic nose. Low-fat yogurt produced a lower concentration of volatile compounds, and addition of 1% buttermilk increased the content of key volatile compounds of esters, aldehydes, alcohols, and acids. Some unique acids, aldehydes, ketones, aromatics, esters, alcohols, and sulfides were also found in 1% LF-BMY. Overall, addition of buttermilk at appropriate concentration can improve the acceptability of low-fat yogurt.

1. Introduction

In recent years, there has been an increasing demand for low-fat yogurt, because fat has been associated with an increased risk of obesity, arteriosclerosis, coronary heart disease, elevated blood pressure, and some cancers (Kaminarides, Stamou, & Massouras, 2007). However, milk fat plays a key role in the flavor and physical properties of dairy products. A reduced fat content not only causes poor textural properties, but it also unbalances the release of flavor; reduced fat also produces an unpleasant flavor in low-fat yogurt, such as sharp sourness and lack of milky aroma, which may ultimately hinder the acceptance of low-fat yogurt from the market. Therefore, it is necessary to improve the flavor and physical properties of low-fat yogurt, which will benefit consumers by helping to reduce their overall fat intake.

Flavor is one of the most important factors that determines the acceptability and preference of yogurts. More than 90 different volatiles that include alcohols, aldehydes, ketones, acids, esters, lactones, sulfur-containing compounds, pyrazines, and furan derivatives have been identified in yogurt (Ott, Fay, & Chaintreau, 1997). The sensory properties of yogurt largely depend on the relative balance of flavor compounds that are derived from fat, proteins, and carbohydrates in milk. Furthermore, fat, which is an important flavor precursor and flavor carrier, affects the distribution of flavor molecules between food headspace and matrix (Lubbers, Decourcelle, Martinez, Guichard, & Tromelin, 2007). Recently, fat substitutes have been popular choices to improve the flavor of low-fat yogurt.

Many fat substitutes that have been investigated to improve the textural properties of low-fat yogurt could also change its flavor. Starch, pectin, guar gum, and locust bean gum were easy to interact with volatile compounds that disturbed their retention/release, and ultimately inhibited the flavor from natural yogurt (Decourcelle, Lubbers, Vallet, Rondeau, & Guichard, 2004; Lubbers et al., 2007). Fruit, fruit jam (e.g., strawberry, peach, and cherry), and sweeteners have been used also to compensate for the natural sourness of low-fat yogurt, but it is a challenge to achieve a plain yogurt (Cheng, 2010). Therefore, a method that is safe and able to improve flavor in addition to textural properties of low-fat yogurt needs to be investigated. Although sodium caseinate and buttermilk have been proved to result in desirable sensory of non-fat yogurt (Isleten et al., 2006; Romeih, Abdel-Hamid, & Awad, 2014), the sensory results were subjective, and the changes in volatile compounds need further investigation using instrumentation, such as GC-MS, electronic nose. Additives to improve the flavor of yogurt are very limited, and more optimal possibilities should to be found.

Milk fat is in the form of fat globules of 4–5 μm in diameter. The flavor of dairy products is not only related to the fatty acid profiles in the core of the milk fat globule, but it may be related also to the milk fat

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globule membrane (MFGM), because MFGM contains lipids (e.g., phospholipids, sphingolipids, and cholesterol) and MFGM protein. Buttermilk, which is a by-product of the butter industry, is very rich in MFGM. Because buttermilk possesses good emulsifying and nutritional properties, it has been used in many food products, such as salad dressings, chocolate, cheese, and yogurt (Govindasamy-Lucey, Lin, Jaeggi, Johnson, & Lucey, 2006; Le et al., 2011; Morin, Pouliot, & Britten, 2008; Romeih, Moe, & Skeie, 2012). Milk fat globule membranes that are derived from buttermilk are a beneficial ingredient for infant formulas, and they carry many health benefits (i.e., inhibition of colon cancer, suppression of gastrointestinal pathogens, and alleviation of stress responses) (Spitsberg, 2005). Therefore, good emulsification, good water-holding capacity, and desirable nutritional properties make buttermilk a good choice to apply to food products. Moreover, it contains the other water soluble components of milk, like casein, whey proteins, lactose (Roesch, Rincon, & Corredig, 2004). These components of buttermilk may also participate in the flavor of food products. Although the effect of buttermilk on the textural properties of products was studied, its influence on sensory properties and the presence of volatile compounds in the low-fat yogurt has been studied rarely. Therefore, it is necessary to investigate the effect of buttermilk on the flavor properties of yogurt subjectively and objectively.

The objective of this study was to test the effect of the addition of buttermilk on the sensory properties, determine the optimal addition amount of buttermilk, and analyze the violate compounds of law-fat yogurt, full-fat yogurt and low-fat yogurt with optimum concentration of buttermilk, through the objective testing (sensory analysis) and subjective testing (electronic nose and GC-MS). This study would be helpful to the development of low-fat dairy products.

2. Materials and methods

2.1. Chemicals and materials

Skim milk powder (SMP), whole milk powder (WMP), and buttermilk were purchased from Fonterra Cooperative Group Ltd. (Auckland, New Zealand) (Table 1). A solid-phase microextraction (SPME) fiber (DVB/CAR/PDMS, 75 μm) was obtained from Supelco (Bellefonte, PA, USA). C7-C30 n-alkanes were obtained from Sigma-Aldrich Company (St. Louis, MO, USA). Direct Vat Set (starter culture Yo-C798-F) that contained *Streptococcus thermophiles* and *L. delbrueckii* subsp. *bulgaricus* was obtained from Inatural Biological Technology Co., LTD (Hebei, China).

