CHAPTER 9
CHARACTERISTICS AND SHELF LIFE OF CORN MILK YOGURT

9.1 INTRODUCTION

Since the 1960s, the industrial production of yogurt has increasingly developed worldwide (Birollo *et al.*, 2000; Park *et al.*, 2005). The increase in yogurt consumption is probably due to its high organoleptic quality and potential health-enhancing effects. The nutritional benefit of yogurt is due to milk constituents and living LAB (Afonso and Maia, 1999; Birollo *et al.*, 2000; Park *et al.*, 2005). However, consumption of the cow's milk is avoided by vegetarian people and people who allergic to cow's milk. Thus, there have been many attempts to make yogurt from a variety of food resource (Granata and Morr, 1996; Kumar and Mishra, 2004; Lal *et al.*, 2006; Öztürk and Öner, 1999). Production of yogurt from corn milk is of interest of its aroma and sweet taste (Pangsanit, 2002; Prasertcheeva, 2003).

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

This research objective was to compare the characteristics and shelf lives of the corn milk yogurt and commercial yogurt during 35 days storage at 5°C.

9.2 MATERIALS AND METHODS

9.2.1 Preparation of sweet corn milk

The sweet corn used in this study was an ATS-5 that harvested on the 23rd day after silking of the corn plant. The sweet corn was purchased from the same place as section 3.2.1 in March-May 2005. The preparation of corn milk solution and storage condition were followed the method as described in section 2.2.1.

9.2.2 Starter cultures preparation

S. thermophilus and *L. delbrueckii* subsp. *bulgaricus* were prepared by following the previous method as described in section 3.2.2 and 3.2.3.

9.2.3 Corn milk yogurt preparation

Distilled water was added into the corn milk in a ratio of 1:2, corn milk to distilled water, and then preheated at 90°C prior to mixing with 2% (w/v) lactose, 4% (w/v) sodium caseinate, and 0.4% (w/v) gelatin. The mixture was stirred for 5 min, following by heating at 95°C for 5 min (Raphaelides and Gioldasi, 2005), and then cooled to 40°C. Consequently, 2% (v/v) of yogurt starter cultures which composed of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* at a ratio of 1:1 was inoculated. 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 triplicates for each treatment.

9.2.4 Commercial yogurt

The commercial yogurt used in this study was a plain yogurt of Dutch Mill Ltd., Thailand. The Dutch Mill yogurt contained 2% of yogurt starter culture.

9.2.5 Storage condition

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

9.2.6 Chemical analysis

9.2.6.1 Chemical compositions of corn milk yogurt and commercial yogurt at the first day of storage

At the first day of storage, corn milk yogurt and commercial yogurt were analyzed for moisture, protein, fat and ash following the method of AOAC no. 990.20, 991.20, 905.02 and 945.46, respectively (AOAC, 2000). Carbohydrate was calculated by this formula: 100 - % moisture - % fat - % protein - % ash.

9.2.6.2 Chemical changes of corn milk yogurt and commercial yogurt during storage

During 35 days of storage at 5°C, the corn milk yogurts and commercial yogurt were analyzed on 1, 7, 14, 21, 28 and 35 days for total solid and total acidity using the method of AOAC no. 990.20 and 947.05, respectively (AOAC, 2000). Total soluble solid measured by hand-refractometer (ATAGO, Japan) and pH values measured by a pH-meter Consort C830 (CE, Belgium).

9.2.7 Color measurement

The corn milk yogurts and commercial yogurts stored for 1, 7, 14, 21, 28 and 35 days were measured for color by a colorimeter (Minolta Data Processor DP-301, Chroma Meter CR-300 Series, Japan).

9.2.8 TPA

The corn milk yogurts and commercial yogurts were taken on 1, 7, 14, 21, 28 and 35 days for investigation of TPA. The TPA method was described in section 4.2.8.

9.2.9 Physical properties

Physical properties of corn milk yogurts and commercial yogurts were evaluated for whey drainage, water holding capacity, syneresis and consistency on 1, 7, 14, 21, 28 and 35 days of storage using the methods described in section 4.2.7.

9.2.10 Sensory evaluation

Sensory analysis for the corn milk yogurts and the commercial yogurts were carried out on 1 and 14 days of storage following Hedonic Scale methods published by Peryam and Pilgrim (1957). The preparation of samples and the condition of sensory testing were modified from the method of Drake *et al.* (2000).

The tested yogurts contained in 50 ml plastic cups were evaluated for sensory attributes by 15 trained panelists. Appearance and color were evaluated under white light. Other attributes including texture, flavor, mouth feel, sweetness, and after taste were evaluated under red light to mask the color differences among the yogurts. Yogurts were tempered to 10°C and presented in 3-digit coded plastic sample cups sealed with lids. The evaluation method applied hedonic scale 7 point (7 = like very much, 4 = neither like nor dislike, 1 = dislike very much) and the testing scores of above 4.0 were considered to be preference. Panelists were presented with unsalted crackers, water, and expectoration cups to clean the palate between samples.

