CHAPTER 4
RESULTS AND DISCUSSION

4.1 The composition of corn milk

The physical, chemical and microbiological characteristics of corn milk used in this study were shown in Table 4.1. The data was compared with the physical and chemical values of raw sweet corn from some literatures, including Pomeranze *et al*. (1987), Makhlouf *et al*. (1995), DeMan (1990), and Barrett *et al*. (2000) and a commercial brand of corn milk, Malee brand.

Table 4.1 Analyses of raw sweet corn and corn milks

Nutrition	Raw sweet corn	Malee's corn milk	Corn milk******
Fat (g/100g)	5.20**	0.48	0.27±0.02
Carbohydrate (g/100g)	72.10**	9.71	5.45±0.01
Protein Nx6.25 (g/100g)	9.90**	0.97	0.84±0.01
Invrese sugar (g/100g)	-	-	2.03±0.06
Sucrose (g/100g)	-	6.8	1.62±0.04
Ash (g/100g)	1.40**	-	0.21±0.01
Fiber (g/100g)	2.10**	0	0.19±0.01
Acid (lactic acid) (g/100g)	-	-	0.03±0.01
Moisture content (g/100g)	13.80**	-	93.38±0.05
Vitamin C(mg/100g)	8.00±1.70***	-	5.80±0.01
Carotenoid (mg/100g)	0.49(β-carotene)****	-	0.76±0.75
Bacteria(cfu/g)	-	-	$8.93x10^4$±$7.62x10^3$
Yeast&mold (cfu/g)	-	-	$2.58x10^5$±$1.88x10^5$
Color			
L* value	67.80*****	-	63.19±1.64
a* value	-	-	-8.00±0.38
b* value	-	-	23.77±5.44

** from Pomeranze *et al*.(1987)

*** from Makhlouf *et al*.(1995) corn-on-the-cobs were cooked in boil

**** from DeMan (1990)

***** from Barrett *et al*.(2000)

****** from this study

From Table 4.1, it showed clearly that the main nutrients, including fat, carbohydrate, protein, moisture content, fiber and ash, of raw sweet corn were much higher than the corn milk prepared for this study. The differences were due to the preparation method to produce the corn milk, which included an addition of water for 200 % of the amount of sweet corn. This addition may also affect the composition of the corn milk used in this study compared to a commercial corn milk, Malee®. The corn milk used in this study had slightly lower values of fat and protein compared with the commercial corn milk (Table 4.1) However, the commercial corn milk had almost a double value for the carbohydrate content as compared to the laboratorium-made corn milk. The difference in the carbohydrate content was mainly due to a sugar addition in the commercial corn milk. Sucrose in the commercial corn milk was 6.80 % compared to 1.62±0.04 % in the corn milk used in this study. Besides these factors, differences in the nutrient contents of sweet corn products can be attributed from other elements, including genetic differences, such as species, cultivars; environmental factors, such as climatic and soil conditions; seasonal changes; location; cultural practices; stage of maturity at harvesting time and harvesting conditions. Post harvesting conditions, such as transportation, handling, storage conditions and processing are also determinants on the nutritional quality. It is also well known that preparation and cooking have considerable influence on the nutrient contents at the point of consumption (Makhlouf *et al*., 1995). For the physical characteristic of the corn milk, it was represented by color values measured using a colorimeter. Table 4.1 displayed that there was a difference in L* value or lightness characteristic between the raw sweet corn and the corn milk used in this study. The raw sweet corn was brighter with a L* value of 67.80 compared with the corn milk, which was 63.19±1.64. This result was in an agreement with the reports of Arunratsamee (1999) and Barrett *et al*. (2000), which stated that raw sweet corn had a brighter color than blanched sweet corn. The L* value of the corn milk was also similar to the L value of the blanched sweet corn, which was 63.68 as reported by Barrett *et al*. (2000).

Besides the main nutrients, sweet corn also contains a fat-soluble vitamin, vitamin A, in a form of pigment carotenoid in which the human body can produce into vitamin A, and a water-soluble vitamin, vitamin C (ascorbic acid). A serious deficiency of vitamin A is still found in some tropical populations. One of the important functions of vitamin A and vitamin C is to protect of the body from free radical damages. Vitamin A can be obtained from two sources. The first one is from retinal, usually in the form of retinyl esters which can be found and therefore, absorbed only from animal tissues and the second is carotenoids or provitamin A, mainly from plant tissues. These carotenoids can be cleaved in the body to yield retinal. The main source of carotenoid derived retinal is β-carotene, though other carotenoids such as α-carotene, can also be converted to retinal. From Table 4.1, it could be seen that the carotenoid content in corn milk was 0.76 mg/100g, whereas raw sweet corn had 0.49 mg/100g in the form of β-carotene. Since the carotenoid analysis in the corn milk used in this study was done by using a total carotenoid content, therefore its amount would be higher than the report for β-carotene only. For the content of vitamin C, the amount of the vitamin was lower in the corn milk compared to the boiled sweet corn as reported by Makhlouf *et al*.(1995). The differences in the vitamin C content could be due to a water addition in the corn milk, which was 200 % of the amount of the milk. In addition, there was also differences in the heating condition for both products. In this study, the cut seed of sweet corn was steamed for 10 min before making the corn milk, whereas the sweet corn-on-the-cobs were cooked in boiling water for 7 min. Percentage of extraction of the corn milk used in this study, which was 85.56 ± 7.85 %, was similar to the percentage extraction reported by Arunratsamee (1999), which was 82.41 %.

As mentioned before, the seed of sweet corn used in this study was steamed for 10 min before producing corn milk. The process of this step was done to inactivate a critical enzyme in sweet corn, which is lipoxygenase (LPO). The presence of LPO in sweet corn would catalyze off-odor formation. Blanched treatments of sweet corn was expected to inactivate enzyme. Therefore, the formation of off-odor could be reduced. Beside that, blanching treatment would enhance desirable characteristics in sweet corn products, such as sweetness and corn flavor (Theerakulkait *et al.*, 1995).

4.2 A study on appropriate foamimg agent, sugar and maltodextrin concentrations to produce a stable foam.

Foam-mat drying is a process in which liquid foods are whipped into stable foams which must be able to withstand a number of mechanical operations including pumping spreading, cratering and extrusion, as well as drying. The foams must be fluid enough to be extruded or cratered, stiff enough to retain the extruded or cratered shape and the air-dried. During heated air drying it is desirable that the foams remain stable and retain their typical open structures to facilitate rapid drying and detraying. If foams collapse during drying, this undesirable feature increases the drying rate, reduces product quality and hinders detraying (Bates, 1964).

Three types of foaming agents, including GMS, methocel and a combination of GMS and methocel at a ratio of 1:1, were studied to make a stable foam. Each type of foaming agents were prepared in solutions at 1, 2 and 5 % (w/w). In addition to the foaming agents, 3 concentrations of maltodrextrin at 20, 25 and 30 % (w/w) and two concentrations of sugar addition at 15 and 20 °brix were also investigated. The results of these 3 factors combination in making a stable foam before and during drying in an oven were showed in Table 4.2, 4.3 and 4.4 for the combination of GMS, sugar and maltodextrin, a combination of methocel, sugar and maltodextrin and a combination of GMS:methocel (1:1), sugar and maltodextrin, respectively. The statistical analysis of the results was conducted separately for each analysis result for all foaming agent, maltodextrin and sugar combinations and was showed to be significantly different ($P \leq 0.05$) within different concentrations of foaming agent, maltodextrin and sugar addition. The result's discussion would be separated into 3 subchapters, which were the effect of foaming agents on the foam formation and stability, the effect of maltodextrin on the foam formation and stability and the effect of sugar on foam formation and foam stability.

4.2.1 The effect of foaming agents on foam formation and stability

4.2.1.1 Glyceryl monostearate (GMS)

GMS was the most effective foaming agent for producing a stable foam with the widest range of food products (Bates, 1964). From Table 4.2, it could be seen the effect of GMS concentrations on the physical characteristics of foam formation from corn milk, including foam density, overrun, syneresis, viscosity and appearance of the foam, and the stability of the foam during drying in an oven. In general, the data showed that there was a trend between the GMS concentrations with the same sugar and maltodextrin concentrations with the foam density and syneresis results. At 2 % (w/w) GMS concentration, the foams had lower density values than those of the foams made from 5 % (w/w) GMS concentration, while the 1 % (w/w) GMS concentration had the highest density. This trend was also applied to the syneresis properties in which the 2 % GMS concentration had the lowest syneresis values followed by the 5 % and 1 % GMS concentrations. The most clearly relationship for the density and the syneresis properties could be seen from the foams made from 1 and 2 % GMS concentrations. The foams with 2 % GMS concentration had lower density values and produced less syneresis as compared with the foams prepared with 1 % GMS concentration. As a result, at this GMS concentration, the foam had significantly ($P \leq 0.05$) higher overrun values than those of 1 % GMS foams. The low overrun values for the 1 % GMS foams caused the foams to be unstable and collapsed during drying at 60 °C in an oven (Table 4.2). These foams had a physical appearance like a liquid when observed with naked eyes (see Appendix A). As the 2 % GMS foams had higher overrun values, the foams were more stable, especially when they were added with sugar at 15 °Brix and 20 or 25 % (w/w) maltodextrin. However, it was only the foam with the highest overrun value (642.68 ± 37.83 %) that could stand during a drying process. This foam was made from 2 % GMS concentration, a sugar addition at 15 °brix and 25 % maltodextrin (Table 4.2). This foam also had low density and syneresis values, which were 0.13±0.01 g/ml and 0.10±0.10 ml/min, respectively. The physical appearance of the foam was stable before and during a drying process and the foam could maintain its extruded shape until it was completely dried. It seemed that 2 % GMS concentration with a combination of sugar at 15 °Brix and 25%

Table 4.2 Effect of GMS, sugar and maltodextrin on the physical characteristics of foam formation and its stability during drying.

GMS concentration (%)	Sugar (°Brix)	Maltodextrin (% w/w)	GMS (g)	Density+ (g/ml)	Overrun+ (%)	Syneresis+ (ml/min)	Viscosity+ (cP)	Foam appearance	Foam stability during drying
1	15	20	100	0.30±0.02efg*	260.83±15.05jk	41.67± 2.89efg	19.84±1.76a	Unstable foam	Foam collapsed
		25	100	0.37±0.01jkl	194.96±5.74gh	37.67± 2.52efg	25.54±1.19ab	Unstable foam	Foam collapsed
		30	100	0.47±0.01pq	133.90±6.33cd	80.60± 2.37kl	35.57±1.57abc	Unstable foam	Foam collapsed
	20	20	100	0.40±0.02lmn	173.40±9.76fg	67.22± 7.5i	26.97±0.60ab	Unstable foam	Foam collapsed
		25	100	0.42±0.01no	162.28±7.95ef	77.72± 13.56jkl	35.36±2.59abc	Unstable foam	Foam collapsed
		30	100	0.49±0.02q	121.89±5.69c	85.2± 4.32l	44.19±3.91abc	Unstable foam	Foam collapsed
2	15	20	100	0.19±0.01b	464.65±20.81m	0.30± 0.12a	26.16±1.53ab	Stable foam	Foam collapsed
		25	50	0.13±0.01a	642.68±37.83p	0.10± 0.1oa	33.87±1.95abc	Stable foam	Foam stable
		30	100	0.26±0.01cd	312.53±19.67l	4.32±1.07bc	39.89±1.06abc	Unstable foam	Foam not stable
	20	20	100	0.32±0.01ghi	237.13±7.68ij	5.29±1.92efg	34.8±2.05abc	Unstable foam	Foam collapsed
		25	100	0.34±0.01ij	216.56±6.60hi	4.78±1.07h	39.62±2.68abc	Unstable foam	Foam collapsed
		30	100	0.49±0.02q	123.84±6.57cd	11.17±5.58ij	48.89±3.92abc	Unstable foam	Foam collapsed
5	15	20	100	0.26±0.01c	318.77±11.89l	3.46±0.92b	43.26±2.20abc	Unstable foam	Foam collapsed
		25	100	0.31±0.01fgh	255.61±8.32jk	2.79±0.67cde	56.90±2.86abcd	Unstable foam	Foam collapsed
		30	100	0.39±0.01lm	182.13±5.37fg	10.05±2.56h	95.57±4.52abcdef	Unstable foam	Foam collapsed
	20	20	100	0.30±0.02efg	266.06±17.37k	12.08±2.60 bcd	64.54±9.63abcde	Unstable foam	Foam collapsed
		25	100	0.32±0.02fghi	237.83±20.55ij	18.83±13.75 efg	92.16±2.36abcdef	Unstable foam	Foam collapsed
		30	100	0.40±0.02lmn	173.59±13.41fg	25±3.82ijk	131.1±6.29efgh	Unstable foam	Foam collapsed

* : Different letters that followed numbers within the same column indicated significantly different (P≤0.05) between the treatments.

