Characteristics and Shelf-Life of Corn Milk Yogurt

Piyawan Supavititpatana[1], Tri Indrarini Wirjantoro[2] and Patcharin Raviyan[2*]

[1]Faculty of Food and Agricultural Technology, Pibulsongkram Rajabhat University, Phitsanulok 65000, Thailand
[2]Department of Food Science and Technology, Faculty of Agro-Industry, Chiang Mai University, Chiang Mai 50100, Thailand

**Corresponding author E-mail: p.charin@chiangmai.ac.th*

ABSTRACT

The chemical, physical and microbial characteristics, and shelf-lives of corn milk and cow milk yogurts were compared. Fat content of the corn milk yogurt was lower but protein content, hardness, consistency and counts of Streptococcus thermophilus and Lactobacillus delbrueckii subsp. bulgaricus were higher than those of the cow milk yogurt. In the sensory evaluation study, the appearance, color and flavor of both yogurts were not significantly different (P>0.05) at the end of 14 days of storage at 5°C. Fatty acid esters were not found in the cow milk yogurt while they were present as the main flavor compounds in corn milk yogurt. Shelf-lives of corn milk and cow milk yogurts were 14 days at 5°C. Results obtained suggest that corn milk is a potential raw material for making a novel yogurt.

Key words: Corn milk yogurt, Yogurt, Characteristics, Shelf-life

INTRODUCTION

Thailand exported canned and frozen sweet corn products for an amount of more than 650 million Baht in 2002 (Ketnil, 2002). Sweet corn also has been processed locally to produce corn milk, either pasteurized or heat-treated in the range of UHT treatment. The attractive color, aroma and appearance, together with the sweetness of the corn milk, are the main sensory characteristics that are sought by its consumers. The corn milk also has a good vitamin composition (USDA, 2004).

The industrial production of yogurt has increasingly developed worldwide (Birollo et al., 2000; Park et al., 2005) due to the nutritional benefit of milk constituents and live lactic acid bacteria (LAB) (Afonso and Maia, 1999; Birollo et al., 2000; Park et al., 2005). However, consumption of cows' milk is avoided by vegetarian people and people who are allergic to cows' milk. Thus, there have been many attempts to make yogurt from a variety of food resources (Granata and Morr, 1996; Öztürk and Öner, 1999; Kumar and Mishra, 2004; Lal et al., 2006). Production of yogurt from corn milk was aimed to combine the good sensory characteristics of the corn milk with the well-known yogurt flavor.

In general, the overall properties of yogurt such as acidity level, production of aroma compounds, textural characteristics, sensory attributes and nutritional value are influenced by the chemical composition of milk base (Tamime and Robinson, 1999; Bonczar et al., 2002). In addition, microbiological, sensory and physicochemical parameters undergo changes during storage of yogurt (Dave and Shah, 1997; Birollo et al., 2000; Al-Kadamany et al., 2003).

The objective of this research was to compare the characteristics and shelf-life of the corn milk yogurt with those of commercial cow milk yogurt during 35 days of storage at 5°C.

MATERIALS AND METHODS

Preparation of sweet corn milk

The sweet corn variety used in this study was an ATS-5 that was harvested on the 23rd day after silking of the corn plant. The sweet corn was purchased from Thaweesak Sweet Corn Group, Chiang Mai province, Thailand during September-November 2003. To prepare the corn milk, the sweet corn cobs were firstly husked, the silks removed and washed with water. The seeds were then separated from the cleaned cobs using knives. The corn seeds were extracted using a fruit extractor (Moulinex, Spain) to produce a milk solution. The corn milk solution was then filtered through a clean cloth and stored at -18°C until use.

Starter cultures preparation

Stock culture

The freeze-dried starters of *S. thermophilus* No. 894 (ATCC 19258) and *L. delbrueckii* subsp. *bulgaricus* No. 892 (ATCC 11842) (Thailand Institute of Scientific and Technological Research, Thailand) were grown for 18 h at 37°C in M17 broth (Merck, Germany) and MRS medium (Merck, Germany), respectively. One loop of each culture was transferred into 10 ml of litmus milk prepared by mixing 16% (w/v) skim milk powder (SMP) (Mission, Thailand), 2% (w/v) of 1% (w/v) litmus concentration (BDH, England) and 0.3% (w/v) yeast extract (Difco, USA). The inoculated culture was incubated for 18 h at 37°C and stored at 5°C until use.

Mother culture

An individual mother culture was freshly prepared before conducting the experiment by inoculating one loop of stock culture into 100 ml of sterilized milk medium containing 16% (w/v) SMP and 0.1% (w/v) yeast extract. The inoculated culture was incubated at 37°C for 18 h and kept at 5°C until use.

Corn milk yogurt preparation

Distilled water was added to the corn milk in a ratio of 1:2, corn milk to water. The diluted corn milk was then preheated to 90°C prior to adding 2% (w/v) lactose, 4% (w/v) sodium caseinate and 0.4% (w/v) gelatin. The mixture was stirred for 5 min, followed by heating at 95°C for 5 min (Raphaelides and

Gioldasi, 2005), and then cooled to 40°C. It was then inoculated with 2% (v/v) of yogurt starter culture which was composed of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* in a ratio of 1:1. The inoculum was poured into sterilized plastic cups and incubated at 40°C for 4 h until a pH 4.4-4.6 was reached. The corn milk yogurts were prepared in triplicate for each experiment.

Cow milk yogurt

The cow milk yogurt used in this study was a plain yogurt of a manufacturer in Thailand. The cow milk yogurt contained 2% of yogurt starters of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus.*

Chemical analysis

The yogurt samples were stored at 5°C for 35 days. Data were collected at suitable times for each analysis.

Chemical composition of corn milk and cow milk yogurts at the first day of storage

At the first day of storage, both yogurt samples were analyzed for chemical composition using the methods of AOAC (2000). Moisture was determined by drying samples at 103±2°C in a hot air oven. Crude protein was analyzed by Kjeldahl method. Crude lipid was analyzed by solvent extraction. Ash was determined by igniting samples at 550°C in a furnace. Percentage of carbohydrate was calculated by the formula:

100 - % moisture - % crude lipid - % crude protein - % ash

Chemical changes of corn milk and cow milk yogurts during storage

During 35 days of storage at 5°C, both yogurt samples were analyzed on 1, 7, 14, 21, 28 and 35 days for total solid and total acidity using the methods of AOAC 990.20 and 947.05, respectively (AOAC, 2000). Total soluble solid was measured by hand refractometer (ATAGO, Japan) and pH values were measured by a pH-meter Consort C830 (CE, Belgium).