9.2.11 Flavor composition

The fresh corn milk, corn milk mixture which was fresh corn milk added with distilled water, lactose, sodium caseinate and gelatin that was pasteurized at 95°C for 5 min, corn milk yogurt, and commercial yogurt were determined for flavor composition. The fresh corn milk was freezed at -18°C for about 7 days prior to conducting the flavor analysis. The corn milk mixture was analyzed within 1 day

after pasteurization. The corn milk yogurt, and commercial yogurt were kept for 1 and 14 days at 5°C before the analysis. The flavor compositions were determined by Solid Phase Microextraction-Gas Chromatograp-Mass Spectrometry (SPME-GC-MS) using a modified method form Pripdeevech (2003).

The sampling vial was held 40 min for equilibrium at room temperature. A manual SPME holder was used to perform the experiments. A fused silica fiber of 10 mm in length, 100 µm in diameter, and 100 µm thickness of polydimethylsiloxan (PDMS) was chosen to extract the volatile components in the samples. A new PDMS microextraction fiber must be thermally conditioned prior to adsorption at 240°C in a injection port of a 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.

9.2.12 Microbial analysis

The corn milk yogurts and commercial yogurts were checked on 1, 7, 14, 21, 28 and 35 days of storage for the number of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, psychrotrophs as well as yeast and mould.

The methods for enumeration the amount of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* were described in the section 3.2.7. Psychrotrophs were enumerated using plate count agar (Merck, Germany) and were incubated at 5°C for 10 days (Al-Kadamany *et al.*, 2003). Yeast and mould counts were enumerated using potato dextrose agar (Merck, Germany) following the AOAC method no. 997.02. After autoclaving at 121°C for 15 min, potato dextrose agar was acidified to pH 3.5 by 10% of tartaric acid, and then incubated at 25°C for 5 days (AOAC, 2000).

9.2.13 Statistical analysis

Statistical analysis was performed using a SPSS version 10.0.1.

The collected data from the section 9.2.6.1 was analyzed by an analysis of variance using a T-test.

The data from the section 9.2.6.2, 9.2.7, 9.2.8., 9.2.9 and 9.2.12, except the number of yeast and mould, were analyzed by an analysis of variance using a Factorial Experiment in CRD with 2 factors. The first factor was type of yogurts, which were corn milk yogurt and commercial yogurt. The second factor was the day of storage, which were 1, 7, 14, 21, 28 and 35 days of storage. If the F value was significant, the Duncan's New Multiple Range Test was used to determine differences between the treatment means.

The results from the section 9.2.10 were analyzed by an analysis of variance using a Factorial Experiment in Randomized Complete Block Design (RCBD) with 2 factors. The first factor was type of yogurts, which were corn milk yogurt and commercial yogurt. The second factor was the day of storage, which were 1 and 14 days of storage. As far as the F value is significant, the LSD was used to determine differences between the treatment means.

The number of yeast and mould from section 9.2.12 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.

9.3 RESULTS AND DISCUSSION

9.3.1 Chemical composition

Tables 9.1, 9.2 and Figure 9.1 illustrated that the chemical compositions of corn milk yogurt and commercial yogurt were within the specification of fermented milk product of Ministry of Public Health of Thailand (No. 289).

Corn milk yogurt contained higher protein and moisture content, but lower fat, ash, total solid, total soluble solid and carbohydrate than commercial yogurt. Especially, fat content of corn milk yogurt was less than that of commercial yogurt about 10 times. It was because the fat content in corn milk was only 1.05%. The corn milk was also diluted with distilled water. The corn milk yogurt could be classified as nonfat yogurt which contained less than 0.5% fat (Kosikowski, 1997).

Carbohydrate content of corn milk yogurt was less than that of commercial yogurt about 2 times. It might be related to the use of sugar in production of commercial yogurt.

Table 9.1 Chemical compositions of corn milk yogurt and commercial yogurt at the first day of storage

Chemical compositions (%)	Corn milk yogurt	Commercial yogurt	Specification[1]
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
Ash	0.26±0.02[b]	0.74±0.04[a]	No specification
Carbohydrate	7.66±0.12[b]	13.61±0.17[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)

The changes of total solid and total soluble solid of corn milk and commercial yogurts during storage were shown in Table 9.2. The total solid of corn milk yogurt was less than that of the commercial yogurt, but was still within the range, 12-20%, of cow's milk yogurt (Tamime and Robinson, 1999). The changes of total solid content of both yogurts were not significant ($P<0.05$) during storage. Whereas, the total soluble solid contents of both yogurts reduced with the extended storage. It could be due to the utilization of sugar by the starter cultures as reported by Vasiljevic and Jelen (2002); Wang, *et al.* (2003).