+ : Values are mean from 3 replications ± S.D.

Table 4.3 Effect of methocel, sugar and maltodextrin on the physical characteristics of foam formation and its stability during drying.

Methocel concentration (%)	Sugar (°Brix)	Maltodextrin (% w/w)	methocel (g)	Density+ (g/ml)	Overrun+ (%)	Syneresis (ml/min)	Viscosity+ (cP)	Foam appearance	Foam stability during drying
1	15	20	100	0.92±0.01t*	19.07± 2.52ab	80 ml<8sec	149.26±13.6fghi	Can not make foam	ND**
		25	100	0.99±0.07uv	10.87± 3.44a	80 ml<8sec	187.1±4.1hij	Can not make foam	ND
		30	100	1.12±0.02yz	0a	80 ml<8sec	277.73±17.5klm	Can not make foam	ND
	20	20	100	1.07±0.01xyz	2.17± 0.67a	80 ml<8sec	176.19±26.4ghij	Can not make foam	ND
		25	100	1.08±0.02xyz	0.99± 1.81a	80 ml<8sec	220.41±6.7ijk	Can not make foam	ND
		30	100	1.12±0.01yz	0a	80 ml<8sec	305.68±40.1klm	Can not make foam	ND
2	15	20	100	0.82±0.01r	33.77± 1.02b	80 ml<8sec	177.27±10.1ghij	Can not make foam	ND
		25	100	1.11±0.02yz	0a	80 ml<8sec	265.12±15.0klm	Can not make foam	ND
		30	100	1.12±0.01yz	0a	80 ml<8sec	425.70± 7 8.9n	Can not make foam	ND
	20	20	100	1.09±0.01xyz	0.59± 1.17a	80 ml<8sec	291.88±22.4klm	Can not make foam	ND
		25	100	1.10±0.02yz	0a	80 ml<8sec	465.43±10.5n	Can not make foam	ND
		30	100	1.11±0.01yz	0a	80 ml<8sec	649.06±11.6p	Can not make foam	ND
5	15	20	100	1.06±0.01xyz	3.39± 0.72a	80 ml<8sec	736.51±9.6q	Can not make foam	ND
		25	100	1.11±0.02yz	0a	80 ml<8sec	903.5±80.9s	Can not make foam	ND
		30	100	1.13±0.01yz	0a	80 ml<8sec	1139.03±13s.4	Can not make foam	ND
	20	20	100	1.09±0.02zyz	0.21±0.16a	80 ml<8sec	800.54±45.8qr	Can not make foam	ND
		25	100	1.10±0.01yz	0a	80 ml<8sec	917.91±62.8s	Can not make foam	ND
		30	100	1.12±0.02yz	0a	80 ml<8sec	1242.01±241.0u	Can not make foam	ND

*: Different letters that followed numbers within the same column indicated significantly different (P≤0.05) between the treatments.

** : ND = Not Determine

+ : Values are mean from 3 replications ± S.D.

Table 4.4 Effect of GMS:methocel (1:1), sugar and maltodextrin on the physical characteristics of foam formation and its stability during drying.

GMS:methocel concentration (1:1) (%)	Sugar °Brix	Maltodextrin (%)	GMS: methocel (g)	Density+ (g/ml)	Overrun+ (%)	Syneresis+ (ml/min)	Viscosity+ (cP)	Foam appearance	Foam stability during drying
1	15	20	100	0.81±0.04r*	36.04± 6.01b	80 ml<8sec	98.98±7.74bcdef	Can not make foam	ND**
		25	100	0.87±0.01s	25.98± 1.04ab	80 ml<8sec	124.68±9.02defgh	Can not make foam	ND
		30	100	0.96±0.03u	13.87± 2.99ab	80 ml<8sec	173.71±4.90ghij	Can not make foam	ND
	20	20	100	1.01±0.01vw	8.14± 1.35a	80 ml<8sec	109.98±5.32cdefg	Can not make foam	ND
		25	100	1.03±0.01wx	5.92± 0.75a	80 ml<8sec	140.52±11.65fgh	Can not make foam	ND
		30	100	1.05±0.01xyz	4.64± 0.73a	80 ml<8sec	260.23±25.04klm	Can not make foam	ND
2	15	20	100	0.31±0.02fgh	251.18±16.01jk	33.93± 33.76def	226.27±14.60jkl	Unstable foam	ND
		25	100	0.29±0.01def	270.86±9.05k	34.74± 2.56def	266.23±4.3klm	Unstable foam	ND
		30	100	0.38±0.01kl	191.86±11.1gh	42.04± 2.94fg	318.39±23.02m	Unstable foam	ND
	20	20	100	0.34±0.01hi	224.48±7.11i	40.45± 9.84efg	241.53±8.28jkl	Unstable foam	ND
		25	100	0.39±0.02lmn	182.33±10.40fg	47.86± 4.95gh	297.54±4.86lm	Unstable foam	ND
		30	100	0.44±0.02op	147.28±7.07de	95.67± 11.59m	412.29±20.58n	Unstable foam	ND
5	15	20	100	0.19±0.02ab	568.02±51.54o	0.69± 0.27a	397.01±8.70n	Stable foam	Foam collapsed
		25	43	0.17±0.02ab	535.81±51.22n	0.15± 0.02a	547.68±10.92o	Stable foam	Foam stable
		30	100	0.29±0.01cde	299.42±10.81l	1.40± 0.35a	781.39±20.70g	Unstable foam	Foam not stable
	20	20	100	0.35±0.02ijk	213.30±17.64hi	3.69± 0.33a	465.51±35.53n	Unstable foam	Foam collapsed
		25	100	0.38±0.01kl	191.65±5.74gh	5.19± 1.72a	611.80±12.80p	Unstable foam	Foam collapsed
		30	100	0.41±0.01mno	164.85±4.73ef	5.76± 1.35a	853.18±43.63rs	Unstable foam	Foam collapsed

* : Different letters that followed numbers within the same column indicated significantly different (P≤0.05) between the treatments.

** : ND = Not determine

+ : Values are mean from 3 replications ± S.D.

maltodextrin could reduce the surface and interfacial tension to a low level to form strong interfacial films around stable bubbles.

For the 5 % GMS concentration, the foam had higher density and syneresis values and lower overrun values compared to the 2 % GMS foam. Therefore the foams were unstable and collapsed during drying in an oven. One factor that might contribute to the unstability of the 5 % GMS foam was the solubility of the foaming agent. At this concentration of GMS, it was observed that some of the GMS particles were not dissolved completely even a warm water at 70 °C was used. According to Singhagajen and McBean (1968), GMS would be effective as a foaming agent when it was blended in hot water to give a dispersion in the form of a stiff suspension without visible particles. It would be difficult for GMS to be dispersed completely through simple stirring. The writers also found that GMS was the most suitable additive for foaming banana purees. On the contrary, Sankat and Castaigne (2004) found that the addition of GMS did not produce foams when it was added on banana purees. Using GMS as a foaming agent in foam-mat drying of cowpea pastes has also been studied by Falade *et al*. (2003). In their study, GMS was incorporated into cowpea pastes at 2.5 , 5.0 , 7.5, 10.0, 12.5 and 15 % (w/w) . Their results showed that only the addition of GMS at 12.5 and 15 % (w/w) in the pastes that could produce foams with low foam density values, which were significantly different with the lower GMS concentrations which made high density foams with values nearly 1 g/cm^3.

4.2.1.2. Methocel

From Table 4.3, it showed clearly that 1, 2 and 5 % (w/w) methocel with different sugar and maltodextrin additions could not make stable foams. The mixtures had high density values between 0.82 to 1.13 g/ml and very low overrun values. When the mixtures were observed with naked eyes, the mixtures could only form a few big bubbles after they were aerated and could not be taken into a hot air oven. According to Bates (1964), several factors that would affect foam formation, foam density and stability included chemical nature of fruits, soluble solid content, pulp fraction, type of foaming agents and type and concentration of foam stabilizers. Beside these factors, variations in crop uniformity and changes in production techniques may occasionally result in raw

materials that may have foaming characteristics varying from the mean. They also found that avocado puree and coconut milk could not be foamed using foam inducers. A study by Ratchaniyom (2002) about foam-mat drying of longan juice showed that methocel 65 HG, a combination of methocel 65HG and egg albumin (EA) and a combination of methocel 65 HG and GMS could make stable foams of longan juice. However, foams could not be produced by using EA, GMS, and carboxy methyl cellulose (CMC). Another study about foam-mat drying of makeang juice, found that GMS could not make foams from makeang juice, while CMC could make stable foams from the same raw material (Bunthawong, 2004).

4.2.1.3 A combination of GMS and methocel ratio (1:1)

For a combination of foaming agent, which was GMS and methocel at a ratio of 1:1, the results for its effect on physical properties of the formed foams from corn milk and their stability during drying were shown in Table 4.4. In this table, the data clearly showed that there was a direct relationship between the concentration of foaming agents with the physical measurements of the produced foams. As the amount of foaming agents increased, the density and syneresis values of the foams were decreased whereas the overrun values were increased. Therefore the stability of the foam formation become better as higher amounts of foaming agents were added into the corn milk. At 1 % concentration of GMS: methocel, the corn milk could make foams in the first few minutes of whipping, but the amount of bubbles was not increased when the whipping process was continued for up to 8 min. As a result, the mixture had high density values between 0.81-1.05 g/ml, low overrun values of below 36.04 %, high syneresis values, which were below 8 s and foams could not be dried in an oven.

Contary to the results of 1 % concentration of GMS and methocel, the 2 % and 5 % concentrations gave a significant effect in producing foams from corn milk. When the corn milk was added with 2 % concentration of GMS and methocel, the foams had significantly lower density values than the 1 % concentration. However, the foams were still looked like liquid when was observed with naked eyes and they were collapsed during drying. Better foams characteristics could be achieved when the corn milk was added with 5 % concentration of GMS and methocel. High overrun values for up to

568.02 ± 51.54 % could be produced from this foaming agent concentration. Nevertheless, good foam formation could only be made when the 5 % concentration of GMS and methocel was combined with a sugar addition at 15 °brix and 25 % maltodextrin. At this combination, the foam had a density value of 0.17 ± 0.02 g/ml, an overrun value of 538.81 ± 51.22 % and a syneresis value of 0.15 ± 0.02 ml/min. The foam was stable and could maintain its extruded shape until a drying process was completed. It seemed that at this combination, the foaming agent could reduce the surface and interfacial tensions to a level low enough to form good interfacial films around the bubbles and stabilize them. Bates (1964) reported that GMS was acted as a foam inducer and methocel 90 HG as a foam stabilizer in foam-mat drying of tropical fruit. In addition, methocel could aid in the formation of strong film and stabilize interfacial films. At low concentration of methocel, air bubbles were not stable because the critical thickness required for interfacial films could not be formed. The results from this study was also similar to the results of Ratchaniyom (2002) that studied foam-mat drying of longan juice. In his study, it was found that the rate of foam density and syneresis were decreased as the concentrations of GMS : methocel at a ratio of 1:1 were increased from 0.06 to 0.56 % (w/w).