Texture profile analysis (TPA)

TPA was carried out within 24 h after the yogurt fermentation had completed by a modified method of Kumar and Mishra (2004). It was performed using a TA-XT Plus (Stable Micro Systems, UK) with a 5 kg-load cell. Experiments were evaluated by compression tests which generated plot of force (g) vs. time (s). A 35 mm diameter cylindrical aluminum probe was used to measure the textural profile of a set yogurt sample prepared in a 100 ml cup at a temperature of 10±0.5°C. At the first stage, the corn milk yogurts were compressed by 30% of their original depth. The speed of the probe was fixed at 0.5 mm/s during the pre-test, compression and the relaxation of the samples. The data presented were averages of three replications.

Physical analysis

Color measurement

The yogurt samples stored for 1, 7, 14, 21, 28 and 35 days were measured for their color by a colorimeter (Minolta Data Processor DP-301, Chroma Meter CR-300 Series, Japan), using the CIE L*C*h scale values.

Whey drainage

Whey drainage was removed from the corn milk yogurt, using a syringe within 24 h after the yogurt fermentation had completed. The relative amount of whey drained off (in ml per 100 ml of initial sample) was calculated as the whey drainage. This method was modified from the method of Fiszman et al. (1999).

Syneresis

An amount of 20 g of the yogurt was spread in a thin layer to cover the surface of the Whatman No 1 filter paper. The yogurt was filtered under vacuum for 10 min. The liquid that passed through the filter paper was collected and recorded. The percentage of syneresis was calculated as the weight of the liquid divided by the weight of the initial sample multiplied by 100 (Wu et al., 2001).

Water holding capacity

A 10-g sample was centrifuged at 3,000 rpm for 60 min at 10°C. The supernatant was removed within 10 min and the wet weight of the pellet was recorded. The water holding capacity was expressed as percentage of pellet weight relative to the original weight of corn milk yogurt (Parnell-Cluies et al., 1986).

Consistency

Yogurts were stirred for 1 min at 1,500 rpm at 10°C before measuring the consistency by a Bostwick consistometer (González-Martínez et al., 2002).

Sensory evaluation

Sensory evaluation of yogurts was carried out by 50 trained panelists, using the 7 point Hedonic Scale after 1 and 14 days of storage at 5°C. The preparation of samples and the condition of sensory testing followed the method of Drake et al. (2000).

Flavor composition

The volatile flavour components of the following were analyzed: fresh corn milk; the corn milk mixture contained fresh corn milk, distilled water, lactose, sodium caseinate and gelatin, and pasteurized at 95°C for 5 min; corn milk and cow milk yogurts. The fresh corn milk was kept at -18°C for 7 days prior to conducting the flavor analysis. The corn milk mixture was analyzed within 1 day after pasteurization. The corn milk and cow milk yogurts were kept for 1 and 14 days at 5°C before the analysis. The flavor volatiles were determined by Solid Phase Microextraction – Gas Chromatography – Mass Spectrometry (SPME-GC-MS). The sampling vial was held 40 min for equilibrium at room temperature. A fused silica fiber of 10 mm in length, 100 μm in diameter, and 100 μm in thickness of polydimethylsiloxan (PDMS) was chosen to extract the volatile components. A new PDMS microextraction fiber was thermally conditioned prior to adsorption at 240°C in an injection port of an Agilent 6890 Series gas chromatograph (Hewlett Packard, U.S.A.) equipped with a 5973 Mass Selective Detector (Hewlett Packard, U.S.A.). Volatiles were separated with an Alltech AT-1MS column (30 m in length×0.25 mm ID×0.25 μm film thickness; Alltech, U.S.A.). Helium was used as carrier gas at the flow rate of 1 ml/min. Oven temperature was increased from 50°C to 80°C at 6°C/min and then to 230°C at 10°C/min. The MS ion source was maintained at 230°C throughout analysis. Mass spectra were acquired with ionization energy of 70 eV and within the mass range of m/z 29-250.

Microbial analysis

The yogurt samples were enumerated after 1, 7, 14, 21, 28 and 35 days of storage for *S. thermophilus, L. delbrueckii* subsp. *bulgaricus* (International Dairy Federation, 1997), psychrotrophs (Al-Kadamany et al., 2003) and yeasts and moulds (AOAC, 2000).

Statistical analysis

Statistical analysis was performed using SPSS version 10.0.1. The collected data from the chemical composition of corn milk and cow milk yogurts at the first day of storage were analyzed by an analysis of variance using a T test. The data from the chemical changes of corn milk and cow milk yogurts during storage, color measurement, TPA, physical properties and microbial analysis except the number of yeast and mould, were analyzed by an analysis of variance using a Factorial Experiment in a Complete Randomized Design (CRD) with 2 factors. The results from sensory evaluation were analyzed by an analysis of variance using a Factorial Experiment in a Randomized Complete Block Design (RCBD) with 2 factors. The number of yeasts and moulds from microbial analysis was analyzed by an analysis of variance using a CRD. If the F-value was significant, the Duncan's New Multiple Range Test was used to determine differences between the treatment means.

RESULTS AND DISCUSSION

Chemical composition

Table 1 showed that the chemical compositions of corn milk and cow milk yogurts were within the specification of fermented milk product of the Ministry of Public Health of Thailand (No. 289). The corn milk yogurt contained higher protein and moisture, but lower fat, ash, total solid, total soluble solid and carbohydrate as compared with the cow milk yogurt. In particular, the fat content of the corn milk yogurt was about one-tenth that of cow milk yogurt. This was because the fat content in corn milk was only 1.05% and the corn milk was also diluted before yogurt manufacture. The corn milk yogurt could be classified as non-fat yogurt as it contained less than 0.5% fat (Kosikowski, 1997). The carbohydrate content of the corn milk yogurt was about half that of cow milk yogurt. This can be explained by the use of sugar in production of cow milk yogurt.