Table 9.2 Total solid and total soluble solid of corn milk yogurt and commercial yogurt during 35 days of storage at 5°C

Yogurt		Total solid (%)	Total soluble solid (°Brix)
Corn milk		12.30±0.15^{B}	7.11±0.21^{B}
Commercial		21.57±0.15^{A}	15.17±0.16^{A}
Storage time (day)		Total solid (%)	Total soluble solid (%)
1		17.07±5.07^{ns}	11.33±4.38^{a}
7		17.02±5.10^{ns}	11.27±4.38^{a}
14		16.96±5.10^{ns}	11.22±4.36^{ab}
21		16.92±5.12^{ns}	11.13±4.46^{b}
28		16.83±5.06^{ns}	10.98±4.47^{c}
35		16.81±5.06^{ns}	10.88±4.44^{c}
Yogurt	Storage time (day)	Total solid (%)	Total soluble solid (%)
Corn milk	1	12.45±0.10^{b}	7.33±0.12^{d}
	7	12.37±0.10^{b}	7.27±0.12^{d}
	14	12.30±0.03^{b}	7.23±0.06^{d}
	21	12.25±0.20^{b}	7.07±0.12^{e}
	28	12.21±0.16^{b}	6.90±0.10^{f}
	35	12.19±0.22^{b}	6.83±0.06^{f}
Commercial	1	21.69±0.21^{a}	15.33±0.12^{a}
	7	21.67±0.10^{a}	15.27±0.12^{ab}
	14	21.61±0.13^{a}	15.20±0.00^{ab}
	21	21.59±0.14^{a}	15.20±0.00^{ab}
	28	21.45±0.14^{a}	15.07±0.12^{bc}
	35	21.43±0.03^{a}	14.93±0.12^{c}

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

Figure 9.1 appeared that the reduction of pH of corn milk yogurt during storage were greater than that of the commercial yogurt. During 35 days of storage, the corn milk yogurt had lower total acidity than the commercial yogurt, but their acidities were higher than the minimum requirement of 0.6% (The Ministry of Public

Health, 2005). It was observed that at the end of storage time the total acidity of commercial yogurt were higher than that of corn milk yogurt, but the pH value of commercial yogurt was higher. It might be because the cow's milk has higher buffering capacity than corn milk.

Changes of pH and acidity of corn milk yogurt were in agreement with reports of Kosikowski (1997) who revealed that initially, cow's milk yogurt should not have more than 1.2% acid, but acidity could rise to 1.5% during distribution. The drop of pH of cow's milk yogurt during refrigerated storage, from about 4.4 to below 4.0, resulted from lactic acid production by *L. delbrueckii* subsp. *bulgaricus* (Dave and Shah, 1997).

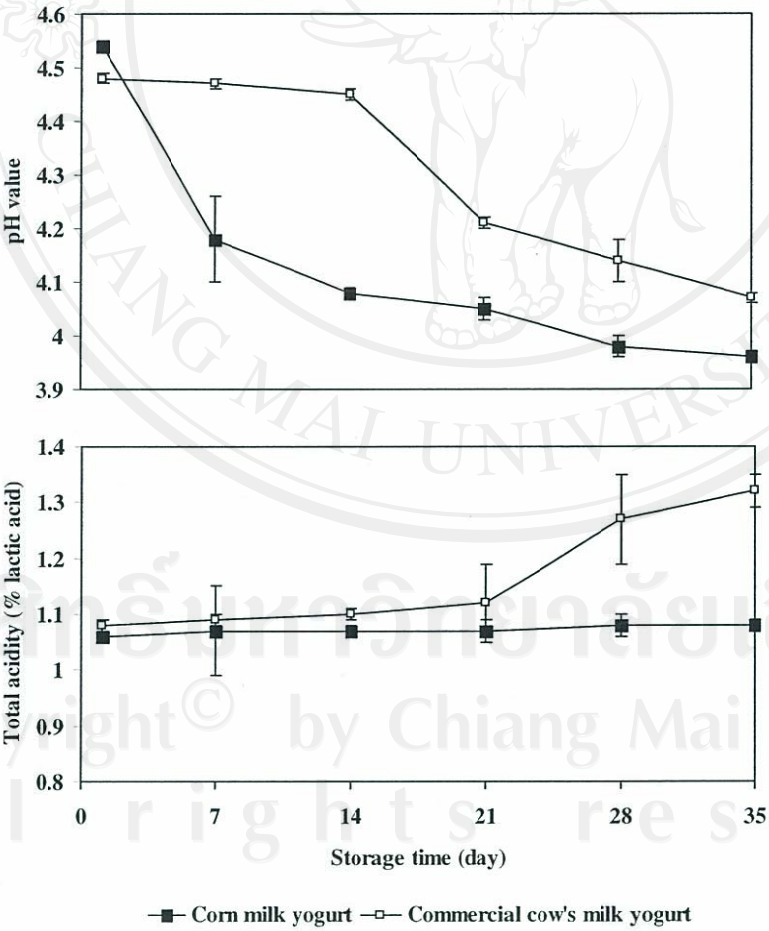

Figure 9.1 pH value and total acidity of corn milk yogurt and commercial yogurt during 35 days of storage at 5°C.