4.2.2 Effect of maltodextrin on the foam formation and stability

Maltodextrin is a hydrolyzed product from starch that contains linear amylose and branched amylopectin products. As a digestion product, maltodextrin can help the formation of foam because of the gelation property of the compound. Besides that, maltodextrin has a significant portion of average chain length long enough to form thermally reversible gel. The mechanism of network formation of maltodextrin can be inferred from the gelation of starch. Maltodextrin gels are resulted from coupling interactions between soluble amylose molecules and branch and linear chains of amylopectin molecules (Chronakis, 1998). The effect of maltodextrin on the foam formation from corn milk in this study was carried out by using different concentration of the compound at 20, 25 and 30 % (w/w). At any levels of foaming agents and sugar additions, it was found out that as the concentrations of maltodextrin increased the foam

density and syneresis increased significantly whereas the overrun values decreased significantly.

It has been reported by Reuther *et al*. (1984) that below a certain concentration of maltodextrin, maltodextrin gel will remain elastic after compression, while at higher concentrations the gels are increasingly more brittle and fragmentation after compression. This is an indication that at a high concentration of maltodextrin, part of the polysaccharide is acting as a filler within the gel network, rather than being involved in the tertiary structure. Therefore, in general higher concentrations of maltodextrin tend to be more brittle.

Comparing the above information with the finding of this study that the foam density was increased and the foam overrun was decreased as the added amounts of maltodextrin into corn milk was increased, it could be assumed that the higher concentration of maltodextrin caused brittle foams to be increased. As the number of brittle foams increased, breakdown of the foams during whipping would be increased and caused the trapping air to be decreased. This assumption was parallel with the results from the syneresis rate, which was increased as the concentrations of maltodextrin increased. The rate of syneresis was affected by unstable foams and gravity, which affected film surrounding the foams, would have a more significant effect in causing the film drainage. When taking these foams in a hot air oven, they were collaped due to their structures (brittle foams). Therefore this study found that stable foams from corn milk could only be made by 20 and 25 % (w/w) maltodextrin (Table 4.2-4.4). These maltodextrin concentrations were combined with a sugar addition at 15 ^{0}Brix and a foaming agent either 2 % concentration of GMS or 5 % concentration of GMS and methocel (1:1). However, in the futher drying processes of the foams, the foams that were made using 20 % concentration of maltodextrin could not stand during the process at 60 ^{0}C and collapse before the process finished.

A study by Vongsawasdi *et al.* (2002) about a production of instant fruit and vegetable juices by using a spray drying foam method used solubilized soya protein as a foaming agent and 3 concentrations of maltodextrin, which were 13, 16 and 19 %. The results of this study showed that 13 % maltodextrin could not be used to make powders because this amount of maltodextrin was not enough to cover foam's structure. The juice

tended to stick to the walls of a dryer and gave a paste like structure instead of powder. Another study by Bhandari *et al.* (1993) about a production of fruit juice powder by using a foam spray dryer found that the suitable ratios of the juices, which were blackcurrant, apricot and raspberry, per maltodextrin were 63:35, 60:40 and 55:45 (w/w), respectively. However, Siravanichayagul and Premsaman (1984) found that 15 % (w/w) of maltodextrin was propered to be used in making fruit juice powders. The use of maltodextrin to overcome high hygroscopic in sugar-rich mango pulp that had low molecular weight sugars, such as fructose, glucose, sucrose and acids was reported by Jaya and Das (2003). The low molecular weight sugar have a low glass transition temperature. They are very hygroscopic in their amorphous state and loose free flowing nature at high moisture contents. Therefore, maltodextrin was added to get nonsticky, free flowing powder (Bhandari *et al*., 1993). Besides that, maltodextrin was also used to help drying juice into powders and increase total soluble solid in products.

4.2.3 Effect of sugar on the foam formation and stability

The addition of sugar in the foam formation from corn milk was aimed to increase the total soluble solid of the corn milk. Two values of total soluble solid, which were 15 and 20 °Brix were studied together with different foaming agents and maltodextrin concentrations. The results in Table 4.2-4.4 showed that in general as the amount of sugar increased or higher total soluble solid contents, the foam density and syneresis would be increased significantly and the foam overrun would be decreased significantly. It was suggested by Sommanut (1997) that sugar could be used to reduce a liquid-like appearance of juices and increase thickness of interfacial films. Therefore, these liquid would prevent the trapping air during whipping. According to Bates (1964) that studied the effect of soluble solids upon foam density, they report that as the soluble solid content of fluids increased the foam density would also be increased. The data that they obtained was similar for juice and puree systems. Another reported by Jittana and Anong (1982) stated that the foam formation made from samples that had high total soluble solid would be affected by whipping time. The whipping time of samples with high total soluble solids would be increased to make stable foams. In this study, the whipping time of corn milk was fixed for 8 min. There was a possibility that at this whipping time, stable foams

could not be made from the corn milks that had a total soluble solid of 20 ^{0}Brix. The corn milk would not have enough time to prevent trapping of the air during whipping and a long whipping time was needed. A study by Sommanut (1997) found that as total soluble solids of banana purees increased from 18.23 to 21.74 ^{0}Brix, the whipping time was also increased from 6 to 17 min.

As an overall, it could be concluded that a production of stable foams from corn milk could be made by combining either 2 % concentration of GMS at 50 g (25 % w/w) or 5 % concentration of GMS and methocel (1:1) at 43 g (21.5 % w/w) with 25 % maltodextrin and a sugar addition at 15 ^{0}Brix. Using this combination, stable foams that had low density and syneresis rate and high overrun values could be produced. The foam's appearance was stable and it could maintain its extruded shape during spreading and extrusion as well as drying. The foams could also retained their typical open structures throughout drying processes. These structures would be benefit in supporting rapid drying and easiness of detraying. At a combination of 2 % concentration of GMS, a sugar addition at 15 °Brix and 25 % (w/w) maltodextrin, stable foams that had a foam density of 0.13 ± 0.01 g/ml, a foam overrun of 642.68 ± 37.83 % and a syneresis rate of 0.10 ± 0.10 ml/min were obtained. Whereas a combination of 5 % concentration of GMS and methocel (1:1), a sugar addition at 15 °Brix and 25 % (w/w) maltodextrin, stable foams that had a foam density of 0.17 ± 0.02 g/ml, a foam overrun of 535.81 ± 51.22 % and a syneresis rate of 0.15 ± 0.02 ml/min were produced.

4.2.4 Effect of whipping time on foam formation

4.2.4.1. Glyceryl monostearate (GMS)

The effect of whipping time on the foam density of formed foams was studied for 2 foaming agents, which were GMS and a mixture of GMS and methocel at ratio of 1:1. For the GMS, the results of foam density as a function of whipping time could be seen in Figure 4.1. In the Figure, it was shown that the density of the corn milk foams was decreased rapidly in the first few minutes (up to 6 min) of whipping. The lowest density was achieved after 8 min of whipping followed by increasing density on the prolonged whipping up to 14 min. The foam density was decreased with an increase in whipping time because air that was trapped in the foam structure was increased and this gave rise to

lower foam density. In addition, GMS can stabilize interfacial films, so it can prevent the diffusion of gas from small bubbles into big bubble (disproportionation). The minimum density is limited by the fact that no new air can be introduced once the whipping rod is covered by foam. Agitation during whipping causes local pressure fluctuations, which in turn induce surface tension fluctuation due to rapid changes in bubble volume and surface area. Beyond a certain whipping speed, the surface tension fluctuation become so intense that the liquid film between the bubbles are ruptured and hence the foam collapses. Other reasons that caused the foam density increased with the increasing whipping time were the coarse of foam to be deformed because of their large size and the more susceptible of the formed foam to disturbing influences such as evaporation, dust, temperature gradients, vibration and the addition of foam-breaking chemicals (Dickinson, 1992).

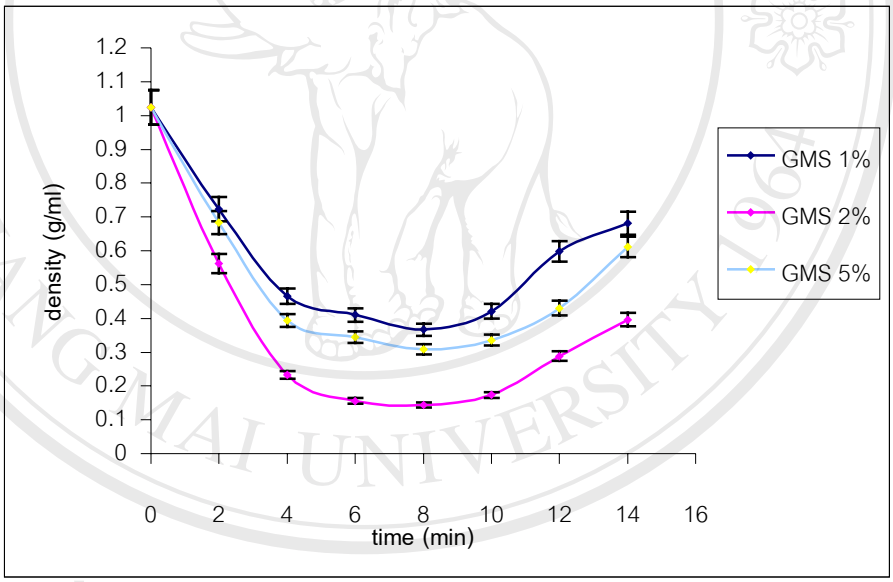

Figure 4.1 Effect of whipping time on the foam density of corn milks made by different concentrations of GMS as a foaming agent.

The rupture of foam by increasing time was called as “fatigue phenomena” (Sommanut, 1997). The foaming behavior produced by GMS which was found in this experiment was similar to foaming characteristics (foam density) of other food products that were prepared by GMS, including tomato puree (Hart *et al.*, 1963). They also reported that performance of a particular food in batch test affected by the type and

amount of agitation, the temperature and foaming gas. The rate of foam formation usually increases with agitator speed. However in some cases, excessive whipping speed produces a coarse foam that presents foaming altogether. Prolonged whipping causes some foams to collapse. An example of this was tomato purees that was foamed with GMS. After 10 min of whipping the foam density of tomato purees was increased rapidly. While other food foams exhibited a minimum density after only 1-2 min of whipping. These short whipping times were not instances of over-whipping. The rapid foamed foam had a coarse structure. Further whipping produced a slight loss of gas while large bubbles were being subdivided. This small bubble diameter and uniform size promoted foams stability. For these types of food, whipping time should be long enough to permit this finely divided bubbles. For different GMS concentrations, the Fig 4.1 showed that foam made by 2 % GMS concentration could produce lower density values compared with 1 and 5 % GMS concentration thoughout the whipping process. The reasons for these results could be seen in the section 4.2.1.1.

A study about foam-mat drying of cowpea using GMS as a foaming agent by Falade *et al.* (2003) found that the density of cowpea was decreased rapidly in the first few minutes of whipping. After that the foam density was increased rapidly. A minimum foam density was achieved after 9 min of whipping.