The total solid contents of the corn milk yogurt (about 12%) and cow milk yogurt (about 21%) remained constant during 35 days of storage at 5°C ($P<0.05$) and were within the normal range of commercial cow milk yogurt (Tamime and Robinson, 1999). However, the total soluble solid contents of the yogurts reduced with extended storage from 7.33±0.12% to 6.83±0.06% and 15.33±0.12% to 14.93±0.12%, for corn milk and cow milk yogurts, respectively. These reductions could be due to the utilization of sugar by the starter cultures as reported by Vasiljevic and Jelen (2002); Wang et al., (2002).

The corn milk yogurt had a greater reduction of pH and a lower total acidity during 35 days of storage (Figure 1). This difference might be due to the lower buffering capacity of the corn milk. However, the lowest acidity (1.1%) of corn milk was still higher than the minimum requirement (0.6%) for yogurt (The Ministry of Public Health, 2005).

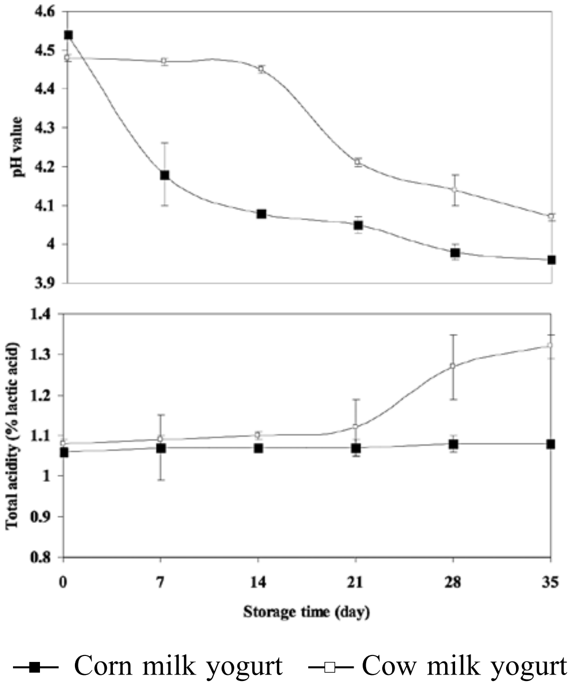

Figure 1. pH value and total acidity of corn milk yogurt and cow milk yogurt during 35 days of storage at 5°C.

Table 1. Chemical compositions of corn milk and cow milk yogurts at the first day of storage.

Chemical compositions (%)	Corn milk yogurt	Cow milk yogurt	Specification1
Moisture	87.55±0.10[a]	78.31±0.21[b]	No specification
Protein	4.17±0.08[a]	3.89±0.10[b]	>2.7
Fat	0.35±0.01[b]	3.46±0.07[a]	<15
Carbohydrate	7.66±0.12[b]	13.61±0.17[a]	No specification
Total solid	12.25±0.07[b]	21.56±0.07[a]	No specification
Total soluble solid	7.33±0.12[b]	15.33±0.12[a]	No specification

*Values in a row followed by different letters were significantly different treatments (P<0.05).
[1]The Ministry of Public Health (2005).

Color of yogurts

The color of the corn milk yogurt was noticeably more yellow as compared with the cow milk yogurt (Figure 2, Table 2). At the h value of 90, the color of sample was yellow. Thus, the corn milk yogurt had higher yellow component (lower h value) than the cow milk yogurt. Carotene, that is primarily responsible for the yellow color of corn and cow milks (Fox and McSweeney, 1998; Omueti and Ajomale, 2005), should be considerably higher for the corn milk yogurt. The storage time did not significantly (P≥0.05) influence the purity and color shade of both yogurts while the lightness was reduced with longer storage time.

Figure 2. Appearance of corn milk yogurt (left) and cow milk yogurt (right).

Textural characteristics

Textural characteristics of the yogurts are presented in Figure 3. The gel structure of corn milk yogurt was harder than that of the cow milk yogurt. The hardness and springiness of both yogurts were reduced with storage time. In contrast, the adhesiveness was increased when the storage time was prolonged. The textural changes would be mainly caused by degradation of the gel structure. Afonso and Maia (1999) reported the occurrence of after-acidification and proteolysis during the storage of yogurt. The after-acidification occurred because of the enzymatic activity of LAB, and although reduced at refrigeration temperatures, was not completely stopped. Further decrease in pH during storage induced ionic changes in the protein network. The disruptions of protein would reduce the hardness and springiness of corn milk yogurt.

Physical properties

Whey drainage refers to the appearance of whey on the gel structure (Lucey, 2002). The whey drainage of the corn milk yogurt appeared after storage for 14 days and the amount increased with storage time. The whey drainage indicated weakness of the gel network, reducing the water holding capacity and increasing syneresis. These observations were also made of milk protein gel as studied by Lucey (2002). A correlation between the results of syneresis and water holding capacity of the cow milk yogurt was observed, although whey drainage had not occurred throughout 35 days of storage (Table 3). The higher syneresis of the cow milk yogurt possibly resulted from the less gel strength.

Table 2. Color parameters of corn milk and cow milk yogurts during 35 days of storage at 5°C.