9.3.2 Color of yogurt

Table 9.3 and Figure 9.2 showed clearly that commercial yogurt was noticeably whiter than the corn milk yogurt. The corn milk yogurt was more yellow and the purity of color was greater. Although, carotene is primarily responsible for the yellow color of both corn and cow's milk (Fox and McSweeney, 1998; Omueti and Ajomale, 2005). Carotene content in corn milk yogurt should be considerably higher than that in commercial yogurt.

The storage time was not significantly ($P \geq 0.05$) influenced on purity and color shade of both yogurts while the lightness would be reduced with longer storage time.

Corn milk yogurt Commercial yogurt

Figure 9.2 Visual characteristic of corn milk yogurt and commercial yogurt.

Table 9.3 Color parameters of corn milk yogurt and commercial yogurt 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}
Commercial	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}
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 followed by different letters were significantly different treatments (P<0.05).

9.3.3 Textural characteristics

Textural characteristics of corn milk yogurt and commercial yogurt were shown in Figure 9.3. Gel structure of corn milk yogurt was harder than that of commercial yogurt. This could be due to the reason that the corn milk yogurt was prepared as a set type yogurt, while the commercial yogurt, available in the Thailand market was a stirred type yogurt. In the preparation of stirred yogurt, milk was inoculated and gelled in a fermentation tank. Before filling in the cup, yogurt was stirred to break up the gel (Afonso and Maia, 1999). As a result, the hardness of yogurt was reduced.

The hardness and springiness of corn milk yogurt and commercial yogurt were reduced with increasing of storage time. In contrast, the adhesiveness was increased when the storage time was prolonged (Figure 9.3). The textural changes would mainly caused by the degradation of gel structure of yogurts. Afonso and Maia (1999) reported the occurrence of some enzymatic phenomena such as after-acidification and proteolysis during the storage of yogurt. The after-acidification was occurred because the enzymatic activity of LAB, though reduced, was not completely stopped. Further decrease in pH during storage induced ionic changes in the protein network. The effect of proteolytic enzymes generated from the contaminated yeast would break down the polypeptide chains and make them shorter (Cheng *et al.*, 1990). These disruptions of protein would negatively alter the hardness and springiness of corn milk yogurt.

