

STUDY ON COCONUT MILK EMULSION STABILITY

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ABSTRACT

The study was conducted to determine some factors which affect the stability of coconut milk.

The milk stability from desiccated coconuts decreased with increase in drying temperature due to the denaturation of protein. However, milk stability increased with decrease in moisture, sugar and protein contents and with increase in total solids, NFE and phospholipid content.

By using stepwise regression analysis, a statistical model was established, defining the stability of coconut milk from desiccated nuts.

INTRODUCTION

The fruit of the coconut palm (*Cocos nucifera* L.) is the most commercially useful component of the coconut. In turn, the meat or white kernel is the most economically important part of the fruit. The meat is mostly dried into copra from which coconut oil is extracted. The fresh meat of mature coconuts yields coconut milk, which is used as food ingredient in all coconut producing countries or in the manufacture of jams like "coco honey" (Ignacio, 1976). Currently, there is a wide spread interest in the development of commercial methods of preparation yielding products of extended shelf life, such as canned coconut milk and creams (Timmins and Kramer, 1977).

Although fresh coconut meat contain only about 4% protein, they are nevertheless a potential source of protein because of the great world production of coconut, primarily in regions deficient in high protein foods. The world's coconut yield in terms of copra has been estimated to be 5.6 million metric tons annually (Orr and Adair, 1967). The coconut oil has been well characterized (Child, 1974), while amino acid composition and nutritional value of the coconut protein have been studied by some researchers, such as Srinivasan *et al.* (1964), Krishnamurthy *et al.* (1958), Phung-Le-Anh and Lugay (1967), Luis (1969), Melo (1969), Samson *et al.* (1971), Hagenmaier *et al.* (1972), Wu and Ingle (1974), Velasco (1978), Baptist (1963) and Lachance and Molina (1974). However, insufficient data has been obtained on the physico-chemical properties of coconut milk.

Little has been known of the nature of the coconut emulsion systems. Anyhow, parallels can be reasonably drawn with similar emulsions containing oil and water, stabilized by proteins like the cow milk emulsion which has been

studied extensively (Dendy and Timmins, 1973). The oil content of coconut milk differs markedly from that of cow's milk, which has about ten times as much oil as protein. The inherent instability of the coconut milk emulsion system could be attributed to its high fat content, which is 26.4% (Tejada, 1973). The difference in density of fat compared to the aqueous skim milk portion, together with the inherent immiscibility of the two phases, would cause the fat to rise to the surface of the aqueous phase resulting in creaming. Clemente and Villacorte (1933) claimed that the coconut milk emulsion is stabilized by protein. Furthermore, it was found out that phospholipids and galactomannan found in coconut milk may also affect its stability (Balasubramaniam, 1976; Balasubramaniam and Sihotang, 1979; Payawan, 1974).

Thus, it is important to study the physical and the chemical properties of coconut milk in relation to its emulsion stability and other factors which may affect the resulting processed coconut milk products. It is envisioned that this study will contribute to the improvement of the quality of preserved coconut milk, separation of proteins and oils in aqueous process, and the isolation of coconut protein.

Objectives of the Study

This study aims to determine the stability of coconut milk from fresh and desiccated coconuts and to determine the effect of heat on coconut milk stability and other factors which influence the stability of the coconut milk.

MATERIALS AND METHODS

Materials

12-month old nuts of Gading coconut (yellow dwarf variety) were used in this study. The nuts were obtained from the Lembaga Penelitian Tanaman Industri (Industrial Crop Research Institute), Bogor, Indonesia.

Methods

Chemical Composition, Physical Properties and Stability of Milk from Nuts of Varying Maturity.

Preparation of fresh coconut milk. The nuts were dehusked by using a bolo (a big knife), then broken into 2 parts, and followed by the removal of the meat from coconut shell. Measurement of the meat thickness was done at proximal, middle and distal with at least 3 measurement for each part.

The testa of coconut meat was removed by paring carefully with a knife and the meat comminuted with the use of stainless steel "parutan" (Indonesian term for manual grater).