Yogurt		L*	C*	h
corn milk		84.90 ± 0.66^{b}	26.64 ± 0.45^{a}	97.46 ± 0.37^{b}
cow milk		91.86 ± 2.06^{a}	10.65 ± 0.29^{b}	109.93 ± 0.51^{a}
Storage time (day)		L*	C*	h
1		90.81 ± 5.68^{a}	18.29 ± 8.79^{ns}	103.68 ± 6.60^{ns}
7		88.83 ± 3.57^{b}	18.39 ± 8.82^{ns}	103.95 ± 6.82^{ns}
14		88.35 ± 3.68^{c}	18.55 ± 8.71^{ns}	103.32 ± 6.46^{ns}
21		87.92 ± 3.49^{d}	18.76 ± 8.69^{ns}	103.73 ± 7.01^{ns}
28		87.60 ± 3.20^{e}	18.92 ± 8.82^{ns}	103.47 ± 6.90^{ns}
35		86.77 ± 3.26^{f}	18.98 ± 8.75^{ns}	104.03 ± 7.24^{ns}
Yogurt	Storage time (day)	L*	C*	h
Corn milk	1	85.63 ± 0.33^{g}	26.30 ± 0.43^{b}	97.67 ± 0.32^{c}
	7	85.58 ± 0.35^{g}	26.44 ± 0.32^{ab}	97.73 ± 0.50^{c}
	14	85.00 ± 0.09^{h}	26.50 ± 0.28^{ab}	97.43 ± 0.47^{c}
	21	84.74 ± 0.12^{hi}	26.70 ± 0.12^{ab}	97.37 ± 0.12^{c}
	28	84.68 ± 0.03^{i}	26.96 ± 0.78^{a}	97.47 ± 0.12^{c}
	35	83.79 ± 0.07^{j}	26.96 ± 0.39^{a}	97.43 ± 0.46^{c}
Yogurt	Storage time (day)	L*	C*	h
Commercial	1	95.99 ± 0.16^{a}	10.27 ± 0.12^{e}	109.70 ± 0.26^{b}
	7	92.08 ± 0.07^{b}	10.34 ± 0.05^{de}	110.17 ± 0.06^{ab}
	14	91.71 ± 0.11^{c}	10.60 ± 0.09^{cde}	110.20 ± 0.10^{ab}
	21	91.11 ± 0.12^{d}	10.83 ± 0.06^{cde}	110.13 ± 0.29^{ab}
	28	90.52 ± 0.06^{e}	10.88 ± 0.05^{cde}	110.30 ± 0.10^{ab}
	35	89.75 ± 0.06^{f}	10.99 ± 0.15^{cde}	110.47 ± 0.15^{ab}

*Values in a column within the same group followed by different letters were significantly different ($P<0.05$).

Water holding capacity, the method for indirect evaluation of network homogeneity (Sodini et al., 2004), of cow milk yogurt was higher than that of corn milk yogurt. It was probably because the commercial yogurt was homogenized before fermentation while homogenization was not included in preparation of corn milk yogurt. Homogenization produces small-sized fat globules (Keogh and O'Kennedy, 1998). As a result, more protein is absorbed on the surface of the fat globules, leading to increased ability to immobilize water.

The Bostwick distance is the indicator of fluid consistency that implies the gel rupture. The longer Bostwick distance demonstrates lower consistency of the gel. The consistency of both samples reduced with the extension of storage time,

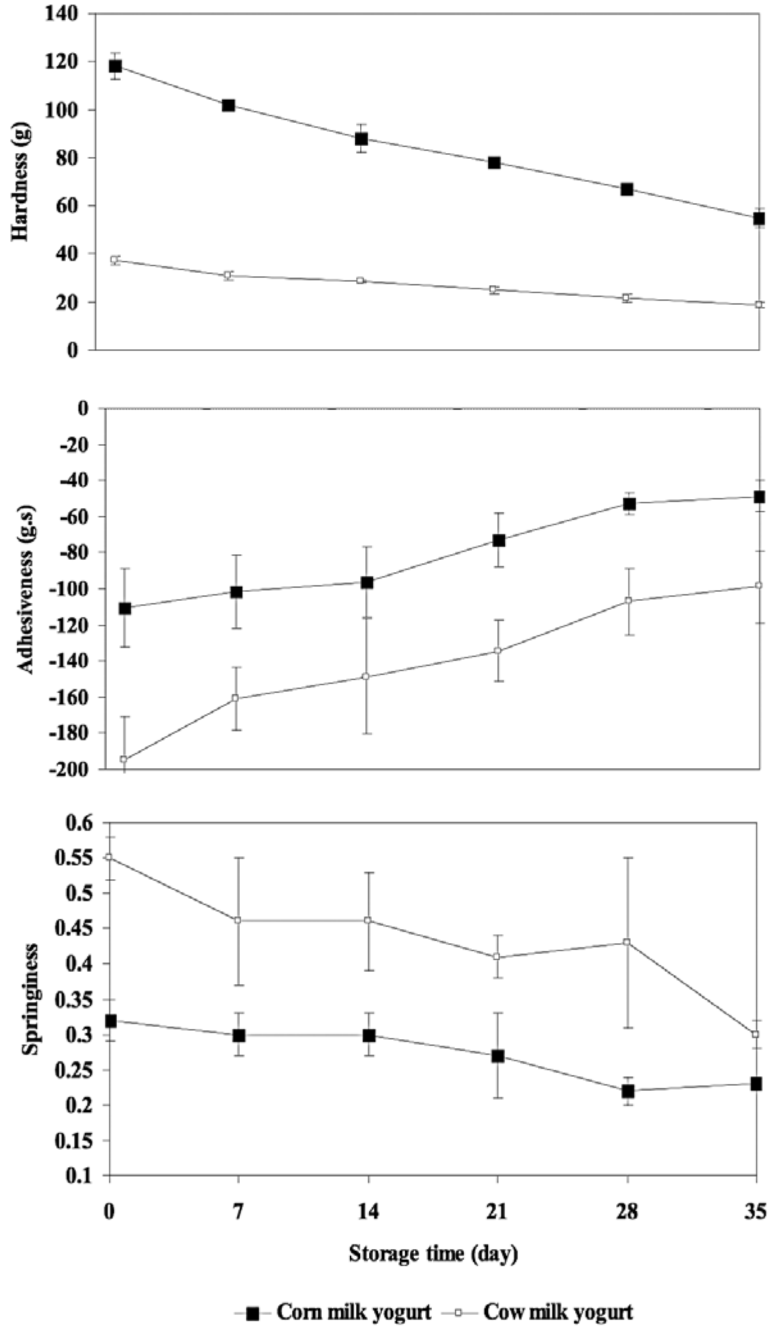

Figure 3. Changes of textural characteristics of corn milk and cow milk yogurts during storage for 35 days at 5°C.

Table 3. Physical properties of corn milk and cow milk yogurts during 35 days of storage at 5°C.

