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Comparative analysis of nutritional composition and droplet size of coconut milk due to dilution and emulsification

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Abstract

The high-fat content of coconut milk leads to instability of the emulsion and becomes the major limitation for its application in the food and beverage industries. It is also high in calories, which becomes a major debate among the consumers. Dilution and emulsification are important processes that are used to reduce the effect of high fat during the preservation process. In this study, water, sodium caseinate, and maltodextrin were added to the coconut milk. A sonicator and a high-shear homogenizer were used to homogenize the droplet. This study aimed to evaluate the effect of dilution and emulsification on the nutritional quality and stability of the emulsion. The nutritional composition was determined using proximate analysis. The stability of the emulsion was determined based on the properties of the droplets via particle size and microscopic analyses. The dilution process reduced the fat content; however, the addition of additives altered the nutritional quality of the emulsion, especially protein and carbohydrate content. It was also found that the emulsification process improves the particle size of the droplet as it creates a uniform size of the droplet and reduces the primary particle size to less than 6 µm. However, only the sonicated coconut milk has high stability with a creaming index of 0%.

1. Introduction

Coconut milk is one of the most popular plant-based milk alternatives to replace animal-based milk. The increasing demand for coconut milk worldwide is contributed by several main factors, i.e., increasing veganism, increasing demand for lactose-free milk, and the discovery of the health benefits of coconut milk fats and vitamins. Pure coconut milk contains more than 30% of saturated fat and lauric acid is the most predominant saturated fat. It is predicted that the powder form will conquer the market due to the increased use of coconut milk powder in food production worldwide (Market Research Future, 2019).

Attempts to prolong the shelf life of coconut milk to powder form are usually conducted using a spray drying process, but this process is aggravated by the high-fat content of coconut milk emulsion. The existing natural coconut milk protein is insufficient to emulsify the high amount of fat in the emulsion in its natural state and to withstand high shear during the atomization process. Therefore, there are two approaches usually conducted prior to the spray drying process in order to reduce the negative impact of fat during dehydration. The first approach is by adding water to coconut milk at a certain ratio to reduce the fat content of the emulsion. This step is also needed in order to allow the extraction process. However, the high moisture content of the feed is undesirable in the spray drying process as it will lead to a high moisture content in the produced powder (Fatimah *et al*., 2017), and more energy is required to remove the moisture (Fox *et al*., 2010). Secondly, it is important to add drying agents and emulsifiers to the coconut milk prior to the spray drying process in order to maintain the stability of the emulsion throughout the drying process (Campelo *et al*., 2017) and to allow free-flowing powder in the drying chamber (Seow and Gwee, 1997). However, this leads to a reduction in the nutritional quality of the dried powder. Commercial coconut milk powder produced in Asia has been found to consist of a high concentration (>50%) of maltodextrin to stabilize the fat (Viet Delta, 2015). On the other hand, Santana *et al*. (2017) found out that a high amount of maltodextrin (>20%) needs to be added to coconut milk emulsion in

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order to allow free flowing in the spray drying chamber due to its low interfacial properties.

The food composition of coconut milk after undergoing different processes needs to be evaluated as it might alter the composition of coconut milk. Food composition is important to estimate daily micronutrient intake (Grande and Vincent, 2020). In order to benefit from the goodness of lauric acid, it is suggested for an adult take 10 to 20 g of this nutrient per day (Suyitno, 2003). On the other hand, excessive intake of maltodextrin leads to weight gain, insulin resistance, and an increase in blood cholesterol and blood lipids (Hofman *et al*., 2016).

This study was conducted to evaluate the effect of dilution and emulsification on the nutritional composition of coconut milk. The stability of the emulsion is determined based on the particle size of the fat droplets.

2. Materials and methods

2.1 Sample preparation

The matured coconut was purchased from a local market in Selangor, Malaysia. The coconut was de-shelled, and the coconut meat was grated. For raw coconut milk, the coconut meat was filtered using a cloth filter to separate the liquid coconut milk from the solid. To study the effect of dilution and emulsification, water with a weight ratio of 1:1 was added to the grated coconut meat prior to extraction, and the extraction was conducted by using a slow juice extractor.

2.2 Homogenization process

Coconut milk is an oil-in-water (O/W) emulsion where the oil/fat is the dispersed phase and water is the continuous phase. Therefore, an emulsification process is needed to break the fat droplets to a smaller size and simultaneously emulsify the fats with an emulsifier to form a homogeneous mixture, i.e., the fat droplets remain suspended in the water.

Two different emulsified coconut milk were prepared namely, sonicated coconut milk and high-sheared coconut milk. For sonicated coconut milk, the diluted coconut milk was added with 2% of sodium caseinate (SC) and 8% of maltodextrin (Abdullah *et al*., 2020). Approximately 2% w/w of SC is added in the emulsion and pre-dispersed using a high-shear homogenizer (Sastec Laboratory Equipment, Malaysia) at 2,000×g for 30 s. Ultrasonic homogenization was then conducted using the Qsonica Q500 sonicator (Qsonica, Newtown, Connecticut, United States) with a 13 mm sonication probe. The ultrasonic frequency was fixed at 20 kHz with an input power of 500 W. The ultrasonic amplitude was fixed at 80% of 120 µm of the total amplitude and the homogenization time was fixed at 5 mins. Then, 8% w/w of maltodextrin was added to the emulsion and stirred for 30 mins at 500 rpm.

