CHAPTER 2

THE EFFECTS OF DIFFERENT CULTIVARS AND HARVEST STAGES OF SWEET CORNS ON THE CORN MILK COMPOSITION

2.1 INTRODUCTION

Sweet corn (*Zea mays Saccharata*) is classified in a Gramineae family (Puhlam, 1997). Sweet corn is one of the most popular vegetables in Thailand. The sweet corn plant can grow well all year around in Thailand with its highest yield on January to May (Sweetcorn Products Co., Ltd., 2006). The sweet corn plant is widely cultivated in Chiang Mai, Ratchaburi, Suphan Buri and Buri Rum (Ketnil, 2002).

The varieties of sweet corn in Thailand are comprised of ATS-1, ATS-2, ATS-5, Bicolor, Suwan-1, Suwan-3, Hybrid, Sweet-50 and Sweet-45 (Puhlam, 1997; The National Research Council of Thailand, 2000). The two most varieties cultivated in Chiang Mai are ATS-2 and ATS-5 because of their high yield and high quality sweet corns product. The ATS-2 and ATS-5 were the popular varieties in Thailand. The ATS-5 gives a higher yield production, bigger size of ear and sweeter than the ATS-2, while the ATS-2 has a better aroma. The total soluble solid of the ATS-5 and ATS-2 are 14-16°Brix and 15°Brix, respectively (Thanwiset, 2003).

After the sweet corn pollinated, the sweet corn seeds will be developed on the cobs. In general, the ATS-2 and ATS-5 will produce silk for pollination after seeding for 48-52 days and will be harvested on the 19-23 days after 50% of sweet corn has exerted silks which this stage is also called as a milky stage (Chamornman, 2000; Department of Agriculture, 2002; Puhlam, 1997).

Sweet corn is a healthy food. Sweet corn has only 1.18-1.26% fat, which within this amount contains 83.0% of unsaturated fatty acids. The unsaturated fatty acid of sweet corn has 57.8% linoleic acid (Pomeranz, 1987). The sweet corn also contains carotenes, which is precursor of vitamin A (Omueti and Ajomale, 2005).

Sweet corn has high sugar content from its sucrose and fructose (Hall, 2003; Permoranz, 1987). The high correlation between sensory data and sugar concentration

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reveals a preference for high-sugar sweet corn. The greater quantity of sucrose over fructose or glucose emphasizes the importance of sucrose as a determinant of quality, which is a key sensory attribute that determines overall acceptability of fresh and processed sweet corn. Its aroma is also reported as an important component of the eating quality (Azanza *et al.*, 1996; Olsen *et al.*, 1990). However, the sugar content as well as other nutrients varies according to genetic differences and harvest period. Thus, both varieties and harvest time affect the eating quality of sweet corn (Makhlouf *et al.*, 1995; Olsen *et al.*, 1990; Tracy, 2001).

In this study, sweet corn milk was used as a yogurt material to increase the diversification of fermented products. The corn milk yogurt will combine the good sensory characteristics of the corn milk with the well-known yogurt flavor. Moreover, the corn milk yogurt would give an advantage of a low fat content and the absence of cholesterol in the final product. This would offer a benefit for people that are aware of health food products. The objective of this work was to assess the effects of different cultivars and harvest stages of sweet corns on the corn milk composition. The data obtained will be used to select the sweet corns cultivars and harvest stages that are suitable for use as the raw material for yogurt making in the followed experiments.

2.2 MATERIAL AND METHODS

2.2.1 Sweet corn milk preparation

Sweet corn milk was prepared from two sweet corn varieties of ATS-2 and ATS-5 that were harvested at 3 different harvest time after silking, which were at 19, 21 and 23 days. The sweet corn was purchased from Thaweesak Sweet Corn Group, Chiang Mai province, Thailand in September-November 2003. To prepare the corn milk, the sweet corns were firstly husked, taken off the silk and cleaned. Following the cleaning procedure, the corn seeds from the cleaned corns were separated using knives. After separation, these corn seeds were extracted using a fruit extractor (Moulinex, Spain) to produce a milk solution. This milk solution was then filtered through a cleaned cloth to ensure that the solution was free from any remaining hull particles. The liquid that passed the cloth was recognized as corn milk. The corn milk samples were stored at -18°C until use, within 6 months.