Yogurt	Storage time (day)	Whey drainage (%)	Syneresis (%)	Water holding capacity (%)	Bostwick distance (cm)
Corn milk	1	$0.00±0.00^{b}$	$28.05±1.66^{f}$	$53.59±0.64^{f}$	$7.86±0.04^{k}$
	7	$0.00±0.00^{b}$	$29.08±0.25^{e}$	$52.67±0.81^{g}$	$8.48±0.27^{j}$
	14	$0.04±0.01^{b}$	$29.82±0.26^{d}$	$51.75±0.58^{h}$	$8.96±0.10^{i}$
	21	$0.13±0.08^{a}$	$30.51±0.42^{d}$	$49.77±0.43^{i}$	$9.65±0.28^{h}$
	28	$0.15±0.05^{a}$	$32.01±0.32^{c}$	$48.03±0.52^{j}$	$10.22±0.10^{g}$
	35	$0.17±0.06^{a}$	$33.65±0.63^{b}$	$47.63±0.36^{j}$	$11.14±0.34^{f}$
Cow milk	1	$0.00±0.00^{b}$	$76.46±0.35^{a}$	$70.23±0.40^{a}$	$11.14±0.04^{f}$
	7	$0.00±0.00^{b}$	$76.59±0.23a^{q}$	$67.09±0.18^{d}$	$11.62±0.27^{e}$
	14	$0.00±0.00^{b}$	$76.66±0.08^{a}$	$66.43±0.25^{b}$	$12.37±0.28^{d}$
	21	$0.00±0.00^{b}$	$76.71±0.03^{a}$	$65.46±0.45^{c}$	$12.73±0.24^{c}$
	28	$0.00±0.00^{b}$	$76.72±0.04^{a}$	$64.32±0.14^{d}$	$13.19±0.12^{b}$
	35	$0.00±0.00^{b}$	$76.87±0.03^{a}$	$63.28±0.36^{e}$	$13.76±0.10^{a}$

*Values in a column followed by different letters were significantly different treatments ($P<0.05$).

but the gel of the cow milk yogurt had lower consistency. A similar trend was observed in the hardness (Figure 2), suggesting that the consistency of the yogurt is related to the strength of the protein-protein interactions of the gel structure.

Sensory evaluation

Sensory scores are presented in Table 4. The panelists preferred cow milk yogurt to the corn milk yogurt in texture and mouth feel attributes. The higher whey drainage of the corn milk yogurt (Table 3) may be the factor responsible for the lower scores. A better taste result of corn milk yogurt could have been achieved by adding sugar that reduced the sour taste. Nevertheless, the panelists still liked the flavor of both yogurt samples during 14 days of storage. Besides, the appearance, color and flavor of both yogurts were not significantly different ($P≥0.05$). The growth of psychrotrophs, yeasts and moulds should not be responsible for the decrease of the scores because the amounts found in all samples (Figure 4) were less than the amounts that could have a detrimental effect on the flavor quality of the yogurt (Walstra et al., 1999; Al-Kadamany et al., 2003).

Flavor composition

Table 5 reveals that *trans*-2-nonenal, tridecane, ethyl acetate, ethyl palmitate, ethyl linoleate and ethyl oleate were the most important flavor compounds of fresh corn milk while tridecane, n-heptanal, ethyl linoleate, dodecane, furan and ethyl oleate were the major flavor compounds for the corn milk mixture. The differences could be caused by the heat treatment as well as the added ingredients. These observations differed from the previous reports of Azanza et al., (1996) and Tracy (2001) who reported that ethanol, acetaldehyde, methanethiol and hydrogen

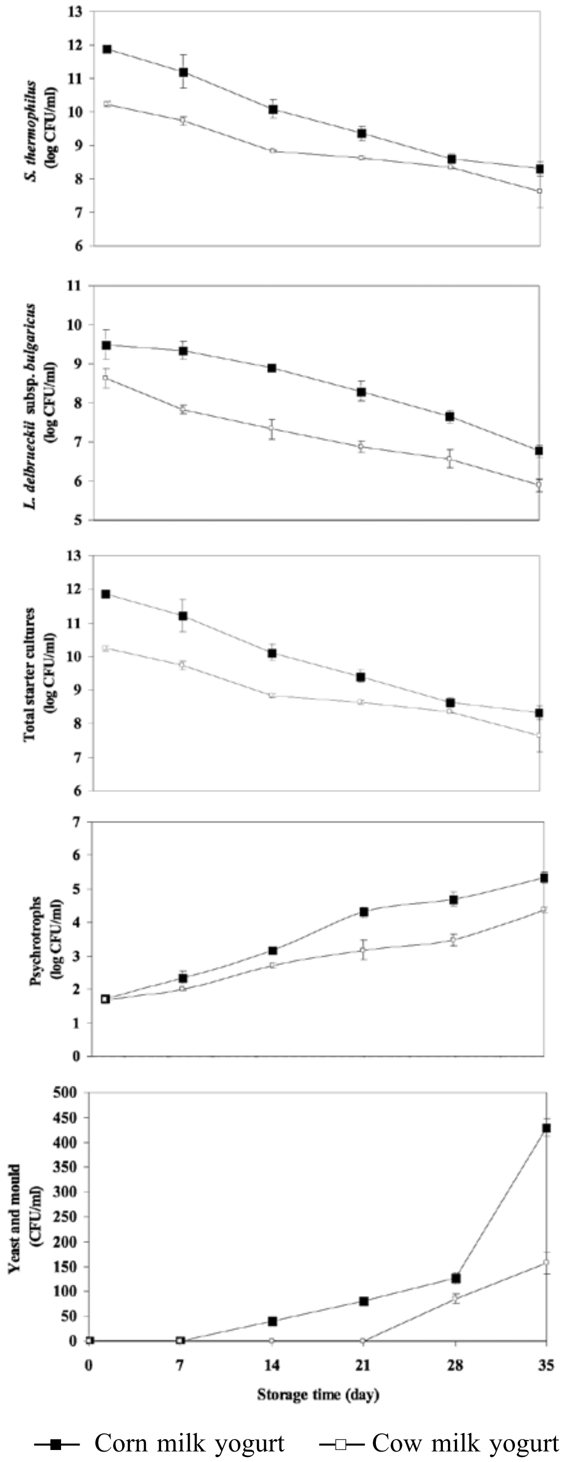

Figure 4. Microbial counts of corn milk and cow milk yogurts during 35 days of storage at 5°C.

Table 4. Sensory characteristics of corn milk and cow milk yogurts during 14 days of storage at 5°C.