Grated coconut meat was mixed with distilled water using a ratio of 1:1 (w/w), 1:2 (w/w) or 1:3 (w/w). The samples were first mixed with 2/3 of the water needed and then homogenized in Waring blender for 5 minutes at room temperature. The resulting slurry was squeezed and re-extracted by using the rest of the water. Extracts were pooled and strained through a fine cloth.

The yield of milk was obtained by weighing the grated coconut meat plus water added and the milk and then the value of the yield was calculated using the following equation:

$$\text{Yield} = \frac{\text{weight of coconut milk}}{\text{weight of grated coconut meat plus water added}} \times 100\%$$

Preparation of Milk From Heat-Treated Coconut Meat

- a. Preparation of dried coconut meat (desiccated coconut).

12-month old Gading coconuts were used in this preparation.

Grated coconut meat was dried to constant weight in an oven at 50, 60, 70, 80 and 90°C.

- b. Preparation of milk from dried coconut meat (desiccated coconut).

The procedure was the same with the preparation of fresh coconut milk.

Chemical and Physical Analysis

Chemical analysis. The coconut milks were analyzed for their chemical composition as follows:

Moisture content, ash content, crude fat, crude protein and crude fiber were determined by using AOAC standard methods (1970).

NFE - The amount of carbohydrate substances excluding cellulose was referred to as nitrogen-free extract (NFE). This value was obtained by subtracting the sum of percentages of moisture, ash, crude fat, crude protein and crude fiber from 100.

Total solid - This value was obtained by subtracting the percentage of moisture from 100.

Sugar content - The sugar content was determined by using the Anthrone method. The equipment used was Spectronic 20 (B & L) (Hari Suseno *et al.*, 1974).

Galactomannan content - The galactomannan content was determined by following the procedure described by Rao *et al.* (1961).

Phospholipid content - This procedure was adapted from a procedure to determine lipid phosphorus by MacDonald and Hall (1957).

Physical analysis. pH was measured by using a Beckman pH meter, while viscosity was determined by using Ostwald viscosimeter (Joslyn, 1970).

Coconut Emulsion Stability

There are no standard methods available for measuring the functional properties of components found in the emulsion relative to their ability to stabilize emulsion (Dubrow *et al.*, 1973, Rasekh and Metz, 1973).

Stability of emulsions can be evaluated by measuring three general phenomena characteristics of emulsion degradation: creaming, phase inversion and complete demulsification.

In this study the coconut milk emulsion stability was evaluated by using a modified method of Lamar *et al.* (1976), i.e. separation on standing method. The test was simple and had been used by some workers, and found applicable in comparing the stability of coconut milk.

The coconut milk (50 ml) was placed in 50 ml cylinders and the separation of the cream layer was observed at hourly intervals. A perfect emulsion system had 100% oil-rich layer and a very poor emulsion system had most of the oil separated into free oil with the bottom layer as a water-rich emulsion (serum).

RESULTS AND DISCUSSION

The chemical analysis of milks used in this study are shown in Appendix 1—3, while the results of stability test are shown in Table 1—3.

Table 1 shows that the milk from coconut meat dried at 50°C will still be stable up to 360-minute standing time. This was still observed up to 10-hour standing time. Those from meat dried at 60°C were stable only up to 5-hours, and after this point the values were also constant up to 10-hour standing time. Milk from meat dried at 70°C were still stable up to 4-hour standing time, those from meat dried at 80°C up to 150-minute standing time, and those from meat dried at 90°C up to 30-minute standing time. These indicate that the milk from meat dried at lowest temperature were more stable compared with those from meat dried at higher temperature, while those from fresh meat showed the lowest stability compared with the milk from dried meat. The phenomena significantly correlated with the denaturation of the protein, where the higher the drying temperature the higher the denaturation of the protein (Fig. 1) leading to lower stability of the coconut milk.