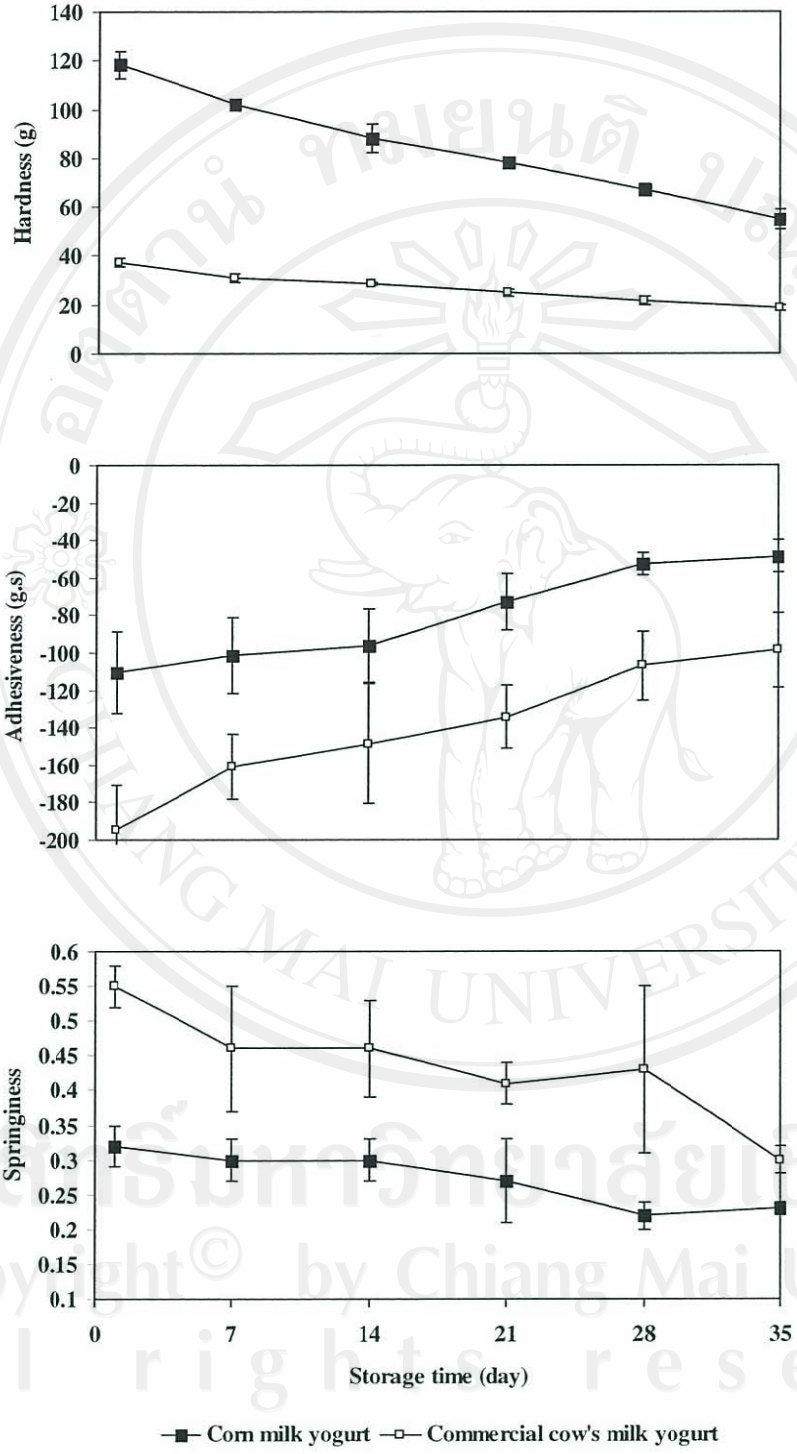

Figure 9.3 Changes of textural characteristics of corn milk yogurt and commercial yogurt during storage for 35 days at 5°C.

9.3.4 Physical properties

Whey drainage is the appearance of whey on the gel structure (Lucey, 2002) which is one of the most important factors for keeping quality of both set and stirred yogurt (Nergiz and Seckin, 1998; Sodini *et al.*, 2004). As can be seen from Table 9.4, the whey drainage of corn milk yogurt and commercial milk yogurt were not occurred at the first day of storage. But the corn milk yogurt appeared to have whey drainage after storage for 14 days. During storage, whey drainage of corn milk yogurt increased with time. The whey drainage indicated the weakness of gel network. Thus, reduction of the water holding capacity and increasing of syneresis was observed. These observations were also noted by Lucey (2002). However, for the commercial yogurt, whey drainage had not occurred throughout 35 days of storage. The correlated result of syneresis was found, although reduction of the holding capacity was shown.

Water holding capacity, the method for indirect evaluation of network homogeneity (Sodini *et al.*, 2004), of commercial yogurt was higher than that of corn milk yogurt (Table 9.4). It was probably because the commercial yogurt was homogenized before fermentation, while homogenization was not included in preparation of corn milk yogurt. Keogh and O'Kennedy (1998) explained that homogenization produced the small size of fat globule. Then, greater proteins could be absorbed on the surface of the fat globules, leading to increasing the ability of protein to immobilized water. The water holding capacity was then increased.

The syneresis of the commercial yogurt was higher than of corn milk yogurt, which was not expected because of the high water holding capacity of the commercial yogurt. The high syneresis of the commercial yogurt possibly resulted from the stirring of yogurt that reduced the strength of gel.

The Bostwick distance was the indicator of fluid consistency that implied the gel rupture. The longer Bostwick distance demonstrated lower consistency of the gel. According to Table 9.4, consistency of both sample reduced with the extension of storage time, but gel of the commercial yogurt had lower consistency than corn milk yogurt. A similar trend was observed to the hardness (Figure 9.3). The consistency of the yogurt then might be related to the protein-protein interaction of the gel structure.

Table 9.4 Physical properties of corn milk yogurt and commercial yogurt during 35 days of storage at 5°C

Yogurt	Whey drainage (%)	Syneresis (%)	Water holding capacity (%)	Bostwick distance (cm)
Corn milk	0.08 ± 0.07^{A}	30.52 ± 2.02^{B}	50.57 ± 2.38^{B}	9.39 ± 1.14^{B}
Commercial	0.00 ± 0.00^{B}	76.67 ± 0.20^{A}	66.13 ± 2.30^{A}	12.47 ± 0.93^{A}
Storage time (day)	Whey drainage (%)	Syneresis (%)	Water holding capacity (%)	Bostwick distance (cm)
1	0.00 ± 0.00^{b}	52.26 ± 26.53^{e}	61.91 ± 9.13^{a}	9.50 ± 1.80^{f}
7	0.00 ± 0.00^{b}	52.84 ± 26.02^{de}	59.88 ± 7.91^{b}	10.05 ± 1.74^{e}
14	0.02 ± 0.01^{b}	53.24 ± 25.65^{cd}	59.09 ± 8.05^{c}	10.67 ± 1.88^{d}
21	0.07 ± 0.06^{ab}	53.61 ± 25.30^{c}	57.61 ± 8.60^{d}	11.19 ± 1.70^{c}
28	0.08 ± 0.07^{a}	54.37 ± 24.49^{b}	56.17 ± 8.93^{e}	11.71 ± 1.63^{b}
35	0.08 ± 0.07^{a}	55.26 ± 23.67^{a}	55.46 ± 8.58^{f}	12.45 ± 1.45^{a}

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

Table 9.4 (Continue)

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}
Commercial	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±0.23^{a}	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).