Yogurt	Appearance	Color	Texture	Flavor	Mouth feel
Corn milk	5.73±0.58^{ns}	6.20±0.65^{ns}	5.20±0.71^{b}	6.25±0.43^{ns}	4.62±0.78^{b}
Cow milk	6.02±0.53^{ns}	5.78±1.12^{ns}	6.03±0.43^{a}	6.13±0.60^{ns}	6.18±0.73^{a}

Storage time (day)	Appearance	Color	Texture	Flavor	Mouth feel
1	6.03±0.55^{a}	6.10±0.89^{ns}	5.82±0.58^{a}	6.23±0.52^{ns}	5.70±0.78^{a}
14	5.72±0.57^{b}	5.88±0.98^{ns}	5.42±0.80^{b}	6.15±0.53^{ns}	5.10±1.27^{b}

Yogurt	Storage time (day)	Appearance	Color	Texture	Flavor	Mouth feel
Corn milk	1	5.93±0.50^{a}	6.33±0.59^{ns}	5.53±0.48^{b}	6.30±0.46^{ns}	5.17±0.36b
	14	5.53±0.61^{b}	6.07±0.70^{ns}	4.87±0.77^{c}	6.20±0.41^{ns}	4.07±0.70^{c}
Cow milk	1	6.10±0.60^{a}	5.87±1.07^{ns}	6.10±0.54^{a}	6.17±0.59^{ns}	6.23±0.73^{a}
	14	5.93±0.46^{a}	5.70±1.19^{ns}	6.00±0.30^{a}	6.10±0.63^{ns}	6.13±0.40^{a}

Yogurt	Sweetness	Sourness	After taste	Total preference
Corn milk	3.50±0.63^{b}	3.68±0.82^{b}	4.03±0.79b	4.77±0.69^{b}
Cow milk	5.77±0.81^{a}	5.98±0.62^{a}	6.12±0.61a	6.20±0.48^{a}

Storage time (day)	Sweetness	Sourness	After taste	Total preference
1	4.75±1.32^{ns}	4.93±1.44^{ns}	5.12±1.27^{ns}	5.62±0.87^{ns}
14	4.52±1.39^{ns}	4.73±1.31^{ns}	5.03±1.27^{ns}	5.35±0.99^{ns}

Yogurt	Storage time (day)	Sweetness	Sourness	After taste	Total preference
Corn milk	1	3.63±0.64^{b}	3.73±0.92^{b}	4.07±0.84^{b}	4.97±0.67^{b}
	14	3.37±0.61^{b}	3.63±0.72^{b}	4.00±0.76^{b}	4.57±0.68^{b}
Cow milk	1	5.87±0.72^{a}	6.13±0.58^{a}	6.17±0.52^{a}	6.27±0.46^{a}
	14	5.67±0.90^{a}	5.83±0.65^{a}	6.07±0.70^{a}	6.13±0.52^{a}

*Values in a column within the same group followed by different letters were significantly different treatments ($P<0.05$).

sulfide were the main aroma compounds of heated sweet corn. One explanation for the difference is the use of different cultivars of corn.

Compounds found most in corn milk and cow milk yogurts in this study were tridecane, tetradecane, benzothiazole and dodecane. However, acetaldehyde and diacetyl were reported to be essential aroma compounds of typical yogurt (Tamime and Robinson, 1999; Walstra et al., 1999). It has been reported that sorbic acid reduced acetaldehyde production of yogurt starter cultures (Tamime and Robinson, 1999). This might be the reason for not finding acetaldehyde in the cow milk yogurt.

Table 5. Flavor compounds of fresh corn milk, corn milk mixture, corn milk yogurt and cow milk yogurt stored for 1, 7 and 14 days at 5°C.

		% of total / % corrected with standard							
Retention Time (min)	Compounds	Corn milk	Corn milk mixture	Corn milk yogurt			Cow milk yogurt		
				1 day	7 days	14 days	1 day	7 days	14 days
2.06	Acetic acid	-	-	1.45/90	2.54/86	0.75/83	-	-	-
2.10	Chloroform	-	-	-	-	1.62/91	-	-	9.66/87
2.13	Ethyl acetate	8.50/78	-	-	-	-	-	-	-
2.15	2-Methylfuran	-	3.72/72	-	-	-	-	-	-
2.69	Diacetyl	-	-	-	-	-	-	3.34/86	-
2.75	Benzene	-	-	-	-	3.33/97	-	-	5.88/94
2.81	1,3-Bis(trifluoromethyl)-benzene	-	-	-	-	-	-	-	3.02/72
3.69	Dimethylethylene glycol	2.32/78	-	-	-	-	-	-	-
3.94	Hexylaldehyde (Hexanal)	1.87/86	-	-	-	-	-	-	-
5.40	Hexanol	7.29/83	-	2.17/83	2.99/90	-	-	-	-
5.42	Hexylformate	-	2.36/72	-	-	-	-	-	-
5.68	Amyl methyl ketone	-	-	-	-	-	1.43/91	-	-
5.95	Heptanal	-	12.47/91	-	-	-	-	-	-
7.67	Heptanol	-	-	1.84/90	4.07/86	2.78/90	-	-	-
7.88	Sabinene	-	-	-	-	3.00/95	-	-	1.86/91
8.26	Furan	-	8.75/91	1.50/91	-	-	-	-	-
8.83	3-Ethyl-2-methyl-1,3-hexadiene	4.56/83	-	-	-	-	-	-	-
9.08	1-Limonene	-	-	-	-	13.62/98	-	7.37/98	
9.93	Sorbic acid	-	-	-	-	-	27.15/94	13.78/95	30.48/91
10.10	Heptyl methyl ketone	-	-	-	1.39/87	-	2.73/91	-	2.37/87
11.31	Trans-2-nonenal	19.21/93	-	-	-	-	-	-	-
11.81	6-Methyltridecane	0.88/64	-	-	-	-	-	-	-
11.83	Decamethylcyclopentasiloxane	-	-	1.10/90	1.40/83	1.06/83	1.05/74	0.87/90	-
12.07	Ethyl octanoate	4.10/96	6.35/97	1.29/93	-	-	-	-	-
12.39	Dodecane	7.04/95	9.28/95	6.73/95	8.91/94	6.19/95	7.15/95	7.35/95	5.29/95
12.64	2,6-Dimethylundecane	1.23/90	1.63/78	1.39/91	1.68/90	1.31/72	1.43/94	1.56/90	-
13.26	5-Propyldecane	-	-	-	-	-	-	1.36/68	-
13.32	2,3,5-Trimethyldecane	-	-	-	-	1.67/59	-	-	-
13.32	2,3,6-Trimethyldecane	-	-	-	-	-	-	-	1.50/50
13.32	4,8- Dimethylundecane	0.79/72	-	-	-	-	-	-	-
13.39	9-Methylnonadecane	1.14/72	-	2.07/80	-	-	-	-	-
13.43	10-Methylnonadecane	-	-	-	1.32/72	1.39/64	1.77/83	1.42/72	-
13.48	3-Methyldodecane	1.35/78	1.60/78	1.42/83	-	-	1.68/86	-	-
13.49	2,3,7-Trimethyloctane	-	-	-	-	2.81/72	-	-	-
13.54	7-Methyltridecane	1.61/59	2.68/64	2.85/72	3.53/72	-	4.86/64	3.34/72	-
13.90	Tridecane	9.53/97	14.99/97	17.32/97	15.73/97	13.58/97	17.10/97	16.25/96	11.60/97
14.43	Heptylcyclohexane	-	-	-	-	-	1.27/64	0.88/87	-
14.66	Benzothiazole	-	-	-	14.66/94	9.95/94	-	16.01/94	5.58/93
14.75	Heptadecane	-	-	-	1.48/72	-	1.33/72	-	-
14.76	2-Methyltridecane	-	-	1.80/78	-	-	-	-	-
14.80	6,9-Dimethyltetradecane	-	1.07/83	-	-	-	-	-	-
15.00	2,6,10-Trimethyldodecane	-	2.16/72	3.39/87	2.86/93	2.89/91	2.34/91	2.60/89	1.75/83