4.2.4.2 A mixture of glyceryl monostearate (GMS) and methocel at a ratio of 1:1

For the mixture of GMS and methocel (1:1), the effect of whipping time on the foam density of corn milks could be seen in Figure 4.2. The figure showed that the foam density of corn milks was decreased within the first 4 min of whipping. In general, the foams with minimum density values were produced after 8 min of whipping. After this whipping time, the density of the formed foams was increased slightly. Applying different concentrations of the GMS : methocel (1:1) mixture produced the same trend that after 8 min of whipping, their density were increased slightly. The lowest density almost similar patterns during 14 min of whipping. However, 5 % concentration of GMS and methocel (1:1) could produce foams with lower density values compared with the other concentrations. Reasons for this result have been explained in the section 4.2.1.3.

Comparing this result with the result of GMS, it could be noticed that using GMS as a foaming agent, the density of the foamed foams after 8 min of whipping was increased much more quickly compared with the density of the foams made using the combination of GMS and methocel (1:1). Different results between different foaming agents was due to the extra addition of methocel. Methocel has an ability in helping the formation of strong film and stabilizes interfacial films. Its viscosity can stabilize the interfacial films by increasing their thickness. Methocel could also be used to reduce separation of the liguid phase from interface layers, which could result thinning of the interface that eventually leaded to foam collapsing and to resist to disturbing influences. Bates (1964) that studied mango purees used GMS as a foam inducer and methocel as a foam stabilizer.

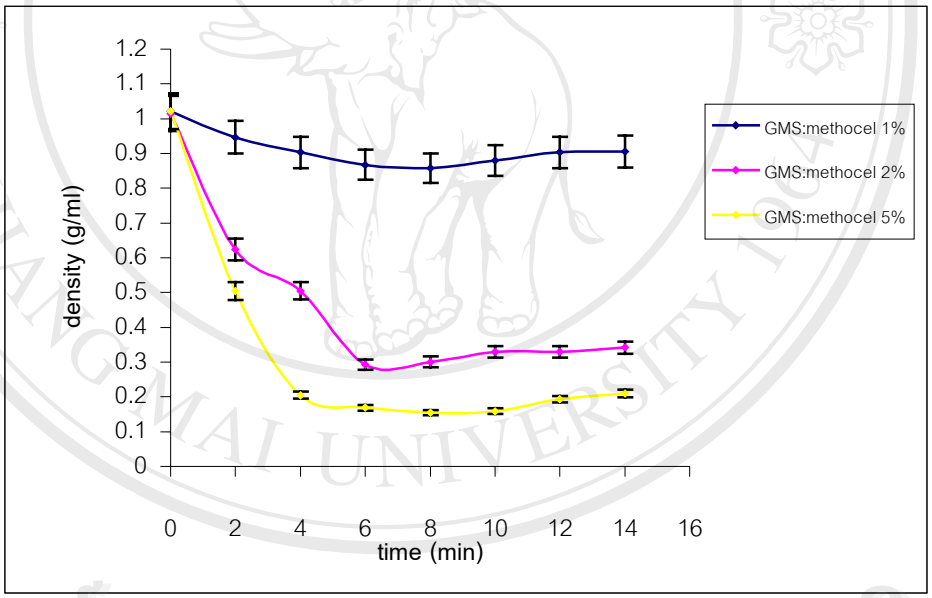

Figure 4.2 Effect of whipping time on the foam density of corn milks made by different concentrations of GMS and methocel (1:1) as a foaming agent.

4.2.5. Effect of whipping temperature on foam formation

Bates (1964) has noted that mixing temperature is one of the influencing factors that affects foam formation and stabilization. The temperature may affect the rate of foam formation (Hart *et al*., 1963). Assessing the effect of whipping temperature on foam formation in this study was done using 2 foaming agents, which were 2 % concentration

of GMS and 5 % concentration of GMS and methocel (1:1) and a whipping temperature of 30 and 60 ^{0}C. The results of the whipping temperatures could be seen in Figure 4.3 and 4.4 for GMS and the mixture of GMS and methocel (1:1), respectively. Both figures clearly showed that the foam density of corn milk was decreased as the mixing temperature increased. All of the samples were also shown to reach the minimum foam density after 8 min of whipping. Using the 2 % concentration of GMS, the formed foam would have minimum density values of 0.46 g/ml and 0.14 g/ml when used whipping temperatures at 30 and 60 ^{0}C, respectively. Whereas producing foams by the 5 % concentration of GMS and methocel (1:1) would make foams with minimum density values of 0.30 g/ml and 0.15 g/ml for whipping temperature at 30 and 60 ^{0}C, respectively. Since the corn milk contained 0.84 ± 0.01% protein (Table 4.1), this protein could act as surfactants of the formed foam, as showed in Figure 2.10, Chapter 2. The adsorption mode of protein are varied and they are always changed in conformation. For instance, most of enzymes completely lose their activity after adsorption at an oil-water interface due to their conformation change (Walstra, 1996). At high temperature, protein is also changed its conformation. Therefore when whipping the corn milk at 60 ^{0}C, there was a possibility that the protein in the milk changed their conformation and this changing might help the foam formation. The used of high whipping temperatures was also reported by Bates (1964). They used a whipping temperature of 70 ^{0}C with GMS as a foaming agent for canned banana, coffee extract, lemon juice concentrates, molasses, pea, pear, potato, prune, strawberry, and tomato paste.

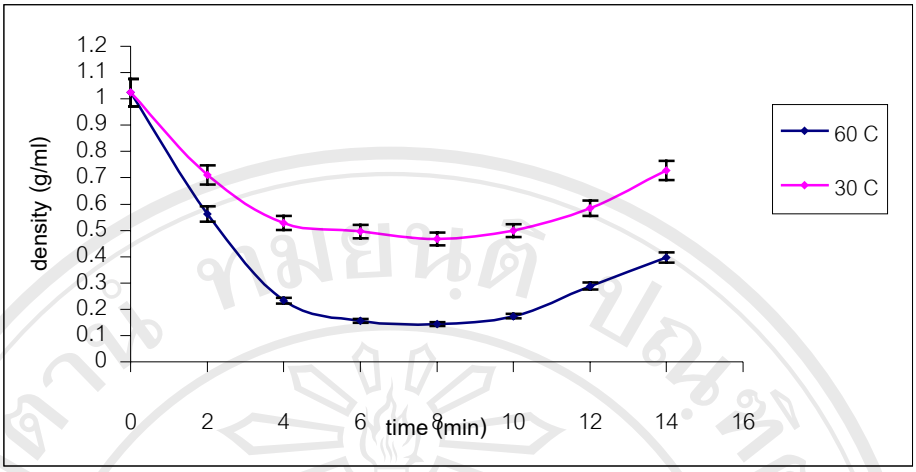

Figure 4.3 Effect of whipping temperatures on the foam density of corn milk prepared using 2 % concentration of GMS.

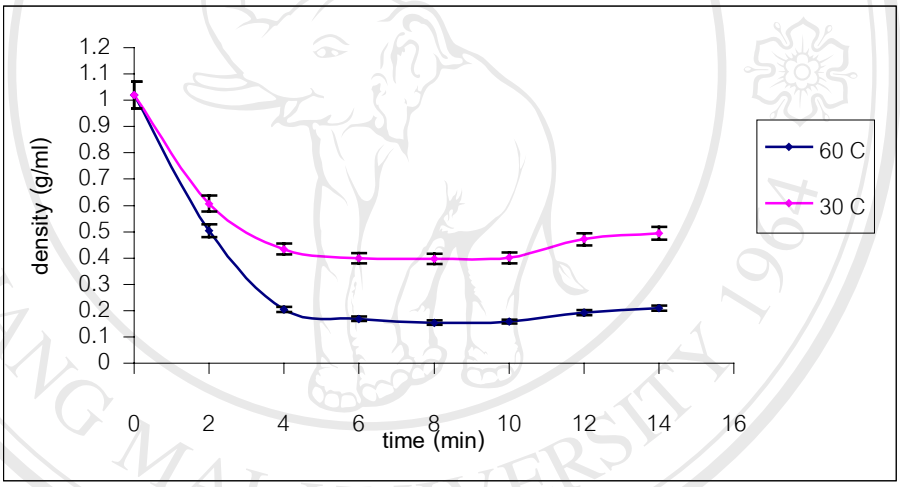

Figure 4.4 Effect of whipping temperatures on the foam density of corn milk prepared using 5 % concentration of GMS and methocel (1:1).

4.3 Study on the suitable amount of foaming agent in production of corn milk powder by foam-mat drying

In this study, 2 foaming agents which were 2 % (w/w) concentration of GMS and 5 % (w/w) concentration of GMS and methocel (1:1) with 25 % (w/w) maltodextrin and a sugar addition at 15 ^{0}Brix were chosen to figure out the suitable amount and type of foaming agent to produce corn milk powder by foam-mat drying. The amount of foaming agent that would be studied was divided into 5 levels. The first level would be the

minimum amount of foaming agent that could make stable foams. After this first level, the amount of foaming agent was increased for another 4 levels, in which each level would be an increase of 10 g of the previous level. It was found out that the minimum amounts of 2 % concentration of GMS and 5 % concentration of GMS : methocel (1:1) that could produce stable foams from corn milk were 50 g (25 %w/w) and 43 g (21.5 % w/w), respectively. The 5 levels of added foaming agents could be seen in Table 4.5.

Table 4.5. Different amounts of foaming agents added into corn milk.

Foaming agents	Amount of foaming agents (g) (%w/w)				
	Level 1	Level 2	Level 3	Level 4	Level 5
2 % GMS	50 (25)	60(30)	70(35)	80(40)	90(45)
5 % GMS:methocel (1:1)	43(21.5)	53(26.5)	63(31.5)	73(36.50)	83(41.5)

4.3.1. The properties of foam

The foam properties in the term of syneresis rate, foam density, and foam overrun that were made from different levels and types of foaming agents were presented in Table 4.6.

From table 4.6, it showed clearly that foam density made from GMS or a combination of GMS and methocel as a foaming agent was not significantly affected by the amount of added foaming agents. The foam density was almost similar in every level eventhough the added foaming agents were increased in 10 % steps. All the values of the foam density was falled between 0.12 to 0.16 g/ml. This result was differed from the report of Cooke *et al*. (1976) who reported that the foam density of mango puree was decreased as the amount of foaming agent increased.

Overrun is the amount of air incorporated in a product. Therefore, the overrun percentage is a calculation that measured the ratio of gas to liquid phase in an aerated product. Table 4.6. showed that only different amounts of 5 % concentration of GMS: methocel (1:1) that could significantly affect the foam overrun. Whereas, different amounts of 2 % concentration of GMS did not show any significant effect on the foam

Table 4.6. The properties of foam made from different levels and types of foaming agents.

Foaming agents	Level	Amounts	Foam properties		
		(g)	syneresis (ml/min)	density[ns*] (g/ml)	overrun (%)
2 % concentration of GMS	1	50	0.10±0.02a**	0.12±0.01	682.13±35.68ab
	2	60	0.17±0.02bc	0.14±0.01	615.90±28.92bc
	3	70	0.20±0.03c	0.13±0.01	654.75±30.86ab
	4	80	0.19±0.02c	0.13±0.00	635.10±11.15abc
	5	90	0.20±0.02c	0.12±0.01	682.71±45.68ab
5 % concentration of GMS:methocel (1:1)	1	43	0.14±0.02b	0.16±0.01	567.72±27.74c
	2	53	0.09±0.02a	0.14±0.01	613.68±28.54bc
	3	63	0.06±0.01a	0.12±0.01	698.93±52.92a
	4	73	0.08±0.03a	0.14±0.02	635.13±67.44abc
	5	83	0.07±0.02a	0.13±0.02	631.68±42.94abc

* ns = not significant

** Different letters that followed numbers within the same column indicated significantly different ($P \leq 0.05$) between the treatments.

overrun. Differences in the statistical results between the foaming agents could be affected by the high variation in the produced foam. Beside that, the foam overrun has a close relationship with the foam density, in which higher overrun values will indicate more air is trapped inside the foam and this will give rise to lower foam density. Based on the values obtained in Table 4.6, it showed that the highest overrun value was achieved by using 5 % concentration of GMS and methocel (1:1) with an amount of 63 g (31 %w/w) (level 3).