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2.2.2 Yield of corn milk

The percentage of yield was calculated as (weight of corn milk/weight of whole sweet corn) x 100.

2.2.3 Color

The color of corn milk was measure by a colorimeter Minolta Data Processor DP-301 (Chroma Meter CR-300 Series, Japan).

2.2.4 Chemical analysis

The chemical analysis for corn milk was performed according to the methods published by AOAC (2000). The AOAC methods that were used in the analysis include no. 991.20 for protein content, no. 905.02 for fat content, no. 945.46 for ash measurement, no. 990.20 for moisture content. The total soluble solid was determined by a hand-refractometer (ATAGO, Japan). Carbohydrate was calculated by this formula: 100 - % moisture - % fat - % protein - % ash. The Lane and Eynon method was used to measure the amount of reducing sugars, invert sugar and sucrose (James, 1995). Starch was determined using the following formula:

Starch = % carbohydrate - % invert sugar.

The total acidity was measured by a titration with 0.1 N NaOH solution and expressed as percentage of citric acid, which was recommended in the AOAC method no. 947.05. For the pH measurement, a pH meter (Consort C830, CE, Belgium) was employed.

2.2.5 Statistical analysis

The data were analyzed by an analysis of variance using a Factorial Experiment in Completely Randomized Design (CRD) with 2 factors. The first factor was cultivar of sweet corn, which were 2 cultivars, ATS-2 and ATS-5. The second factor was the harvest stages, which were 3 stages, at 19, 21 and 23 days after silking. If the F value from the analysis of variance was significant, then the Duncan's New Multiple Range Test was used to determine differences between treatment means (Montgomery, 2001). The statistical calculation was performed using SPSS 10.0.1 software (SPSS Inc., Chicago, USA).

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2.3 RESULTS AND DISCUSSION

2.3.1 Yield of corn milk

Yields of corn milk extracted from ATS-2 and ATS-5 varieties which were harvested at 19, 21 and 23 days after silking were shown in Table 2.1. At any harvest time, the ATS-5 sweet corn gave significantly ($P<0.05$) higher yield of corn milk than the ATS-2. This was due to the fact that the ATS-5 sweet corn had a bigger ear (Thanwiset, 2,000). Thus, the ATS-5 produced a higher yield production.

The harvest days significantly ($P<0.05$) affected the yield of the ATS-5, excepted at the 23 days. Yields of the ATS-2 were statistically retained with the extent of harvest period. It was agreed that the moisture content in sweet corn seed would have a considerable influence on the yield of corn milk. Since the moisture content in sweet corn seed reduced with longer harvest time (Tracy, 2001), then the yield of the corn milk would also reduce. However, these results revealed that the extent in moisture loss would vary with the varieties of sweet corn. Based on the yield of corn milk, ATS-5 was the better raw material for yogurt making.

2.3.2 Color

Table 2.2 showed the color coordinate values of corn milk samples, L* indicated lightness, C* was chroma that represented the purity of color, and h indicated the color of sample (Minolta, 1994). Cultivars and harvest period of sweet corn significantly ($P<0.05$) influenced on all color parameters of corn milk. ATS-5 corn milk had higher L* and C* value than ATS-2 corn milk. For both cultivars, lightness and purity appeared to be increased with an increase of harvest period. This could be because the increasing of solid content.

The h values of tested samples generally appeared to decrease with longer harvest time. At the h value of 90, the color of sample was yellow. Thus, the yellowness of both corn milk samples increased with the longer harvest time, while the ATS-5 corn milk had higher yellow component (lower h value) than the ATS-2 corn milk. Omueti and Ajomale (2005) reported that carotenoid was primarily responsible for the yellow color of corn. This result suggested that the ATS-5 corn milk contained higher carotenoid content than the ATS-2 corn milk, and the amount of carotenoid increased with the longer harvest time.