		% of total / % corrected with standard							
Retention Time (min)	Compounds	Corn milk	Corn milk mixture	Corn milk yogurt			Cow milk yogurt		
				1 day	7 days	14 days	1 day	7 days	14 days
15.55	Trans-Caryophyllene	1.27/89	-	2.89/99	-	-	1.74/97	-	-
15.93	2H-Pyran-2-one,tetrahydro-6-pentyl	-	-	-	-	-	2.14/78	-	-
16.40	2,4-Di-tert-butylphenol	-	-	1.55/91	-	-	-	-	-
16.45	4-Methyl-2,6-di-tert-butylphenol	-	-	1.88/90	-	-	-	-	-
16.51	Pentadecane	-	-	2.47/97	1.50/96	1.47/93	1.45/95	2.57/97	1.48/93
16.71	Naphthalene	-	-	-	-	-	-	0.74/96	-
16.82	Trans-gamma-bisabolene	-	-	1.93/91	-	-	0.83/97	-	-
17.16	Diethyl phthalate	-	-	2.28/95	-	3.81/90	1.31/93	2.63/96	2.09/94
17.71	Hexadecane	-	-	1.11/96	-	-	0.93/94	0.98/89	-
21.74	Ethyl palmitate	2.81/95	1.63/95	2.05/98	1.76/97	2.28/95	-	-	-
23.53	Ethyl oleate	7.67/95	6.86/94	9.16/99	6.05/99	6.19/99	-	-	-

Chloroform and 1-limonene that might be produced by yogurt starter cultures in both yogurts were detected at 14 days of storage. According to Laye et al., (1993) the limonene content in cow milk yogurt increased with the increase of storage time.

Changes in flavor compounds of both yogurts during storage were due largely to two factors. The first factor was the reactions that resulted in the formation of or conversion to other compounds. The reactions were due to bacterial metabolic enzymes. The second factor was the loss of flavor compounds due to volatilization (Tamime and Robinson, 1999; Bonczar et al., 2002).

Microbial analysis

The numbers of *S. thermophilus* of both studied yogurts were higher than that of *L. delbrueckii* subsp. *bulgaricus* throughout the storage time (Figure 4). The corn milk yogurt had higher amounts of starter cultures, but its reduction of starter cultures was faster. However, the numbers of starter cultures in both yogurt samples at the end of storage were higher than the minimum requirement of 10^7 CFU/g (The Ministry of Public Health, 2005).

Psychrotroph counts of corn milk yogurt and commercial yogurt increased with increasing storage time, but the rate of increase in the cow milk yogurt was lower than that in corn milk yogurt. The changes in yeasts and moulds in the tested yogurts were similar to that of the psychrotrophs. The slower increase of yeasts and moulds as well as psychrotrophs of cow milk yogurt could be partly due to the presence of sorbic acid (Table 5).

According to the requirement established by the Ministry of Public Health (2005), a maximum viable yeast or mould count in yogurt is 100 CFU/g. The shelf-lives at 5°C of corn milk and cow milk yogurts should be 21 and 28 days, respectively. However, the acceptability of both yogurts by panelists at those times was not evaluated because the appearance of both products was not quite acceptable. Accordingly, the shelf-lives at 5°C of corn milk and cow milk yogurts could be indicated only 14 days.

CONCLUSION

The corn milk yogurt was found to have lower fat content, higher protein content with harder and higher consistency than cow milk yogurt. Appearance, color and flavor of corn milk yogurt and commercial yogurt were not significantly different. The main flavor compounds of corn milk yogurt were tridecane, tetradecane, ethyl oleate and ethyl linoleate, whereas those of the cow milk yogurt were tridecane, tetradecane, dodecane and heptyl methyl ketone. The corn milk yogurt had higher counts of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus.* The shelf-lives at 5°C of corn milk and cow milk yogurts were 14 days.

ACKNOWLEDGEMENTS

The authors gratefully acknowledged a financial support for the study from The Institute for Science and Technology Research and Development, Chiang Mai University. The authors also wish to thank Associate Professor Hilton Deeth from University of Queensland for his valuable suggestions on the manuscript.

REFERENCES

Afonso, I. M., and J. M. Maia. 1999. Rheological monitoring of structure evolution and development in stirred yoghurt. Journal of Food Engineering 42: 183-190.

Al-Kadamany, E., M. Khattar, T. Haddad, and I. Toufeili. 2003. Estimation of shelf-life of concentrated yogurt by monitoring selected microbiological and physicochemical changes during storage. Lebensmittel-Wissenschaft und-Technologie 36:407-414.