Syneresis of foam would result in the separation of liquid phase from the foam interface layer and result in thinning of the interface which eventually leaded to foam collapsing. Foam collapsing during aging is also due to gravity action on the foam and the increase in foam size because of small foams combine or merge together (Karim *et al.*, 1998). From Table 4.6., it could be seen that the amounts of foaming agents would

significantly affect the syneresis rate of the produced foams. For the 2 % concentration of GMS, higher levels of added foaming agents would also increase the syneresis rate of the foam. The syneresis results for the GMS was similar to the finding for tomato purees that was reported by Brygidyr *et al*. (1977). In their report, it was stated that foam with more additives would collapse faster. On the other hand, the observation of the syneresis rate made from GMS was differed from the finding of Karim and Wai (1998) that studied about starfruit puree. For the starfruit puree, it was found that foams with higher concentration of foaming agent exhibited less syneresis as compared to lower concentration of foaming agent. This conflicting observation may be attributed to the types of foaming agent, in which Karim and Wai (1998) used methocel as a foaming agent that varied from 0.1 to 0.5 % (w/w), while in this experiment a 2 % concentration of GMS with different amounts of 50 to 90 g was used. In addition, the nature of the raw material, such as chemical composition may affect the foam stability. One thing that should be noted from the syneresis rate result was its effect on the final yield of corn milk powder. The increasing syneresis rate made from the increasing amounts of the 2 % GMS concentration produced a decreasing yield of the corn milk powder. The final yield of the corn milk powder was reduced from 24.87 to 15.22 % as the syneresis rate of the foam increased from 0.10 to 0.20 ml/min. The syneresis rate had a direct impact on the final product because during drying, fractions of the foam were ruptured and sticked to a tray dryer. If the syneresis rate was high, then the foam fractions that sticked to the tray would also be increased and caused a reduction in the final yield of the corn milk powder.

It is interesting to find that the syneresis rate of 5 % concentration of GMS and methocel (1:1) was contradicted to the results of the 2 % GMS concentration. As the amounts of 5 % concentration of GMS and methocel (1:1) increased, the syneresis rate of the produced foam was significantly decreased. According to Bates (1964) who studied about foam-mat drying of tropical fruits, the role of GMS in the foam formation was worked as a foam inducer while methocel would act as a foam stabilizer. From this author report, it also suggested that at low amount of GMS and methocel (1:1), film interfaces were thin and could collapse easily. There was a high possibility that as the amount of GMS and methocel (1:1) increased, the thickness of the film interfaces would also increase and give a higher stability to the foam formation. One reason that supported

this possibility was because methocel is useful to reduce surface and interfacial tensions and aids in the formation of strong film. The compound can also stabilize interfacial films that help to form a stable foam. Therefore, the addition of methocel in the combination of GMS and methocel could help to make more stable foam formation from corn milk compared to the addition of GMS only as a foaming agent. The importance of methocel in making stable foams was also studied by Karim and Wai (1998), who concluded that foam stability is influenced by the thickness of the interface film, foam size distribution, interface permeability and surface tension.

4.3.2. The quality of corn milk powder

The quality of corn milk powder produced by foam-mat drying using an oven at 60 °C for 90 min was assessed by several parameters that included physical, chemical and microbiological qualities. For the physical properties, the powder was tested for its color, solubility, dispersibility and rehydration characteristics, which were presented in Table 4.7 and 4.8. In Table 4.7, the color of corn milk powder was showed together with the color of reconstituted corn milk. Color of both samples was represented in L*, a* and b* values. The L* values will show the lightness of the food products, the a* values will indicate greeness if it is negative values and redness if it is positive values and the b* values will indicate blueness if it is negative values and yellowness if it is positive values.

The color of corn milk powder that was showed in Table 4.7 showed that the powder had light color with slightly greeness and strong yellowness characteristics. This conclusion could be made because the L* value was in the range of 92.88 to 94.09, the a* value was between –7.09 to –6.60 and the b* value was between 25.08 to 30.88. These color range were represented the color of corn milk powders made either by 2 % concentration of GMS or 5 % concentration of GMS and methocel (1:1) at any addition levels. When analyzed by a statistical method, these color values were not significantly different for both the types and levels of foaming agents. This result was supported with the fact that methocel solution was a clear solution. Therefore, the addition of methocel in the combination of GMS and methocel did not have any effect on the color of the corn milk powder. According to Bunthawong (2004), methocel was used as a foaming agent in

makeang juices. The color values, L* values, a* values and b* values for makeang juice powders and its reconstitution were not significantly different.

For the color of reconstituted corn milk, the color measurement produced color value ranges of 57.37 to 62.76 for the L* value, -8.13 to -7.16 for the a* value and 17.16 to 20.35 for the b* value. These color value ranges were applied for the reconstituted corn milks produced by 2 % concentration of GMS and 5 % concentration of GMS and methocel (1:1) and were not significantly different either for different types or levels of foaming agents. Comparing the color results between the corn milk powders and the reconstituted corn milks, it could be concluded that a water addition caused the reconstituted corn milks to be darker and less yellowness. The reasons for this result are because the corn milk powders are stable foams that contain many gas inclusions in the dry state. Upon reconstitution, these product opacity and reduce apparent color intensity (Hart *et al*., 1963), color of maltodextrin, white powder, might be affect the color of corn milk powders and maltodrextrin. When comparing the color of the raw material corn milk from Table 4.1 with the reconstituted corn milks, it was found that the color of the corn milk was lighter and more yellowness compared to the reconstituted corn milks. The reason for this result is because during the process of making corn milk powders, the corn milk was added with sugar and passed a heat treatment that could cause browning reactions to be occurred.

Other physical analyses for corn milk powders were solubility, dispersibility and rehydration characteristics that were shown in Table 4.8. For the solubility property, the result showed that different types and levels of foaming agent did not significantly affect the solubility of corn milk powders. All the samples had a solubility range within 5.55 to 5.74 min.

Dispersibility is ability of powders to get wetted without formation of dry lumps in water. In this study, the dispersibility of corn milk powders was analyzed by measuring the optical density (OD) of the powders solution at a wavelength of 690 nm using a spectrophotometer. Powders that had a good dispersibility would exhibit higher OD as compared to the powders, which did not have a good dispersibility (lower OD). The reason for this is because foam structures that are retained in the dry product is very

Table 4.7 The color of corn milk powder and reconstituted corn milk made by 2 % GMS concentration and 5 % concentration of GMS and methocel (1:1).

Foaming agents	Level	Amount (g)	Color					
			Corn milk powder^{ns*}			Reconstituted corn milk^{ns}		
			L value	a* value	b* value	L value	a* value	b* value
2 % concentration of GMS	1	50	93.04±0.71	-6.88±0.16	30.88±3.91	58.71±4.08	-7.30±0.92	17.16±0.56
	2	60	93.72±1.59	-6.83±0.33	29.05±.0.46	60.73±2.97	-8.12±0.52	18.96±.3.40
	3	70	93.27±1.89	-6.79±0.40	30.30±1.54	58.10±0.36	-7.64±0.39	19.29±1.89
	4	80	94.09±1.80	-6.80±0.17	26.21±3.28	60.91±0.63	-8.13±0.34	19.47±1.78
	5	90	94.04±1.06	-7.09±0.48	26.89±2.62	57.37±0.97	-7.99±0.10	20.35±1.34
5 % concentration GMS:methocel (1:1)	1	43	93.46±1.15	-6.83±0.23	26.57±2.09	61.01±1.59	-7.16±0.85	18.78±0.28
	2	53	92.88±0.85	-6.62±0.26	26.21±1.67	61.22±2.40	-7.59±0.42	17.97±0.30
	3	63	93.74±0.96	-6.84±0.12	25.40±2.27	61.11±3.02	-8.10±0.16	19.39±1.03
	4	73	93.50±1.02	-6.83±0.20	25.92±1.14	62.45±3.65	-7.59±0.57	19.96±0.61
	5	83	93.36±0.32	-6.60±0.39	25.08±3.32	62.76±0.46	-7.79±0.57	19.65±0.67

* ns = not significant

Table 4.8 The solubility, dispersibility and rehydration characteristics of corn milk powder made by 2% concentration of GMS and 5 % concentration of GMS and methocel (1:1)

Foaming agents	Level	Amount (g)	Physical properties of corn milk powder		
			Solubility[ns*] (min)	Dispersibilty	Rehydration (%)
2 % concentration of GMS	1	50	5.66±0.15	0.47±0.08bcd**	77.95±0.50d
	2	60	5.74±0.19	0.52±0.08abcd	82.99±0.49b
	3	70	5.59±0.17	0.43±0.07cd	83.31±1.09b
	4	80	5.66±0.20	0.51±0.14abcd	81.23±0.34c
	5	90	5.62±0.16	0.36±0.06d	81.39±0.57c
5 % concentration GMS:methocel (1:1)	1	43	5.55±0.13	0.54±0.12abc	81.55±0.56c
	2	53	5.58±0.21	0.58±0.04abc	81.68±0.48c
	3	63	5.59±0.12	0.66±0.07a	84.66±0.19a
	4	73	5.64±0.18	0.65±0.04a	84.31±0.13a
	5	83	5.62±0.16	0.63±0.05ab	84.45±0.31a

* ns = not significant

** Different letters that followed numbers within the same column indicated significantly different ($P \leq 0.05$) between the treatments.

conductive to reconstitution. Therefore, a product that has high foam structures will tend to be dispersed readily in water (Hertzendorf, 1967).

The dispersibility results for the corn milk powders in this study showed that different types and levels of foaming agents were significantly affected the dispersibility of the final products (Table 4.8). The corn milk powders that used 5 % concentration of GMS and methocel (1:1) had higher OD or a better dispersibility than the powders that were made from 2 % concentration of GMS. This result was due to the stability of the formed foams during drying. The foams that were prepared using 5% concentration of GMS: methocel (1:1) were more stable in a drying oven compared with the foams produced by 2 % concentration of GMS. The stability of the foams during drying could

be seen from the syneresis property of the foams (Table 4.6), in which the foams made by 5 % concentration of GMS: methocel (1:1) had lower syneresis values compared to the foams prepared from 2 % concentration of GMS. Since the foams produced by 5 % concentration of GMS: methocel (1:1) were more stable during drying, the final products had a more porous structure than the powders using 2 % concentration of GMS. When the powders had a more porous structure, the powders would exhibit good dispersibility because water can get into the powder rapidly. The dispersibility of corn milk powders was also affected by the addition amount of foaming agents. For the 5% concentration of GMS: methocel (1:1), the dispersibility of the powders was tended to be increased as the amounts of added foaming agents increased. While for the 2 % concentration of GMS, the dispersibility of the powders was slightly to be reduced as the amounts of foaming agent increased. Again, the result was affected by the syneresis results of the foams and strongly determined the final yields of the powder produced. Applying higher amounts of 5 % concentration of GMS: methocel (1:1) would reduce the foam syneresis (Table 4.6), while the powder yields would be increased from 22.67 to 26.91 %. Therefore, when the foams were stable thoughout drying processes, which were shown by low syneresis rates, the produced powders would have a more porous structure, good dispersibility and high percentage of yield. This could be achieved by the addition of 5 % concentration of GMS: methocel (1:1) and the trend become clearer as the amount of foaming agent was increased. For the other reason, the more foaming agent increased, the more viscosity in the powders increased. Lumps of corn milk powders in water could be occurred when increased the higher amount of foaming agent or viscosity so dispersibility could be decreased. On the other hand, the 2 % concentration of GMS gave results in another way around. As the amounts of the 2 % concentration of GMS increased, the foams had higher syneresis rate, the powders had lower dispersibility characteristics and the final yields were reduced. The main reason for these results was due to fractions of foams that were ruptured and sticked to tray dryers causing a decreasing amount of porous structures and a reduction in the final yield. The GMS finding was similar to the report by Jaya and Das (2003) that increasing amount of GMS would decrease the dispersibility of the produced powder. For this study, the powders that had the highest dispersibility of 0.66 ±

0.07 was produced by the 5 % concentration of GMS: methocel (1:1) with an addition amount of 63 g (31.5 %w/w).