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Table 2.1 Yields of corn milk samples prepared from different varieties and harvest stages of sweet corn

Variety	Yield (% w/w)
ATS-2	14.45 ± 0.87^{B}
ATS-5	30.10 ± 4.37^{A}

Harvest time (days)	Yield (% w/w)
19	24.28 ± 10.99^{a}
21	21.29 ± 7.45^{b}
23	21.27 ± 7.60^{b}

Variety	Harvest time (days)	Yield (% w/w)
ATS-2	19	14.57 ± 0.71^{c}
	21	14.47 ± 0.75^{c}
	23	14.32 ± 1.28^{c}
ATS-5	19	34.00 ± 5.47^{a}
	21	28.10 ± 2.29^{b}
	23	28.21 ± 2.11^{b}

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

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Table 2.2 Color of corn milk samples prepared from different varieties and harvest stages of sweet corn

Variety	L*	C*	h
ATS-2	76.95 ± 2.22^{B}	28.23 ± 4.28^{B}	103.00 ± 2.34^{A}
ATS-5	78.96 ± 2.63^{A}	41.11 ± 5.08^{A}	99.72 ± 1.55^{B}

Harvest time (days)	L*	C*	h
19	76.99 ± 2.48^{b}	33.13 ± 9.22^{b}	101.76 ± 2.53^{a}
21	77.10 ± 2.15^{b}	32.57 ± 7.21^{b}	102.66 ± 2.65^{a}
23	79.78 ± 2.36^{a}	38.32 ± 7.18^{a}	99.65 ± 1.63^{b}

Variety	Harvest time (days)	L*	C*	h
ATS-2	19	76.84 ± 2.62^{b}	26.95 ± 6.13^{b}	103.10 ± 2.61^{ab}
	21	75.52 ± 1.38^{b}	25.92 ± 1.26^{b}	104.90 ± 1.69^{a}
	23	78.49 ± 1.83^{ab}	31.84 ± 1.10^{b}	100.98 ± 0.17^{bc}
ATS-5	19	77.15 ± 2.73^{b}	39.31 ± 7.66^{a}	100.41 ± 1.81^{cd}
	21	78.68 ± 1.49^{ab}	39.22 ± 1.30^{a}	100.43 ± 0.42^{cd}
	23	81.06 ± 2.30^{a}	44.79 ± 2.69^{a}	98.33 ± 1.22^{d}

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

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2.3.3 Chemical composition

Proximate analysis results were shown in Table 2.3. On the whole, cultivars of the studied sweet corn affected the composition of corn milk. The moisture content of the ATS-5 corn milk was significantly ($P<0.05$) lower than that of the ATS-2 corn milk. This related to protein and carbohydrate contents of the ATS-5 corn milk, which were higher than those of the ATS-2. There was not significantly different ($P \geq 0.05$) in fat and ash content between the ATS-2 and ATS-5 corn milks.

Harvest period of sweet corn also influenced on the chemical composition of corn milk (Table 2.3), except ash content. However, according to the statistical analysis, the interaction of variety and harvest time also affected on ash content of corn milk. The moisture content of corn milk reduced with the increasing harvest periods, which correlated with the higher of protein and carbohydrate content at longer harvest time. Nevertheless, the fat content reduced at longer harvest time. However, it was observed that the harvest days were not affected on the moisture and carbohydrate content of ATS-5 corn milk.

Table 2.4 showed acidity values of corn milk which extracted from ATS-2 and ATS-5 sweet corn that harvested on 19, 21 and 23 days after pollination. At any harvest period, the total acidity was lower for the ATS-5 corn milk, leading to higher pH value. For both studied cultivars, the total acidity reduced with longer harvest days. The mechanism of this change was still not clear (Tantapanichkul, 1990).

Total soluble solid and carbohydrate of corn milk prepared from different cultivars and harvest stage of sweet corn were shown in Table 2.5. Total soluble solid represented the dissolved compounds such as sugar, organic acid, amino acid and water soluble vitamin (Ruchanakraikan and Ratanapanon, 2001). The ATS-5 corn milk contained significantly ($P<0.05$) higher total soluble solid than ATS-2. The reason could be mainly due to the fact that the ATS-5 sweet corn milk had a greater amount of reducing sugar. Sucrose contents in both studied sweet corn cultivars about 4-5% was considered as high amount. This was in agreement with results found by Azanza *et al.* (1996); Olsen *et al.* (1990); Puhlam (1997); and Tracy (2001). They also observed that sucrose was the main sugar of sweet corn.