9.3.5 Sensory evaluation

Sensory scores of corn milk yogurt and commercial yogurt evaluated by Hedonic Scale methods in preference test were presented in Table 9.5. The panelist preferred commercial yogurt over the corn milk yogurt in texture and mouth feel attributes. On the production date, the appearance, color and flavor of both yogurts were not significant differences ($P \geq 0.05$) whereas the texture, mouth feel, sweetness, sourness, after taste and total preference of corn milk yogurt were less than those of commercial yogurt. Adding of sugar that reduced the sour taste might improve the taste of the commercial yogurt. Ott *et al.* (1997) found that cow's milk yogurt had acetic acid, which gave vinegar-like flavor that might cause the lower score of sensory evaluation in sourness attribute. In addition, homogenization in the production of yogurt would also improve the texture of commercial yogurt.

The storage time was not significantly influenced ($P \geq 0.05$) on the scores of all attributes of commercial yogurt. However, in case of corn milk yogurt, reduction in scores of appearance, texture and mouth feel were exhibited when the storage time was extended. That might be related to the increase of whey drainage, syneresis and water holding capacity as well as dropping of gel consistency (Table 9.4). Nevertheless, the panelists still liked the flavor of corn milk yogurt and commercial yogurt during 14 days of storage. The growth of psychrotrophs, yeast and mould should not responsible for the dropping of the scores because the amounts found in samples (Figure 9.4) were less than the amounts that could cause the detrimental effect to flavor quality of yogurt (Al-Kadamany *et al.*, 2003; Walstra *et al.*, 1999).

Table 9.5 Sensory characteristics of corn milk yogurt and commercial yogurt during 35 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}
Commercial		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		$6.03\pm0.55^{\underline{a}}$	$6.10\pm0.89^{\underline{ns}}$	$5.82\pm0.58^{\underline{a}}$	$6.23\pm0.52^{\underline{ns}}$	$5.70\pm0.78^{\underline{a}}$
14		$5.72\pm0.57^{\underline{b}}$	$5.88\pm0.98^{\underline{ns}}$	$5.42\pm0.80^{\underline{b}}$	$6.15\pm0.53^{\underline{ns}}$	$5.10\pm1.27^{\underline{b}}$
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 ± 0.36^{b}
	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}
Commercial	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 ± 0.4^{a}

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

Table 9.5 (Continue)

Yogurt	Sweetness	Sourness	After taste	Total preference
Corn milk	3.50 ± 0.63^{B}	3.68 ± 0.82^{B}	4.03 ± 0.79^{B}	4.77 ± 0.69^{B}
Commercial	5.77 ± 0.81^{A}	5.98 ± 0.62^{A}	6.12 ± 0.61^{A}	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}
Corn milk 14	3.37 ± 0.61^{b}	3.63 ± 0.72^{b}	4.00 ± 0.76^{b}	4.57 ± 0.68^{b}
Commercial 1	5.87 ± 0.72^{a}	6.13 ± 0.58^{a}	6.17 ± 0.52^{a}	6.27 ± 0.46^{a}
Commercial 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 followed by different letters were significantly different treatments ($P<0.05$).

9.3.6 Flavor composition

Table 9.6 showed the flavor compositions of fresh corn milk, corn milk mixture, as well as corn milk yogurt and commercial yogurt during storage. The chromatograms were also presented in Appendix D. Trans-2-nonenal, tridecane, ethyl acetate, ethyl palmitate, ethyl linoleate and ethyl oleate were the most important flavor compounds of fresh corn milk. For the corn milk mixture that contained sodium caseinate, lactose and gelatin; tridecane, n-heptanal, ethyl linoleate, dodecane, furan and ethyl oleate were the major flavor compounds. The differences in flavor compounds of both samples could be due to heat treatment as well as added ingredients. These observations were differed from the previous reports (Azanza *et al.*, 1996; Tracy, 2001). The authors reported that ethanol, acetaldehyde, methanethiol and hydrogen sulfide were the main aroma compounds of heated sweet corn. The difference could be due to the different cultivars.

Compounds that found most in corn milk yogurt and commercial yogurt in this study were the derivatives of alkane including tridecane, tetradecane, benzothiazole, dodecane. However, aldehyde and diacetyl were reported to be essential aroma compounds for the characteristic yogurt (Tamime and Robinson, 1999; Walstra *et al.*, 1999).

Sorbic acid was found in commercial yogurt. Sorbic acid has been used widely in the dairy industry as preservative agent. This acid is a mycostatic agent that although can not reduce the actual number of yeasts and moulds in the product, but strongly inhibits their activity, perhaps by interfering with their dehydrogenase systems. Therefore, the growth rate of yeast and moulds in commercial yogurt during 35 days of storage were less than that in corn milk yogurt (Figure 9.4). Some previous research reported that sorbic acid reduced acetaldehyde production of yogurt starter cultures (Tamime and Robinson, 1999). This might be the reason for not finding of acetaldehyde in commercial yogurt.