For the last physical property, rehydration, of corn milk powders, the results as were displayed in Table 4.8 showed that different types and levels of foaming agents were significantly affected this property. The rehydration results were even shown similar trends like the dispersibility results. For example, the rehydration property of the powders prepared from 5 % concentration of GMS: methocel (1:1) was higher than that of the powders made by 2 % concentration of GMS. Within the 5 % concentration of GMS: methocel (1:1), as the amount of the foaming agent increased, the rehydration characteristics of the produced powder became better or had higher values. On the other hand, as the amount of the 2 % concentration of GMS increased, the rehydration of the produced powders was slightly increased then it was reduced. The similarity for the results of the dispersibility and rehydration characteristics was due to the porous structure inside the dried powders as it had been expained in the previous paragraph. For the rehydration property, the results were in the range of 77.95 to 84.66 %. The highest value of 84.66 ± 0.19 % was achieved by the powder prepared from 5 % concentration of GMS: methocel (1:1) with an addition of 63 g (31.5 %w/w).

Beside the physical characteristics, the quality of corn milk powders was also compared based on the chemical and microbiological properties. These properties together with the percentage of the corn milk powder yields were shown in Table 4.9. From this table, it could be seen that the water activity (a_w) and moisture content of the powders were not significantly affected by different types and levels of foaming agents. All of these powders were processed at 60 °C for 90 min. The similarity of drying processes for all the powders was mainly determined a narrow range of their water activity and moisture contents. The water activity range for the powders was between 0.23 to 0.24, while the moisture contents had a range of 3.36 to 3.74 %. Although the statistical analysis showed that different levels of foaming agents did not significantly affect the moisture content of corn milk powders, there were some patterns that could be noticed. These patterns included decreasing moisture contents as the levels of the 5 % concentration of GMS: methocel (1:1) increased, while slightly increasing moisture contents as the levels of the 2 % concentration of GMS increased.

Table 4.9 The chemical and microbiological properties and the yield of corn milk powder made by 2 % concentration of GMS and 5 % concentration of GMS and methocel (1:1).

Foaming agents	Levels	Amount	Chemical property of corn milk powder			Microbiological properties of corn milk powder		Yield
		(g)	Carotenoid^{ns}* (μg/g)	a_w^{ns}	Moisture content^{ns} (%)	Total plate count^{ns} (cfu/g)	Yeast & mold^{ns} (cfu/g)	(%)
2 % concentration of GMS	1	50	5.66±0.15	0.24±0.01	3.57±0.27	$9.57x10^2$±2.38	$1.41x10^3$±8.86	24.87±1.04bc**
	2	60	5.74±0.19	0.24±0.02	3.69±0.28	$9.51x10^2$±2.79	$1.55x10^3$±8.72	23.13±1.35c
	3	70	5.59±0.17	0.23±0.02	3.74±0.17	$7.98x10^2$±4.54	$1.68x10^3$±7.56	19.79±2.67d
	4	80	5.66±0.20	0.23±0.02	3.65±0.04	$7.57x10^2$±4.57	$1.83x10^3$±8.34	18.98±0.67d
	5	90	5.62±0.16	0.24±0.01	3.69±0.17	$7.56x10^2$±5.51	$1.89x10^3$±1.07	15.22±1.65e
5 % concentration GMS:methocel (1:1)	1	43	5.55±0.13	0.22±0.01	3.67±0.32	$7.39x10^2$±5.96	$1.52x10^3$±7.72	22.67±0.72c
	2	53	5.58±0.21	0.23±0.02	3.61±0.24	$8.73x10^2$±4.84	$1.54x10^3$±8.87	24.53±0.71c
	3	63	5.59±0.12	0.23±0.02	3.36±0.03	$7.81x10^2$±5.92	$1.22x10^3$±6.03	27.26±0.65a
	4	73	5.64±0.18	0.24±0.03	3.48±0.31	$9.62x10^2$±3.96	$1.51x10^3$±6.38	27.40±0.48a
	5	83	3.62±0.16	0.23±0.02	3.40±0.17	$8.54x10^2$±4.52	$1.52x10^3$±5.98	26.91±0.50ab

* ns = not significant

** Different letters that followed numbers within the same column indicated significantly different ($P \leq 0.05$) between the treatments.

Different patterns between different foaming agents were affected by different structures of the final powders. As the foams made from the 5 % concentration of GMS: methocel (1:1) were more stable during drying processes than that of the 2 % concentration of GMS, the powder structure produced by the 5 % concentration of GMS: methocel (1:1) could retain more porous structures, which also meant higher surface area compared with the 2 % GMS powders that might have less porous structure and lower surface area. In another word, the foams that could have higher stability during heated air-drying would retain more of their open structure, which would eventually facilitate rapid drying and detraying and produce powders with low moisture contents.

Chemical analyses of corn milk powders were also included the carotenoid and vitamin C contents. It could be seen in Table 4.9 that different types and levels of foaming agents did not significantly affect the carotenoid contents of the corn milk powders. The main reason for this finding was because the carotenoid content as with the water activity and moisture contents had a more close relationship with the time and temperature of drying processes than with the foaming agents. Since the drying processes were similar for all the corn milk samples, the corn milk powders contained carotenoids within a narrow range of 10.26 to 11.99 μg/g. For the vitamin C contents, the analysis could not find any traces of this vitamin in the corn milk powders. This result could be due to the high sensitivity of the vitamin to light, oxygen and temperature.

The microbiological analyses for corn milk powders were done for total plate count and the amount of yeast and mold in the final products. The results for both measurents as were shown in Table 4.9 showed that different types and levels of foaming agents did not significantly affect the microbiological quality of corn milk powders. Again, this microbiological quality was more affected by the processing conditions rather than the foaming agents.The result of the analyses showed that the corn milk powders had total microbiological count in a range of $7.39 \times 10^2 - 9.62 \times 10^2$ cfu/g and yeast and mold within the range of 1.22×10^3 to 1.89×10^3 cfu/g. This result indicated that the number of yeast and mold was slightly higher than the total number of microorganisms. The finding was mainly due to the initial numbers of these microorganisms in corn milks. As it was shown in Table 4.1, the number of yeast and mold in corn milk which was 2.58×10^5 cfu/g, was higher than the total number of microorganisms, which was 8.93×10^4

cfu/g. However, the microbiological quality of the corn milk powders was still acceptable, since the FDA of Thailand gave a maximum limit for the total amount of microorganisms in powder food that can be detected is 1.00 x 10^5 cfu/g (Anonymous, 2002).

For the percentage of yield of corn milk powders, Table 4.9 displayed that different types and levels of foaming agents were significantly affected the final results. Between different types of foaming agents, 5 % concentration of GMS: methocel (1:1) showed higher yields than 2 % concentration of GMS. Within the 5 % concentration of GMS: methocel (1:1), higher levels of the foaming agents gave higher yields of the final powders. Whereas for the 2 % concentration of GMS, higher amounts of the foaming agents would produce lower yields of the corn milk powders. As it had been discussed in the previous paragraphs, the foams prepared by the 5 % concentration of GMS: methocel (1:1) were more stable during drying processes compared to the foams made from the 2 % concentration of GMS. Therefore during the drying processes, some fractions of the foams produced by the 2 % concentration of GMS were ruptured and sticked to tray driers causing ploblems in detraying processes, some losses of the powders and decreasing the final yield of corn milk powders. Beside that in the combination of GMS and methocel, methocel aids in formation of strong films and stabilizes the interfacial films. The viscosity of the methocel solution can stabilize the interfacial films by increasing its thickness. Methocel can also help to reduce separation of the liquid phase from the interface layer, which can result in thinning of the interface that can lead to foam collapsing and to resist to disturbing influences. The result of the powder yield was strongly correlated with the syneresis rate (Table 4.6). The highest percentage of yield of 27.40 ± 0.48 % was achieved in the powder produced from the 5 % concentration of GMS: methocel (1:1) with an addition amount of 73 g (36.1 %w/w).

4.3.3 Hygroscopic characteristics

Hygroscopic characteristics of corn milk powders, which were shown as rehydrate rates of the powders could be seen in Figure 4.1. In this figure, the rehydrate rates of the corn milk powders prepared from 2 % concentration of GMS for 5 levels and 5 % concentration of GMS: methocel (1:1) for 5 levels were displayed. For 7 days, these

powder samples were exposed to an open environment at room temperature and the results were clearly indicated that the powder absorbed moisture rapidly in the first five days of storage. According to Chronakis (1998), maltodextrin that was exposed to an open environment of 75 % and more relative humidity was behave more like a pastry in texture after 6 days. For the corn milk powders, the rehydrate rate was very high at the beginning because there was so much differences between the moisture content in the powder and in the environment. The rehydrate rate was reduced by an increase in the storage time because the differences in the moisture content between the samples and environment were reduced until the moisture content in the powder samples was equal to that of the environment. When this condition was achieved, the rehydrate rate would become constant. This study also found that the hygroscopic rate was slightly decreased with increasing amounts of GMS. This finding was similar to the report from Jaya and Das (2003) who also found that the hygroscopic rate of starfruit was decreased with an increase amount of GMS.

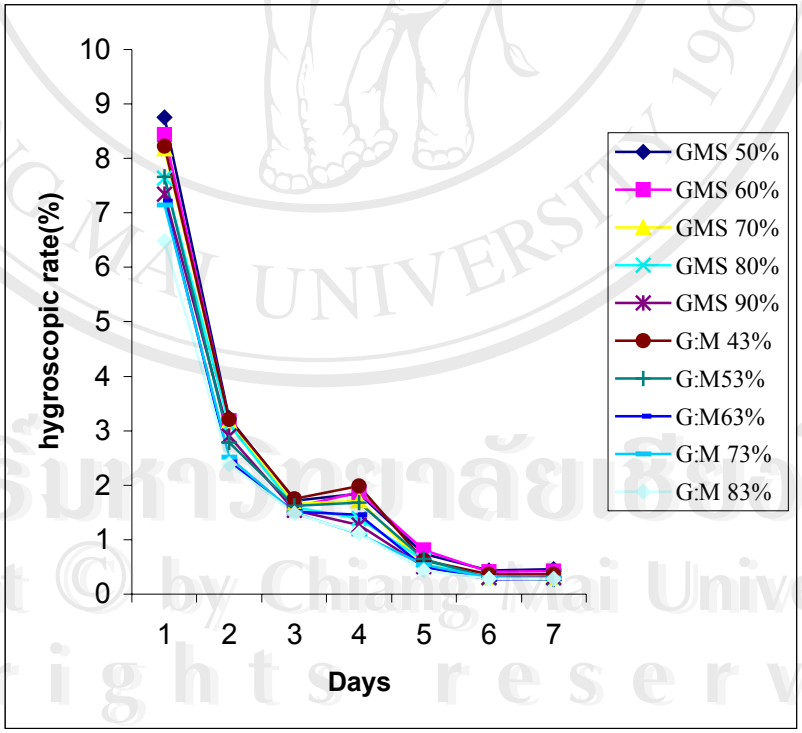

Figure 4.5 Hygroscopic characteristics of corn milk powder made by 2% concentration of GMS and 5% concentration of GMS and methocel (1:1).