As shown in Tables 1, 2 and 3, the stability of fresh milk were lower than those from dried meats. However, the moisture content of fresh milk was higher than those from dried meats. As a result, their emulsion system was more easily destabilized during standing. The density differences between the oil and water resulted in creaming, and the rate of destabilization by creaming is governed by Stoke's law (Gopal, 1968; Petrowski, 1975).

Table 1. Stability of coconut milk (1:1, w/w) from 12-month old Gading nut^a.

SAMPLES	STABILITY OF COCONUT MILKS (1:1, w/w) (%) AT												
	Standing Time (Minutes)												
	0	30	60	90	120	150	180	210	240	270	300	330	360 ^b
Fresh milk	100	76.6	53.2	45.5	40.3	35.8	33.0	30.4	28.3	27.0	26.0	24.9	24.2
Milk prepared from meat dried at:													
50°C	100	100	100	100	100	100	100	100	100	100	100	100	100
60°C	100	100	100	100	100	100	100	100	100	100	100	97.6	96.6
70°C	100	100	100	100	100	100	100	100	100	99.6	99.6	99.3	99.3
80°C	100	100	100	100	100	100	99.7	99.7	99.5	99.2	98.9	98.6	98.3
90°C	100	100	99.0	98.0	97.3	96.6	95.8	95.4	94.6	93.7	92.2	91.0	90.0

^a Average of 3 replications.

^b Up to 10 hour observation the values were constant.

Table 2. Stability of coconut milk (1:2, w/w) from 12-month old Gading nut^a.

SAMPLES	STABILITY OF COCONUT MILKS (1:2, w/w) (%) AT												
	Standing Time (Minutes)												
	0	30	60	90	120	150	180	210	240	270	300	330	360 ^b
Fresh milk	100	56.0	28.8	24.4	22.8	21.8	20.8	20.0	19.7	19.3	18.9	18.5	18.5
Milk prepared from meat dried at:													
50°C	100	100	95.5	94.5	94.0	93.0	91.5	90.3	89.0	87.8	87.0	84.5	82.5
60°C	100	81.5	55.8	49.0	47.0	45.0	45.0	43.0	43.0	42.3	41.5	41.0	41.0
70°C	100	100	100	49.0	46.7	38.0	36.0	35.0	34.0	33.7	33.5	33.3	32.6
80°C	100	100	100	34.8	34.5	34.5	34.3	33.9	33.5	33.0	32.5	32.0	31.5
90°C	100	100	55.3	47.7	40.0	19.3	19.3	18.8	18.5	17.5	16.5	14.5	12.5

^a Average of 3 replications.

^b Up to 10 hour observation the values were constant.

Table 3. Stability of coconut milk (1:3, w/w) from 12-month old Gading nut^a.

SAMPLES	STABILITY OF COCONUT MILKS (1:2, w/w) (%) AT												
	Standing Time (Minutes)												
	0	30	60	90	120	150	180	210	240	270	300	330	360 ^b
Fresh milk	100	19.0	17.0	16.4	16.0	15.6	15.0	14.8	14.6	14.4	14.2	14.2	14.2
Milk prepared from meat dried at:													
50°C	100	95.0	85.0	76.0	60.0	59.0	57.0	56.0	55.0	54.0	53.0	52.0	51.0
60°C	100	60.0	50.0	49.0	48.0	47.0	46.0	45.0	44.0	43.0	43.0	42.0	42.0
70°C	100	80.0	60.0	50.0	42.0	41.0	40.0	38.5	38.0	37.0	36.0	35.0	35.0
80°C	100	32.0	30.0	28.0	26.0	25.0	24.0	23.5	23.0	22.5	22.0	21.8	21.8
90°C	100	22.0	20.0	19.0	18.0	18.0	17.5	16.9	16.5	16.0	15.5	15.0	15.0

^a Average of 3 replications.

^b Up to 10 hour observation the values were constant.