2.2. Physicochemical analysis

Major nutrients in the ingredients (SMP, WMP, and buttermilk) and in the yogurts were determined (Table 1). The fat content was quantified using the Gerber method (IDF, 2008). The total protein content was determined by the Kjeldahl method using 6.38 as the conversion factor according to ISO 8968-1-2014. The ash content was determined by ashing in a furnace at 550 °C according to IDF 27-1964. The lactose content was determined according to the method of ISO 22662–2007. The phospholipid (PL) was determined by measuring lipid phosphorus after hydrolysis of the samples with perchloric acid ($HCLO_4$), as previously described (Rouser, Fleischer, & Yamamoto, 1970). All chemical analyses were measured in triplicate.

2.3. Manufacture of yogurt

Yogurts were manufactured according to the method of Zhao, Wang, Tian, and Mao (2016). Firstly, six different milk bases were prepared. One hundred millilitres low-fat milk base without buttermilk and full-fat milk base were made with 12.42 g skim milk powder (32.20% protein) and 16.46 g whole milk powder (24.30% protein), respectively. One hundred millilitres low-fat milk bases with buttermilk powder were made with 11.31 g, 10.92 g, 9.92 g and 8.18 g skim milk powder, into which 0.50 g, 1 g, 2 g and 4 g buttermilk powder were added, respectively. The protein content of all yogurts was 4% (w/v). Each milk base was stirred for 2 h at 25 °C, and stored at 4 °C overnight to be hydrated completely. Then, all the milk bases were heated to 95 °C for 5min in a thermostatically controlled boiling water bath (DK-8B, Jinghong test equipment co., LTD, Shanghai), and cooled immediately to 42 °C for further fermentation. The prepared yogurts were stored at 4 °C for 12 h, and the following analysis was carried out on the 1day of storage. The six kinds of yogurts were namely full-fat yogurt, low-fat yogurt, low-fat yogurts with 0.5% (w/v), 1% (w/v), 2% (w/v), 4% (w/v) added buttermilk powder (0.5% LF-BMY, 1% LF-BMY, 2% LF-BMY, and 4% LF-BMY), respectively.

2.4. Analysis of volatile compounds by headspace solid-phase microextraction/gas chromatography mass spectrometry (HS-SPME/GC-MS)

Analysis of the volatile compounds of yogurts was performed using headspace solid-phase microextration (HS-SPME) that was coupled to gas chromatography with mass spectrometric detection (GC/MS), according to the method of Condurso, Verzera, Romeo, Ziino, and Conte (2008).

Briefly, 15 g of yogurts was added to a 20 mL vial and capped with a polytetrafluoroethylene-silicon stopper. After pre-equilibrated at 55 °C for 20 min, the volatile compounds were extracted using a SPME fiber in the head space at 55 °C for 40 min. The GC-MS analysis was performed using an Agilent 7890 A GC that was coupled to a 5975C quadrupole mass spectrometer with electron ionization at 70eV. Compounds were separated using a polar DB-WAX capillary column (30 mm × 0.25 mm × 0.25 μm). Helium was employed as the carrier gas, with a constant flow rate of 1.2 mL/min. The ionization source and

Table 1
Compositions of the ingredients and yogurts.

Samples	Total protein (%)	Total fat (%)	PLs (%)	Lactose (%)	Ash (%)
SMP	34.52 ± 0.15	1.24 ± 0.04	0.018 ± 0.06	53.54 ± 0.34	7.24 ± 0.14
WMP	24.13 ± 0.14	26.21 ± 0.12	2.89 ± 0.44	39.80 ± 0.13	5.67 ± 0.15
BMP	33.85 ± 0.01	8.24 ± 0.24	10.45 ± 0.89	22.17 ± 0.14	6.32 ± 0.03
Low-fat yogurt	3.97 ± 0.12[a]	0.14 ± 0.01[e]	0.01 ± 0.01[e]	6.20 ± 0.12[b]	0.84 ± 0.03[a]
Full-fat yogurt	4.11 ± 0.11[a]	4.35 ± 0.02[a]	0.48 ± 0.04[a]	6.61 ± 0.16[a]	0.94 ± 0.04[b]
0.5% LF-BMY	4.02 ± 0.14[a]	0.19 ± 0.04[e]	0.05 ± 0.02[d]	6.33 ± 0.12[ab]	0.87 ± 0.05[ab]
1% LF-BMY	3.92 ± 0.10[a]	0.22 ± 0.01[d]	0.11 ± 0.01[c]	5.95 ± 0.10[c]	0.87 ± 0.03[ab]
2% LF-BMY	4.01 ± 0.05[a]	0.29 ± 0.02[c]	0.21 ± 0.05[b]	5.80 ± 0.15[c]	0.86 ± 0.04[ab]
4% LF-BMY	3.98 ± 0.12[a]	0.43 ± 0.05[b]	0.42 ± 0.05[a]	5.34 ± 0.13[d]	0.84 ± 0.06[ab]

Results are expressed as mean ± standard error. Different letters in the same column indicate significant differences at $P < 0.05$.
PLs = phosphilipids. SMP = skim milk powder. WMP = whole milk powder. BMP = buttermilk powder. 0.5% LF-BMY = low-fat yogurt with 0.5% buttermilk addition, 1% LF-BMY = low-fat yogurt with 1% buttermilk addition, 2% LF-BMY = low-fat yogurt with 2% buttermilk addition, 4% LF-BMY = low-fat yogurt with 4% buttermilk addition.