As an overall result of this subchapter, it could be concluded that 5 % concentration of GMS: methocel (1:1) with an addition amount of 63 g was the best type and amount of foaming agent to produce corn milk powders by foam-mat drying. This conclusion was made based on the optimal characteristics of the produced foams and some properties of the final powders. The foams prepared from the 5 % concentration of GMS: methocel (1:1) for 63 g (31 %w/w) had the lowest density value of 0.12 ± 0.01 g/ml, the lowest syneresis rate of 0.06 ± 0.01 ml/min and the highest overrun value of 698.93 ± 52.92 % (Table 4.6). At the same time the same foaming agent could produce powders with the highest dispersibility of 0.66 ± 0.07, the high rehydration property of 84.66 ± 0.19 % (Table 4.8) and a high yield result of 27.27 ± 0.65 % (Table 4.9). For the other powder characteristics included color, color of the reconstituted corn milks, solubility, carotenoid contents, a_w, moisture contents, the amount of total microorganisms, yeast and mold, the corn milk powders produced by 5 % concentration of GMS: methocel (1:1) for 63 g did not significantly different with the other corn milk powders from different levels of the 5 % concentration of GMS: methocel (1:1) or from different levels of 2 % GMS concentration.

4.4 A study of the suitable time and temperature of drying processes in the production of corn milk powders by foam-mat drying.

4.4.1 Drying processing time

In this study, 3 drying temperatures, which were at 60, 70 and 80 ^{0}C, were studied to produce corn milk powders. Corn milk was firstly foamed by an addition of 5% concentration of GMS and methocel (1:1) for 63 g (31 %w/w) and then dried at different drying temperatures. During the drying processes, samples of corn milk powders were collected every 10 min interval to determine their moisture contents.

The results for the moisture content determination of corn milk powders drying at temperatures between 60 to 80 ^{0}C could be seen in Table 4.10. From these results, it was shown clearly that the moisture content of the corn milk powders was significantly affected by the drying period. As the drying time increased, the moisture content of the powders would be reduced significantly. Corn milk powders with a moisture content of

4% or below could be produced at 60 ^{0}C after drying for 90 to 120 min, whereas at a drying temperature of 70 ^{0}C a shorter drying time of 60 to 90 min would be sufficient. At 80 ^{0}C drying temperature, corn milk powders with a low moisture content could not be produced because the foam of corn milk were collapsed after 20 min in a drying oven. The reason might be the air in the bubbles were expanded at high temperature so small bubles could be diffused to big bubble and made foams collapsed. For the corn milk powders that had a moisture content at or below 4%, the powders were studied further for their physical, chemical, microbiological and overall qualities to determine the best time and temperature drying condition to produce corn milk powders by foam-mat drying. The reason for choosing a moisture content of 4% was because the food regulation of the Food and Drug Administration of Thailand gives a guideline that the maximum moisture content in powder food is 5% (Anonymous, 2002).

Table 4.10 Moisture contents (%) of corn milk powders drying at 60, 70 and 80^{0}C.

Time (min)	Drying temperatures		
	60 °C	70 °C	80 °C
0	88.69±1.31j*	88.71±1.58g	88.87±0.66
10	81.09±1.82i	78.26±1.44f	76.33±0.48
20	75.87±0.51h	72.72±0.51e	71.57±0.54
30	68.88±0.54g	60.11±3.76d	Foam collapsed
40	61.81±1.33f	33.98±3.89c	
50	38.50±0.99e	17.98±2.51b	
60	21.26±0.79d	3.44±0.37a	
70	10.05±1.22c	2.82±0.42a	
80	6.85±1.33b	2.44±0.28a	
90	3.68±0.10a	2.37±0.18a	
100	3.89±0.48a		
110	3.12±0.09a		
120	2.69±0.10a		

* Different letters that followed numbers within the same column indicated significantly different ($P \leq 0.05$) between the treatments.

Drying curves at 60 and 70 ^{0}C for corn milk powders produced by foam-mat drying were illustrated in Figure 4.6. These corn milk powders were made from foams that had an initial moisture content of 88.76 ± 0.19 %. During the drying processes, this moisture content was falled sharply to a moisture content below 4% within 60 min at 70 ^{0}C and 90 min at 60 ^{0}C. After these points, the drying curves became flatter as the moisture content levels approached an equilibrium value and the drying rate approaching zero. The drying profiles for the corn milk powders showed the absence of a constant rate period, instead the major part of the drying process of the corn milk foam occurred in falling rates. Similar observations were reported by Cook *et al*. (1976) for foam-mat drying of mango puree, Karim and Wai (2003) for foam-mat drying of star fruit purees and Ratchaniyom (2002) for foam-mat drying of longan juices. In contrast, Brygidys *et al.* (1977) observed both constant rate and falling rate periods in foam-mat drying of tomato purees. It thus approved that foam-mat drying profiles are product dependent. This could be attributed to the solid content and the chemical composition of raw materials (Karim and Wai, 2003). Between the drying curves at 60 and 70 ^{0}C, it was shown clearly that the falling rate of the foam moisture content at 70 ^{0}C was occurred in higher values compared to that at 60 ^{0}C. Powders with low moisture contents of below 4 % could be achieved 30 min faster at 70 ^{0}C. However, after these levels of moisture contents, the drying rates both at 60 and 70 ^{0}C reduced significantly and became more stable.

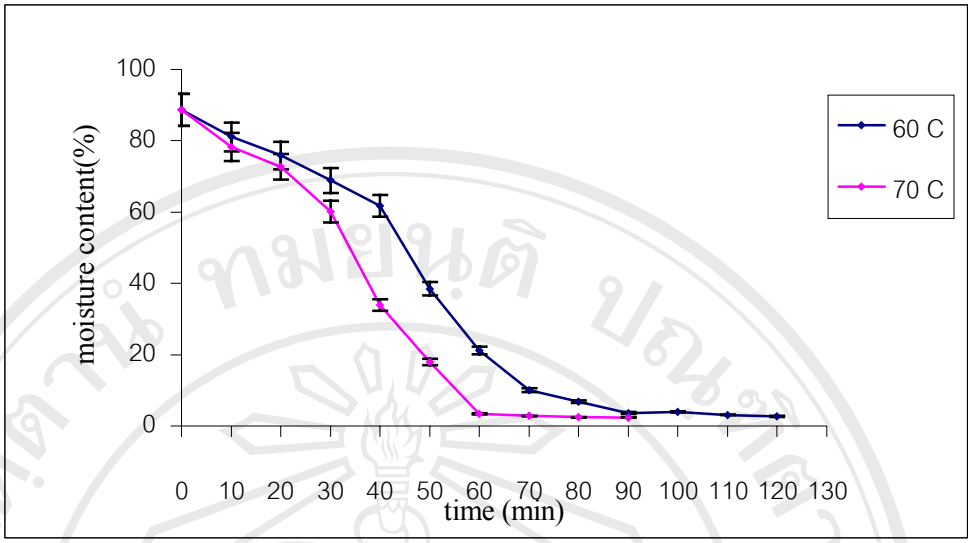

Figure 4.6 Drying curves at 60 and 70 ^{0}C for corn milk powders produced by foam-mat drying.

4.4.2. The properties of corn milk powders.

Based on the previous result of subchapter 4.4.1, in this chapter the qualities of corn milk powders would be evaluated using 2 drying temperatures of 60 and 70 ^{0}C and 4 levels of drying time, which were between 90 to 120 min or between 60 to 90 min respectively. The corn milk would also be added with a 63 g of 5% GMS and methocel (1:1) concentration, a sugar addition at 15 °Brix and 25 % maltodextrin (chapter 4.2 and 4.3). The assessment results of the final powders, which included physical, chemical and microbiological qualities were shown in Table 4.11 and 4.12.

In Table 4.11, the results of color measurement for both corn milk powders and reconstituted corn milks were displayed. From these results, it was shown clearly that the time and temperature of drying processes did not significantly affect the color of the final products. The color of the corn milk powders, were represented as L*, a* and b* values were in the range of 90.47 to 92.48, - 6.73 to – 6.20 and 23.65 to 28.81, respectively. These color values showed that the corn milk powders had a light color with slightly green and yellow color directions. The color results of corn milk powders in this experiment were lighter than the color results of powders from Ratchaniyom (2002) who studied foam-mat drying of longan juices and Sommanut (1997) who studied foam-mat drying of banana. The reason for the differences was due to different sugar contents.

Table 4.11 Color of corn milk powders and reconstituted corn milks made by 63 g of GMS and methocel (1:1) concentration and dried at 60 and 70 ^{0}C.

Temperature (°C)	Time (min)	Color of corn milk powder and reconstituted corn milk					
		Corn milk powder^{ns*}			Reconstituted corn milk^{ns}		
		L value	a* value	b* value	L value	a* value	b* value
60	90	92.09±1.62	-6.38±0.25	23.67±0.78	65.55±1.79	-7.36±0.18	19.26±1.80
	100	91.80±0.73	-6.46±0.27	25.11±0.96	66.02±3.37	-7.03±0.18	18.51±1.68
	110	91.28±2.39	-6.69±0.48	26.80±3.21	66.92±3.24	-7.57±0.98	20.07±0.73
	120	90.47±3.40	-6.73±0.11	25.94±2.15	65.88±1.64	-7.63±0.98	20.37±1.13
70	60	91.72±3.58	-6.33±0.29	28.81±2.88	64.59±2.66	-6.92±0.66	21.02±1.10
	70	92.48±2.46	-6.29±0.30	24.21±3.32	63.00±3.13	-7.20±0.57	21.62±1.19
	80	91.19±2.82	-6.20±0.33	25.41±1.93	62.39±1.99	-6.95±0.88	19.70±2.42
	90	92.17±2.03	-6.52±0.41	23.65±1.67	64.63±3.55	-7.42±0.66	19.24±3.46

* ns = not significant at $P \leq 0.05$

Table 4.12 Physical, chemical and microbiological qualities of corn milk powders made by a 63 % (w/w) of GMS and methocel (1:1) and dried at 60 and 70 ^{0}C.

Temperature	Time	Physical properties of corn milk powder			Microbiological properties of corn milk powder		Chemical properties of corn milk powder		
(°C)	(min)	Solubility^{ns*} (min)	Dispersibilty^{ns}	Rehydration^{ns} (%)	Total plate count (cfu/g)	Yeast & mold (cfu/g)	Caroteniod (μg/g)	$a_w{}^{ns}$	Moisture content^{ns} (%)
60	90	5.88±0.37	0.70±0.14	81.70±3.66	$1.54x10^3±1.02\ x10^2$a**	$8.39x10^2±1.96\ x10^2$a	9.34±0.79ab	0.28±0.03	3.68±0.10
	100	6.21±0.25	0.76±0.12	82.88±1.20	$7.61x10^2±1.09$ x10c	$6.81x10^2±1.07x10^2$ab	8.13±0.26bcd	0.25±0.02	3.89±0.48
	110	6.14±0.36	0.76±0.08	84.37±2.07	$5.45x10^2±5.57\ x10^2$d	$4.56x10^2±1.04\ x10^2$c	6.06±0.58e	0.24±0.04	3.12±0.09
	120	6.32±0.46	0.74±0.10	83.05±1.67	$4.00x10^2±7.44x10^1$c	$3.89x10^2±5.70x10^2$c	6.02±0.55e	0.26±0.05	2.69±0.10
70	60	5.88±0.37	0.65±0.10	84.52±2.22	$1.40x10^3±7.44x10^2$b	$8.10x10^2±1.38\ x10^2$a	9.61±0.33a	0.27±0.02	3.44±0.37
	70	5.99±0.26	0.75±0.03	85.52±3.04	$4.27x10^2±2.64\ x10^2$de	$5.50x10^2±8.08x10^1$bc	8.57±0.78abc	0.28±0.08	2.82±0.42
	80	6.27±0.40	0.78±0.06	84.37±0.22	$3.81x10^2±6.36\ x10^2$e	$3.39x10^2±5.89\ x10^1$c	7.71±0.92cd	0.25±0.02	2.44±2.28
	90	5.91±0.59	0.76±0.05	86.21±1.40	$3.72x10^2±3.56\ x10^2$e	$3.12x10^2±1.60\ x10^1$c	7.16±1.13de	0.23±0.04	2.37±0.18

* ns = not significant $P \leq 0.05$

** Different letters that followed numbers within the same column indicated significantly different ($P \leq 0.05$) between the treatments.