Cultivars and harvest time of the tested sweet corns were not affected on invert sugar and sucrose content ($P\geq0.05$). Starch and reducing sugar of the ATS-5 corn milk were higher than that of the ATS-2 corn milk. At the different harvest stages, the amounts of starch in the ATS-5 corn milk samples were not significant difference ($P\geq0.05$), while that of the ATS-2 appeared to increase with the longer harvest time. For reducing sugar, the amounts contained in both cultivars increased with an increasing harvest period. The changes of starch and reducing sugar could be associated with the genetic as reported by Tracy (2001).

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Table 2.3 Chemical composition of corn milk samples prepared from different varieties and harvest stages of sweet corn

Variety	Protein (%)	Fat (%)	Ash (%)	Moisture(%)	Carbohydrate (%)
ATS-2	2.39 ± 0.26^{B}	1.07 ± 0.14^{A}	0.59 ± 0.03^{NS}	85.01 ± 2.25^{A}	10.96 ± 2.11^{B}
ATS-5	2.58 ± 0.28^{A}	1.02 ± 0.17^{B}	0.60 ± 0.04^{NS}	82.44 ± 0.95^{B}	13.36 ± 0.59^{A}

Harvest time (days)	Protein (%)	Fat (%)	Ash (%)	Moisture(%)	Carbohydrate (%)
19	$2.48\pm0.43^{\underline{ab}}$	$1.19\pm0.03^{\underline{a}}$	$0.61\pm0.03^{\underline{ns}}$	$84.74\pm3.36^{\underline{a}}$	$10.98\pm2.97^{\underline{c}}$
21	$2.39\pm0.11^{\underline{b}}$	$0.89\pm0.10^{\underline{c}}$	$0.57\pm0.02^{\underline{ns}}$	$83.86\pm0.30^{\underline{b}}$	$12.28\pm0.41^{\underline{b}}$
23	$2.59\pm0.22^{\underline{a}}$	$1.05\pm0.12^{\underline{b}}$	$0.59\pm0.05^{\underline{ns}}$	$82.57\pm0.98^{\underline{c}}$	$13.21\pm0.80^{\underline{a}}$

Variety	Harvest time (days)	Protein (%)	Fat (%)	Ash (%)	Moisture(%)	Carbohydrate (%)
ATS-2	19	2.09 ± 0.02^{d}	1.21 ± 0.02^{a}	0.63 ± 0.02^{a}	87.87 ± 0.12^{a}	8.21 ± 0.15^{d}
	21	2.47 ± 0.06^{bc}	0.95 ± 0.05^{c}	0.57 ± 0.02^{ab}	84.09 ± 0.09^{b}	11.93 ± 0.06^{c}
	23	2.61 ± 0.22^{b}	1.04 ± 0.14^{bc}	0.56 ± 0.00^{b}	83.07 ± 1.26^{c}	12.72 ± 0.90^{b}
ATS-5	19	2.87 ± 0.13^{a}	1.18 ± 0.03^{ab}	0.59 ± 0.02^{ab}	81.62 ± 0.49^{d}	13.75 ± 0.31^{a}
	21	2.32 ± 0.10^{c}	0.83 ± 0.11^{c}	0.57 ± 0.02^{ab}	83.64 ± 0.25^{bc}	12.64 ± 0.26^{b}
	23	2.56 ± 0.25^{bc}	1.06 ± 0.12^{bc}	0.63 ± 0.06^{a}	82.06 ± 0.03^{cd}	13.69 ± 0.27^{a}

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

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Table 2.4 Acidity of corn milk samples prepared from different varieties and harvest stages of sweet corn

Variety	pH	Total acidity (% citric acid)
ATS-2	6.61 ± 0.07^{B}	0.52 ± 0.02^{NS}
ATS-5	6.65 ± 0.05^{A}	0.51 ± 0.03^{NS}