AOAC. 2000. Official Methods of Analysis of AOAC International. 17^{th} ed. AOAC International, Arling, VA.

Azanza, F., B. P. Klein, and J. A. Juvik. 1996. Sensory characterization of sweet corn lines differing in physical and chemical composition. Journal of Food Science 61: 253-257.

Birollo, G. A., J. A. Reinheimer, and C. G. Vinderola. 2000. Viability of lactic acid microflora in different types of yoghurt. Food Research International 33: 799-805.

Bonczar, G., M. Wszolek, and A. Siuta. 2002. The effects of certain factors on the properties of yoghurt made from ewe's milk. Food Chemistry 79: 85-91.

Dave, R. I., and N. P. Shah. 1997. Viability of yoghurt and probiotic bacteria in yoghurts made from commercial starter cultures. International Dairy Journal 7: 31-41.

Drake, M. L. A., X. Q. Chen, S. Tamarapu, and B. Leenanon. 2000. Soy protein fortification affects sensory, chemical, and microbiological properties of dairy yogurts. Journal of Food Science 65: 1244-1247.

Fiszman, S. M., M. A. Lluch, and A. Salvador. 1999. Effect of addition of gelation on microstructure of acidic milk gels and yoghurt and on their rheological properties. International Dairy Journal 9: 895-901.

Fox, P. F., and , P. L. H. McSweeney. 1998. Dairy Chemistry and Biochemistry. St. Edmundsbury Press Ltd., Great Britain.

González-Martínez, C., M. Becerra, M. Cháfer, A. Albors, J. M. Corot, and A. Chiralt. 2002. Influence of substituting milk powder for whey powder on yoghurt quality. Trends in Food Science and Technology 13: 334-340.

Granata, L. A., and C. V. Morr. 1996. Improved acid, flavor and volatile compound production in a high protein and fiber soymilk yogurt-like product. Journal of Food Science 61 (2): 331-336.

Keogh, M. K., and B. T. O'Kennedy. 1998. Rheology of stirred yogurt as affected by added milk fat, protein and hydrocolloids. Journal of Food Science 63 (1): 108-112.

Ketnil, N. 2002. The exportable situation of sweet corn from Thailand (in Thai). Journal of Food Institute 4(24): 45-53.

Kosikowski, F. V. 1997. Cheese and Fermented Milk Foods, volume I, Origins and Principles (pp. 91-106) Edwards Brothers, Inc., Michigan.

Kumar, P., and H. N. Mishra. 2004. Mango soy fortified set yoghurt: effect of stabilizer addition on physicochemical, sensory and textural properties. Food Chemistry 87: 501-507.

Lal, S. N. D., C. J., O'Connor, and L. Eyres. 2006. Application of emulsifiers / stabilizers in dairy products of high rheology. Advances in Colloid and Interface Science 123: 433-437.

Laye, I., D. Karleskind, and C. V. Morr. 1993. Chemical, microbiological and sensory properties of plain nonfat yogurt. Journal of Food Science 58(5): 991-995, 1000.

Lucey, J. A. 2002. Foundation scholar award formation and physical properties of milk protein gels. Journal of Dairy Science 85: 281-294.

Omueti, O., and K. Ajomale. 2005. Chemical and sensory attributes of soy-corn milk types. African Journal of Biotechnology 4(6): 847-851.

Öztürk, B. A., and M. D. Öner. 1999. Production and evaluation of yogurt with concentrated grape juice. Journal of Food Science, 64(3): 530-532.

Park, D. J., S. Oh, K. H. Ku, C. Mok, S. H. Kim, and J. Y. Imm. 2005. Characteristics of yogurt-like products prepared from the combination of skim milk and soymilk containing saccharified-rice solution. International Journal of Food Sciences and Nutrition 56 (1): 23-34.

Parnell-Clunies, E. M., Y. Kakuda, K. Mullen, D. R. Arnott, and J. M. deMan. 1986. Physical properties of yogurt: a comparison of vat versus continuous heating systems of milk. Journal of Dairy Science 69: 2593-2603.

Raphaelides, S.N., and A. Gioldasi. 2005. Elongational flow studies of set yogurt. Journal of Food Engineering 70: 538-545.

Sodini, I., F. Remeuf, S. Haddad, and G. Corrieu. 2004. The relative effect of milk base, starter, and process on yogurt texture: a review. Critical Reviews in Food Science and Nutrition 44: 113-137.

Tamime, A. Y., and R. K. Robinson. 1999. Yoghurt Science and Technology. 2nd ed. TJ. International, Cornwall.

The Ministry of Public Health. 2005. Notification of the Ministry of Public Health (No. 289) B.E. 2548 Re: Fermented milk (in Thai). [Online] Available. http://www.qmaker.com/fda/new/images/cms/top_upload/1141801039_ntf 289-2548.pdf [28 December, 2006].

Tracy, W.F. 2001. Sweet corn. In A.R. Hallauer (ed.), Specialty Corns. 2nd ed. CRC Press LLC., Washington, D.C.:

USDA. 2004. Search the USDA national nutrient database for standard reference: corn beverage. [Online] Available. http://www.nal.usda.gov/fnicfoodcomp/ cgi-bin/list_nut_edit.pl [31 March, 2004].

Vasiljevic, T., and P. Jelen. 2002. Lactose hydrolysis in milk as affected by neutralizers used for the preparation of crude β-galactosidase extracts from *Lactobacillus bulgaricus* 11842. Innovative Food Science and Emerging Technologies. 3: 175-184.

Walstra, P., T. J. Geurts, A. Noomen, A. Jellema, and M. A. J. S. van Boekel. 1999. Dairy Technology. Marcel Dekker, Inc., New York.

Wang, Y. C., R. C. Yu, and C. C. Chou. 2002. Growth and survival of bifidobacteria and lactic acid bacteria during the fermentation and storage of cultured soymilk drinks. Food Microbiology 19: 501-508.

Wu, H., G.J. Hulbert, and J.R. Mount. 2001. Effects of ultrasound on milk homogenization and fermentation with yogurt starter. Innovative Food Science and Emerging Technologies 1: 211-218.

none