Longan juices and banana would have higher sugar contents than corn milk that cause browning reactions to be occurred in a higher rate. Slightly different to these results, the color of the reconstituted corn milks were in the range of 62.39 to 66.92 for L* values, -7.63 to – 6.92 for a* values and 18.51 to 21.62 for b* values. This meant that the reconstituted corn milks were much more darker with slightly greener and less yellow color directions compared with the color of the powders. These results were mainly affected by a water addition were similar to the finding of the previous subchapter 4.3.2.

The physical parameters of corn milk powders represented in solubility, dispersibility and rehydration were shown in Table 4.12. All of these physical parameters was shown not to be significantly affected by the time and temperature of drying processes. For the solubility results, it was found that the corn milk powders needed to be mixed within 5.88 to 6.32 min of stirring. After the powders were mixed with water, the reconstituted corn milks had a rehydration range of 80.70 to 86.21 % with a dispersibility range between 0.65 to 0.78. The dispersibility of the corn milk powders was higher than the dispersibility of makeang juice powders. The makeang juice powders had dispersibility values in the range between 0.17 to 0.19 as reported by Bunthawong (2004). Since the dispersibility is the ability of powders to get wetted without the formation of dry lump in water, the higher value of dispersibility, which was done by measuring OD at 690 nm would show that the powders could disperse better than the one that had a low value. For the dispersibility results of corn milk powders, there was a trend that the dispersibility of the powder would be slightly higher as the drying time increased.

Water activity has played a major role in many aspects of food preservation and processing. It is defined as the ratio of vapor pressure of water in food to the vapor pressure of pure water at the same temperature. The effect of water activity was studied not only to define the microbial stability of a product but also on biochemical reactions in the food system and its relation to the food stability. Water activity has become the most useful parameter that can be used as a reliable guide to predict food spoilage or to determine the drying end point required for a shelf-stable product (Joyaraman and Gupla, 1995). Normally, the water activity range for dehydrated foods is less than or equal to 0.4 (Fennema, 1996). In this chapter, 2 drying temperatures of 60 and 70 ^{0}C combined with 4 levels of drying time did not significantly affect the water activity content of corn milk

powders. The powders had a water activity range between 0.23 to 0.28, which was slightly higher than a water activity of makeang juice powders that had a water activity range between 0.21 to 0.23 (Bunthawong, 2004). However, the water activity of the corn milk powders was lower than a water activity of banana powders, which was 0.42 (Sommanut, 1997). For the moisture contents of the corn milk powders, the similar statistical analysis results like the water activity were also applied. These moisture contents were in the range of 2.37 to 3.89 % for all the dried powders. Although the statistical analysis showed that different treatments were not significantly different, the data results indicated that as the drying time increased, the moisture contents and the water activity of the corn milk powders would be decreased. If comparing this finding with the results of rehydration and dispersibility, it could be noticed that as the corn milk powders had lower water activity and moisture content values, the rehydration and the dispersibility of the powders would be increased. Therefore it could be concluded that the physical properties of dried powders had a strong relationship with their moisture contents and water activities. As the powders become drier, their physical properties will also become better.

For the vitamin content of corn milk powders, the analysis results for carotenoid showed that different time and temperature of drying processes were significantly affected the carotenoid content in the powders (Table 4.12). Between different heating temperatures with a similar drying time, the carotenoid content would be less at 70 °C compared with that at 60 °C. Whereas at the same heating temperatures, the carotenoid contents would be significantly lower as the drying time increased. The measurement of carotenoids in this study was used to determine the efficiency of drying processes on the nutrient contents of the corn milk powders, since carotenoids are susceptible to oxidative changes. From the results presented in Table 4.12, it showed that the oxidative change of carotenoids would happen at a higher rate when processed longer at 60 ^{0}C compared with processing at 70 ^{0}C. Increasing the processing time for 30 min at 60 ^{0}C would reduce 3.32 μg/g of the carotenoid content in the corn milk powders. Whereas doing the similar thing at 70 ^{0}C would only reduce 2.45 μg/g . Therefore, to keep a high carotenoid content in the powders, it would be better to dry the corn milk at

higher temperature processing for a shorter time compared with a low processing temperature for a longer time.

The microbial quality of corn milk powders represented by the numbers of Total Plate Count, and yeast and mould showed that different time and temperature of drying processes would significantly affect the number of these microorganisms (Table 4.12). Using a drying temperature of 70 ^{0}C would produce a lower number of microorganisms compared with a drying process at 60 ^{0}C for a similar processing time. Whereas drying the corn milk at a longer processing time within one drying temperature would also significantly reduce the number of microorganisms. All of the results of the microbial analyses showed that the microbial quality of the corn milk powders was within the microbial standard of dried products suggested by the Thai Food and Drug Administration (FDA) (Anonymous, 2002). In addition Vaughn (1951) has stated that several factors that could markedly influence the microbial population of dehydrated products would include the microbial quality of fresh produce, the method of pretreatment of the vegetable, the time elapsed between preparation of the vegetables and start of the dehydration process, the time involved in the dehydration of the product, the temperature of dehydration, the moisture content of the finished product and the general level of sanitation in the dehydration plant. Among these factors, the factors of time and temperature of drying processes were shown to have a significant effect on the microbial quality of the corn milk powders. Beside these factors, the results of microbial analyses would also show some correlationships with the concentrations of water activity and moisture content in the corn milk powders. As the drying time increased , the numbers of microorganisms would be decreased and also the concentrations of water activity and moisture content in the corn milk powders.

4.4.3. Hygroscopic characteristics

The results of hygroscopic characteristics of 8 different treatments of corn milk powders produced using a 63 g (31.5 %w/w) of 5 % GMS : methocel (1:1) concentration and dried at 60 ^{0}C for 90 to 120 min or at 70 ^{0}C for 60 to 90 min were displayed in Figure 4.7. In this figure, the hygroscopic characteristics of the corn milk powders were showed as their rehydrate rates were done by exposing the powder samples to an open

environment for 7 days at room temperature. From the results, it showed that the powders absorbed moisture very rapidly in the first day of storage followed by a reducing rate between 2nd to 5 th days of storage and became almost stable at the end of the storage time. The hygroscopic characteristics for the corn milk powders showed a similarity with the results of makeang juice powders as reported by Bunthawong (2004) who studied foam-mat drying of makeang juices. The makeang juice powders would absorbed moisture very rapidly in the first 3 days of storage followed by reducing rates of moisture absorption. The rehydrate rate behaviour of the corn milk powders could be observed because at the beginning of storage, the differences of moisture contents between the powder samples and the environment was very big, therefore a very high rehydrate rate between 7.19 ± 0.15 to 9.05 ± 0.15 % was occured. A much reducing rehydrate rate was followed afterwards since the moisture content gaps between the environment and the powder samples were decreased. The reducing in the moisture content differences between the environment and the powder samples kept continue with the storage time until it was equal and the rehydrate rate would also become constant, which was happened at the end of the storage time.

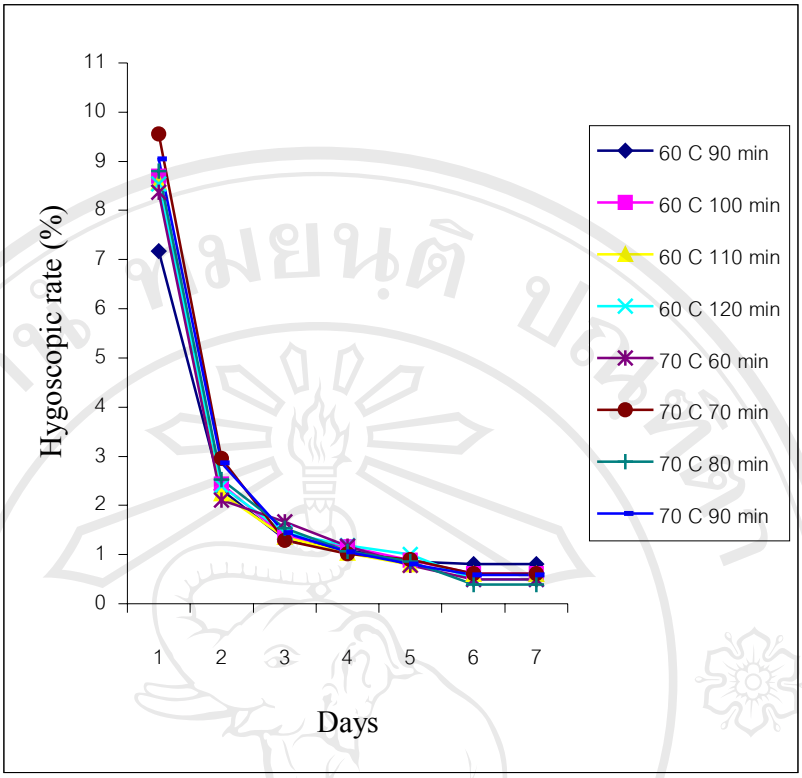

Figure 4.7 Hygroscopic characteristics of corn milk powders from 5 % concentration of GMS and methocel (1:1) and dried at 60 ^{0}C for 90 to 120 min and at 70 ^{0}C for 60 to 90 min during 7 days storage at room temperature.

As a conclusion from this chapter, it could be stated that corn milk powders that were prepared using a 63 g (31.5 %w/w) of 5% GMS : methocel (1:1) concentration combined with a sugar addition at 15 °Brix and 25 % maltodextrin and produced by foam-mat drying should be processed using a drying combination at 70 ^{0}C for 70 min. Applying this drying process would produce the best powder quality within a reasonable short drying time. This powder quality was observed based on the carotenoid content and the microbial quality of the powder. When comparing the carotenoid contents (Table 4.12), the corn milk powder with the highest carotenoid content of 9.61 ± 0.33 µg/g was made by a drying process at 70 ^{0}C for 60 min. However, this amount of carotenoid was not significantly different with the powder samples produced at 70 ^{0}C for 70 min, which had a carotenoid content content of 8.57 ± 0.78 µg/g. Beside that, drying the corn milk powders at 70 ^{0}C for 70 min would produce samples with low numbers of

microorganisms (Table 4.12). These numbers of microorganisms, which were $4.27x10^2 \pm 2.64\ x10^2$ cfu/g for Total plate Count and $5.50x10^2 \pm 8.08x10^1$ cfu/g for yeast and mold were significantly lower than the powder samples produced at 70 ^{0}C for 60 min, but they were not significantly different with the powder samples drying at 70 ^{0}C for 80 and 90 min. Other powder qualities, included powder's color, color of reconstituted corn milks, solubility, dispersibility, rehydration, water activity and moisture content of the powder samples drying at 70 ^{0}C for 70 min were not significantly different than those of the samples processed at the same temperature for 60, 80 and 90 min.