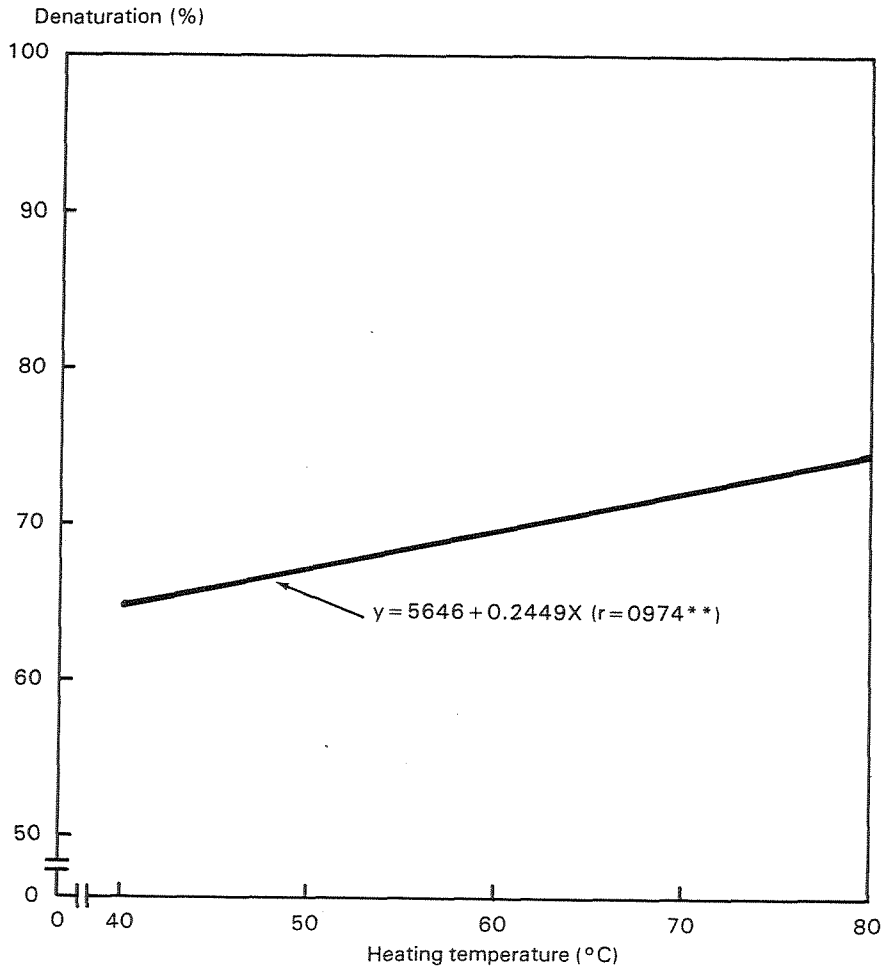


Fig. 1. The percentage of denaturation of coconut protein isolates at various heating temperatures (average).

$$V = \frac{2}{9} r^2 (S_1 - S_2) g / \eta$$

where V is the rate of fall of droplets, r is the radius of the droplet, S_1 is the specific gravity of the aqueous phase, S_2 is the specific gravity of the oil phase, g is the acceleration due to gravity and η is the viscosity.

The equation, therefore, predicts that the rate of creaming decreases with the increase in viscosity or the decrease in continuous phase of the emulsion. With higher viscosity or lower continuous phase, the Brownian motion is decreased, and the viscosity term is the Stoke's equation which leads to a

lower rate of creaming. This is also shown in fresh milk from various preparations, where the moisture content of the milk was higher with the increase of milk preparation. Thus, the milk from higher milk preparation ratio has lower stability values and therefore, the moisture content of the milk played an important role in coconut milk stability. Since total solids were obtained by subtracting the percentage of moisture from 100%, thus, it also could be concluded that the total solids played an important role in coconut milk emulsion stability.

In milks from dried meats (Tables 1, 2 and 3) their stability tended to decrease with the increase of drying temperature. This was significantly shown by milk prepared from 1:2 (w/w) and 1:3 (w/w) ratio. It was also shown by the study that the higher the water content of the milk the lower the stability of the coconut milk. Thus, this result was similar with that in fresh milk.