Harvest time (days)	pH	Total acidity (% citric acid)
19	6.56 ± 0.04^{c}	0.54 ± 0.01^{a}
21	6.64 ± 0.04^{b}	0.51 ± 0.02^{b}
23	6.69 ± 0.02^{a}	0.50 ± 0.03^{b}

Variety	Harvest time (days)	pH	Total acidity (% citric acid)
ATS-2	19	6.54 ± 0.04^{c}	0.54 ± 0.02^{a}
	21	6.61 ± 0.01^{b}	0.52 ± 0.02^{ab}
	23	6.68 ± 0.02^{a}	0.50 ± 0.01^{bc}
	19	6.58 ± 0.02^{b}	0.53 ± 0.01^{ab}
ATS-5	21	6.67 ± 0.02^{a}	0.51 ± 0.01^{bc}
	23	6.69 ± 0.02^{a}	0.49 ± 0.04^{c}

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

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Table 2.5 Total soluble solid and carbohydrate composition of corn milk samples prepared from different varieties and harvest stages of sweet corn

Variety	Total soluble solid (°Brix)	Carbohydrate composition (%)			
		Starch	Reducing sugar	Invert sugar	Sucrose
ATS-2	10.88 ± 0.57^{B}	3.25 ± 2.11^{B}	2.90 ± 0.48^{B}	7.70 ± 0.32^{NS}	4.56 ± 0.63^{NS}
ATS-5	12.09 ± 1.07^{A}	5.51 ± 0.81^{A}	3.46 ± 0.64^{A}	7.85 ± 0.66^{NS}	4.17 ± 0.84^{NS}
Harvest time (days)	**Total soluble solid (°Brix)**	**Carbohydrate composition (%)**			
		Starch	Reducing sugar	Invert sugar	Sucrose
19	11.31 ± 0.88^{ns}	3.47 ± 3.02^{c}	2.80 ± 0.67^{b}	7.51 ± 0.19^{ns}	4.47 ± 0.78^{ns}
21	11.43 ± 0.82^{ns}	4.37 ± 0.46^{b}	3.15 ± 0.57^{ab}	7.92 ± 0.10^{ns}	4.53 ± 0.50^{ns}
23	11.71 ± 1.42^{ns}	5.31 ± 1.06^{a}	3.59 ± 0.37^{a}	7.89 ± 0.83^{ns}	4.09 ± 0.94^{ns}

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

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Table 2.5 (Continue)

Variety	Harvest time	Total soluble solid	Carbohydrate composition (%)			
	(days)	(°Brix)	Starch	Reducing sugar	Invert sugar	Sucrose
ATS-2	19	11.13 ± 0.25^{bc}	0.65 ± 0.26^{d}	2.45 ± 0.06^{c}	7.56 ± 0.12^{ns}	4.86 ± 0.05^{ns}
	21	11.00 ± 0.71^{bc}	4.00 ± 0.10^{c}	2.87 ± 0.15^{bc}	7.94 ± 0.10^{ns}	4.82 ± 0.06^{ns}
	23	10.50 ± 0.58^{c}	5.12 ± 1.37^{b}	3.40 ± 0.47^{ab}	7.61 ± 0.48^{ns}	4.00 ± 0.90^{ns}
	19	11.50 ± 1.29^{bc}	6.29 ± 0.23^{a}	3.16 ± 0.85^{bc}	7.46 ± 0.25^{ns}	4.09 ± 1.00^{ns}
ATS-5	21	11.85 ± 0.78^{ab}	4.73 ± 0.35^{bc}	3.44 ± 0.71^{ab}	7.90 ± 0.10^{ns}	4.24 ± 0.59^{ns}
	23	12.93 ± 0.65^{a}	5.51 ± 0.81^{ab}	3.78 ± 0.10^{a}	8.18 ± 1.07^{ns}	4.19 ± 1.11^{ns}

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

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2.4 CONCLUSIONS

The chemical composition of corn milk was varied according to genetic differences and harvest period. Generally, moisture, acidity and fat contents decreased with the harvest time, whereas reducing sugar content was increased. Based on presences of high yield and high reducing sugar content, corn milk extracted from the ATS-5 sweet corn that harvested on the 23rd day after silking was considered as the best corn milk for yogurt making.

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