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

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

9.2.7 Microbial analysis

Figure 9.4 showed amounts of *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, total starter culture, psychrotrophs, yeast and mould in corn milk yogurt and commercial yogurt during 35 days of storage. The numbers of *S. thermophilus* of both yogurts were higher than that of *L. delbrueckii* subsp. *bulgaricus* throughout the storage time. The corn milk yogurt found higher amounts of starter cultures, but reduction of starter cultures in corn milk yogurt was faster. However, the numbers of starter culture in both yogurt samples at the end of storage time were higher than the minimum requirement of 10^7 CFU/g (The Ministry of Public Health, 2005).

Psychrotrophs counts of corn milk yogurt and commercial yogurt increased with increasing of storage time, but the increasing rate exhibited in the commercial yogurt was lower than that found in corn milk yogurt. The changes of yeast and mould in tested yogurts were similar to that of Psychrotrophs. The slow increase of yeast and mould as well as psychrotrophs of commercial yogurt could be partly because of sorbic acid (Table 9.6).

According to the requirement established by the Ministry of Public Health (2005), a maximum viable yeast or mould in yogurt was 100 CFU/g. Therefore, shelf lives at 5°C of corn milk yogurt and commercial yogurts would be 21 and 28 days, respectively.

Table 9.6 Flavor compounds of fresh corn milk, corn milk mixture, corn milk yogurt and commercial yogurt stored for 1 and 14 days at 5°C

Retention Time (min)	Compounds	% of total / % corrected with standard							
		Corn milk	Corn milk mixture	Corn milk yogurt			Commercial 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	Chlorofom	-	-	-	-	1.62/91	-	-	9.66/87
2.13	Ethyl acetate	8.50/78	-	-	-	-	-	-	-
2.15	2-Methylfuran	-	3.72/72	-	-	-	-	-	-
2.60	Unknown	-	-	-	-	-	-	1.51/-	-
2.65	Unknown	-	-	-	7.24/-	-	-	-	-
2.66	Unknown	1.47/-	3.20/-	1.04/-	-	-	-	-	-
2.69	Acetyl	-	-	-	-	-	-	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	-	-	-	-

Table 9.6 (Continue)

Retention Time (min)	Compounds	% of total / % corrected with standard							
		Corn milk	Corn milk mixture	Corn milk yogurt			Commercial yogurt		
				1 day	7 days	14 days	1 day	7 days	14 days
5.42	Hexylformate	-	2.36/72	-	-	-	-	-	-
5.68	Amyl methyl ketone	-	-	-	-	-	1.43/91	-	-
5.95	n-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
10.17	Ethal	0.98/64	-	-	-	-	-	-	-
10.69	Hendecane	1.15/90	1.25/94	-	-	-	-	1.05/91	-
11.31	Trans-2-nonenal	19.21/93	-	-	-	-	-	-	-
11.81	6-Methyltridecane	0.88/64	-	-	-	-	-	-	-

Table 9.6 (Continue)

Retention Time (min)	Compounds	% of total / % corrected with standard							
		Corn milk	Corn milk mixture	Corn milk yogurt			Commercial yogurt		
				1 day	7 days	14 days	1 day	7 days	14 days
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	-
13.17	Unknown	-	-	-	-	-	1.07/-	0.98/-	-
13.26	Unknown	-	-	-	-	-	1.51/-	-	-
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	-

Table 9.6 (Continue)

Retention Time (min)	Compounds	% of total / % corrected with standard							
		Corn milk	Corn milk mixture	Corn milk yogurt			Commercial yogurt		
				1 day	7 days	14 days	1 day	7 days	14 days
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	-
14.46	Unknown	-	-	-	-	-	-	1.43/-	-
14.58	Unknown	-	-	-	-	-	1.12/-	1.36/-	-
14.62	Unknown	-	-	1.35/-	-	-	1.62/-	-	-
14.66	Benzothiazole	-	-	-	14.66/94	9.95/94	-	16.01/94	5.58/93
14.68	Unknown	-	-	-	-	-	1.21/-	1.01/-	-
14.75	Heptadecane	-	-	-	1.48/72	-	1.33/72	-	-
14.76	2-Methyltridecane	-	-	1.80/78	-	-	-	-	-
14.80	6,9-Dimethyltetradecane	-	1.07/83	-	-	-	-	-	-
14.84	Unknown	-	-	-	-	-	-	1.06/-	-
14.85	Unknown	-	-	1.80/-	1.23/-	-	-	-	-
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
15.00	2,6,10,14-Tretramethyhexadecane	1.36/58	-	-	-	-	-	-	-

Table 9.6 (Continue)