It was found out that the relationship between the moisture content and the milk stability followed the equation:

$$y = 125.767 - 0.995x \quad (r = -0.750^*)$$

Thus, it was found out that the stability of the milk increased with decrease in moisture content, leading to increase in its viscosity.

Other components which influenced the stability of the coconut milk from desiccated coconut were sugars and protein, which followed the equations:

Sugars:

$$y = 74.412 - 6.728x \quad (r = -0.745^*)$$

Protein content:

$$y = 102.181 - 4.635x \quad (r = -0.768^*)$$

The results show that the stability of the milk increased decrease in sugar and protein content.

The stability effect of the above mentioned components is believed to be due to increase in viscosity (Clemente and Villacorte, 1933; Puertolaño, *et al.*, 1970; Petrowski, 1975). It was found also in this study that the viscosity of milk is significantly correlated with the stability, where the higher the viscosity the higher the stability of the milk

$$y = -.3.35 + 12.2286x \quad (r = 0.935^*)$$

The components which affected the stability of the milk from various preparations, besides moisture and total solid were NFE and phospholipid which followed the equations;

NFE:

$$y = -185.52 + 4.25x \quad (r = 0.936^*)$$

Phospholipid:

$$y = -78.48 + 102.57x \quad (r = 0.962^{**})$$

Thus, it was found out that the stability of the milk increased with increase in NFE and phospholipid content.

The stability effect of those components except phospholipid is also believed to be due to increase in viscosity as stated earlier, while the phospholipid acts as an emulsifying agent (Lauridsen, 1976).

In this study the milk from desiccated coconut dried at 50°C showed the most stable emulsion in every milk preparation ratio. According to Monera (1980) the stable coconut milk emulsion will have globule size within the range 0.1 to 50 microns, which was also stated by Petrowski (1973).

By using Stepwise regression analysis it was found that the best model to predict the stability of coconut milk from desiccated coconut is by using the following equation:

$$y = -3541.04 + 35.76x_1 + 36.96x_2 - 5.88x_3 \quad (r = 0.918)$$

where y = stability, which has maximum value of 100

x_1 = moisture content

x_2 = total solids

x_3 = sugar content

Thus, by using the above equation the stability of coconut milk from desiccated nuts can be set by manipulating the value of the components.

In practice, as mentioned earlier, the easiest way to set the stability of milk is by manipulating the value of moisture content. If we have a given milk with the following characteristics: moisture content 75.81%, total solids 24.19%, and sugar content 2.31%, and we want to set its optimum stability, we can determine the value of the moisture content by using the above mentioned equation:

Thus:

Moisture content (x_1) =

$$100 + 3541.04 - 894.06 + 13.58/35.76 = 77.20$$

After we have obtained the value of the moisture content, we can adjust the moisture content of the milk by adding a certain amount of water to achieve the value of 77.20%.

SUMMARY AND CONCLUSION

A study to determine the factors affecting coconut milk stability was conducted using Gading coconut (dwarf variety).

Milk stability from desiccated nuts decreased with increase in drying temperature. This is correlated with the denaturation of the protein, where the higher the drying temperature the higher the denaturation of the protein leading to lower stability of the coconut milk. Other components which

influenced the stability of the milk were moisture, NFE, phospholipids, sugar, protein content and total solids. The stability of the milk increased with decrease in total solids, NFE and phospholipid content. The most stable milk (1:1 w/w) were obtained from the desiccated coconut dried at 50°C, which had the following characteristics: moisture content 41.56%; total solids 58.44%; fat 34.01% (d.b.); protein 9.75% (d.b.); NFE 55.58% (d.b.); crude fiber 0.01% (d.b.); ash 0.65% (d.b.); sugars 1.53% (d.b.); galactomannan 0.03% (d.b.) and phospholipid content 0.165 gr/100 cc.