Retention Time (min)	Compounds	% of total / % corrected with standard							
		Corn milk	Corn milk mixture	Corn milk yogurt			Commercial yogurt		
				1 day	7 days	14 days	1 day	7 days	14 days
15.28	Tetradecane	3.78/97	6.48/97	11.31/97	8.94/97	8.89/97	10.26/97	10.63/97	7.21/97
15.55	Trans-Caryophyllene	1.27/89	-	2.89/99	-	-	1.74/97	-	-
15.56	Unknown	-	1.40/-	-	-	-	-	-	-
15.93	2H-Pyran-2-one,tetrahydro-6-pentyl	-	-	-	-	-	2.14/78	-	-
16.06	Unknown	-	-	-	-	-	-	1.52/-	-
16.08	Unknown	-	-	2.00/-	-	-	-	-	-
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
17.51	Unknown	-	-	2.09/-	-	-	-	-	-

Table 9.6 (Continue)

Retention Time (min)	Compounds	% of total / % corrected with standard							
		Corn milk	Corn milk mixture	Corn milk yogurt			Commercial yogurt		
				1 day	7 days	14 days	1 day	7 days	14 days
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	-	-	-
23.43	Ethyl linoleate	8.10/98	10.23/96	8.78/99	8.63/99	11.43/98	-	-	-
23.53	Ethyl oleate	7.67/95	6.86/94	9.16/99	6.05/99	6.19/99	-	-	-

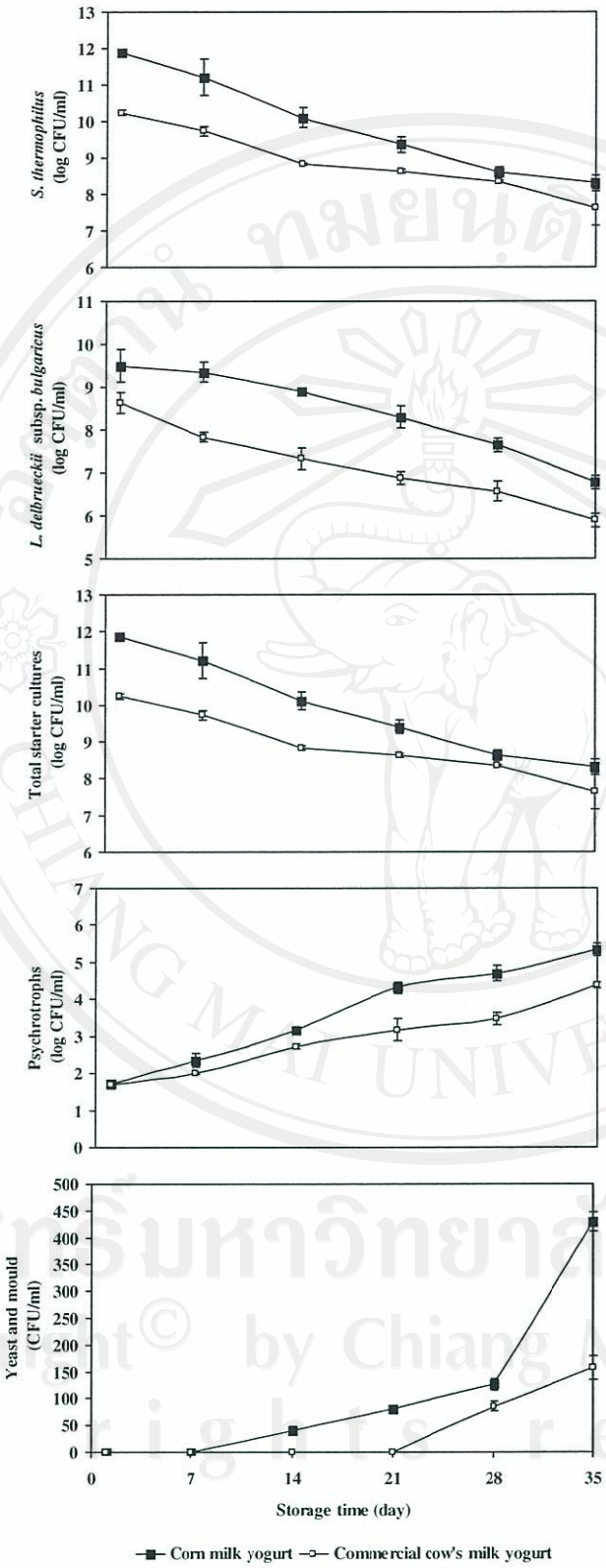

Figure 9.4 Microbial counts of corn milk yogurt and commercial yogurt during 35 days of storage at 5°C.

9.4 CONCLUSIONS

The corn milk yogurt was found to have lower fat content, higher protein content with harder and higher consistency than commercial yogurt. Appearance, color and flavor of corn milk yogurt and commercial yogurt were not significant differences. The main flavor compounds of corn milk yogurt were tridecane, tetradecane, ethyl oleate and ethyl linoleate, whereas that of the commercial yogurt were tridecane, tetradecane, dodecane and heptyl methyl ketone. The corn milk yogurt had *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* higher than those of commercial yogurt. Shelf lives at 5°C of corn milk yogurt and commercial yogurt were 21 and 28 days, respectively.