By using Stepwise regression analysis it was found that the best model to set the stability of coconut milk from desiccated coconut is by using the following equation:

$$y = -3541.04 + 35.76x_1 + 36.96x_2 - 5.83x_3 \quad (r = 0.918)$$

where y = stability, which has maximum value of 100

x_1 = moisture content

x_2 = total solids

x_3 = sugar content

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Appendix 1. Analysis of coconut milk (1:1, w/w) from 12-month old Gading nut^a.

Sample	pH	Mois- ture (%)	Fat (%, d.b.)	Protein (%, d.b.)	NFE (%, d.b.)	Crude fiber (%, d.b.)	ASH (%, d.b.)	Total solids (%)	Sugars (%, d.b.)	Galacto- mannan (%, d.b.)	Phospho- lipid (as lecithin) (gr/100cc)
Fresh milk	6.0	71.81	24.91	5.25	58.87	9.62	1.36	28.19	0.61	0.07	0.083
Milk prepared from meat dried at:											
50°C	5.6	42.56	34.80	6.69	52.98	4.60	0.93	57.44	0.19	0.04	0.132
60°C	5.7	44.65	37.17	5.94	53.46	3.04	0.39	55.35	0.33	0.06	0.176
70°C	5.8	47.48	16.07	6.50	75.02	2.02	0.39	52.52	1.40	0.02	0.160
80°C	5.7	46.81	14.47	6.63	77.71	1.04	0.15	53.19	1.97	0.02	0.256
90°C	5.8	43.31	11.56	6.88	74.59	6.17	0.80	56.69	2.48	0.01	0.197

^a Average of 2 replications.

Appendix 2. Analysis of coconut milk (1:2, w/w) from 12-month old Gading nut^a.

Sample	pH	Mois- ture (%)	FAT (%, d.b.)	Protein (%, d.b.)	NFE (%, d.b.)	Crude fiber (%, d.b.)	ASH (%, d.b.)	Total solids (%)	Sugars (%, d.b.)	Galacto- mannan (%, d.b.)	Phospho- lipid (as lecithin) (gr/100cc)
Fresh milk	6.0	85.48	57.68	7.31	24.20	9.96	0.85	14.52	0.71	0.01	0.072
Milk prepared from meat dried at:											
50°C	5.6	69.86	39.58	7.06	46.90	5.94	0.52	30.14	0.50	0.04	0.116
60°C	5.8	65.28	25.20	6.50	64.70	3.20	0.40	34.72	0.84	0.07	0.165
70°C	5.9	75.81	37.32	11.56	47.88	2.49	0.75	24.19	2.31	0.03	0.076
80°C	5.9	66.89	10.69	7.63	79.78	1.36	0.54	33.11	3.85	0.03	0.160
90°C	5.8	55.31	18.01	5.88	70.80	4.95	0.36	44.68	6.05	0.00	0.164

^a Average of 2 replications.

Appendix 3. Analysis of coconut milk (1:3, w/w) from 12-month old Gading nut^a.

Sample	pH	Mois- ture (%)	FAT (%, d.b.)	Protein (%, d.b.)	NFE (%, d.b.)	Crude fiber (%, d.b.)	ASH (%, d.b.)	Total solids (%)	Sugars (%, d.b.)	Galacto- mannan (%, d.b.)	Phospho- lipid (as lecithin) (gr/100 cc)
Fresh milk	6.3	93.04	63.79	11.50	3.79	14.23	6.69	6.796	0.73	0.02	0.051
Milk prepared from meat dried at:											
50°C	6.2	61.02	9.47	9.54	75.06	3.34	2.59	38.98	0.67	0.04	0.089
60°C	5.8	91.82	26.14	14.34	41.18	11.61	6.73	8.18	0.28	0.14	0.128
70°C	5.9	80.63	27.99	9.77	57.96	1.08	3.20	19.37	3.14	0.01	0.067
80°C	5.9	88.05	14.76	13.55	63.04	3.17	5.48	11.95	1.27	0.02	0.156
90°C	5.8	89.87	10.58	15.67	57.54	10.46	5.75	10.13	5.26	0.01	0.120

^a Average of 2 replications.