For the high-sheared coconut milk, 20% w/w of maltodextrin was added to the diluted coconut milk. Then, the mixture was homogenized using a high-shear homogenizer (Sastec Laboratory Equipment, Malaysia) for 10 mins at 1500 rpm.

2.3 Proximate analysis

The nutritional composition of coconut milk is determined based on proximate analysis by a commercial service provider (UNIPEQ Sdn. Bhd., Universiti Kebangsaan Malaysia). The standard AOAC methods were used to determine the protein (No. STP/Chem/A03 based on AOAC 16th Edition 981.10), total fat (No. STP/Chem/A02 based on AOAC 16th Edition 905.02 and 989.05), total carbohydrate (No. STP/ Chem/A06 based on Promerance Food Analysis: Theory and Practice, 2nd Ed. (pg 637), ash (No. STP/Chem/A05 based on AOAC 16th Edition 923.03), moisture (No. STP/Chem/A04 based on AOAC 16th Edi. 950.46) and energy content (No. STP/Chem/A01 based on Pearson's The Chemical Analysis of Foods (6th Edition, page 578).

2.4 Particle size analysis

The primary and effective droplet size of the emulsion was determined using an Integrated laser light scattering instrument (Mastersizer 2000, Malvern Instruments Ltd., Worcestershire, United Kingdom). Two different dispersants were used in the determination of the primary and effective size of the droplets i.e., distilled water and 1% sodium dodecyl sulfate (SDS) solution, respectively (Tangsuphoom and Coupland, 2005). The effective size measured the actual size of droplets in the emulsion including the flocculated droplets. On the other hand, the primary size determined the size of the individual droplet. The coconut milk refractive index was set at 1.34 (Abdullah *et al*., 2020).

2.5 Microscopic analysis

The microscopic image of fat droplets was analyzed using Leica confocal microscope. The fat size was observed at 100× magnification. In order to obtain an optimal image of the droplet, 0.5 mL of the sample was diluted in 10 mL of distilled water prior to the analysis. A small amount of sample was placed on the glass slide and covered with a coverslip. Three different points were imaged to represent the sample.

2.6 Creaming index

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The creaming index of the emulsion was determined by placing 40g of the emulsion in the transparent cylindrical test tube (Abdullah *et al*., 2018). The total height of the emulsion ($H_{emulsion}$) was measured using a graduated scale. After 24 hrs, the height of the resulting serum layer ($H_{transparent}$) of the emulsion was measured. The creaming index values were determined using the following equation:

$$\text{Creaming index (CI)} = H_{transparent}/H_{emulsion} \times 100$$

3. Results and discussion

3.1 Nutritional composition of coconut milk

The approximate composition of raw and diluted coconut milk is listed in Table 1. It can be seen that the total fat of raw coconut milk obtained is within the range of other undiluted coconut milk from different sources, which is from 30 to 40% (Seow and Gwee, 1997). This result is close to the total fat of coconut milk harvested in Sri Lanka and the Philippines, but with huge differences compared to the total fat of coconut milk obtained from Malaysia (Alyaqoubi, 2015). This might be due to the dilution of the coconut milk as the total fat content obtained by Alyaqoubi (2015) is quite similar to the result of the diluted coconut milk which is around 15%. In this study, the dilution process reduces the calories of coconut milk to more than half of its original value.

Table 1. Proximate composition of raw coconut milk and diluted coconut milk

Parameter	Raw Coconut Milk	Diluted Coconut Milk
Protein, %	3.81±0.00	2.30±0.01
Total Fat, %	36.84±0.57	13.20±0.23
Total Carbohydrate, %	3.47±0.63	3.30±0.25
Ash, %	1.07±0.04	0.50±0.01
Moisture, %	54.81±1.17	80.70±.01
Energy, kcal	356±7.78	141±1.41

The addition of additives to diluted coconut milk resulted in changes in the nutritional composition of coconut milk. The proximate composition of coconut milk added with additives is tabulated in Table 2. As can be seen, slight increase in protein and carbohydrates when SC and maltodextrin were added to the coconut milk. This is due to the fact SC is a protein-rich food additive and maltodextrin is a carbohydrate-rich food additive. Adding 20% w/w of maltodextrin to the diluted coconut milk increases the total carbohydrate from 3.3% to 16%, thus leading to an increase in calories from 141 kcal to 217 kcal. This is because carbohydrate also contains calories.

Table 2. Proximate composition of raw coconut milk with addition of sonicated coconut milk and high-sheared coconut milk

Parameter	Sonicated coconut milk	High-sheared coconut milk
Protein, %	3.3±0.05	2.7±0.28
Total Fat, %	15.0±0.44	15.8±0.84
Total Carbohydrate, %	7.1±0.10	16±1.20
Ash, %	0.5±0.00	0.5±0.00
Moisture, %	74.1±0.01	65.0±0.03
Energy, kcal	173±2.12	217±2.07

3.2 Stability of the emulsion

Emulsion stability is the most crucial parameter to be considered in the preservation of food products (Abdolmaleki *et al*., 2016). In this study, the stability of the emulsion was determined based on the droplet size of the emulsion as it is one of the most important factors affecting the emulsion's stability (Goodarzi and Zendehboudi, 2019). The emulsion is considered in stable condition if the average size of the droplet is between 0.1 to 10 μm. On the other hand, the degree of flocculation is also used to determine the stability of the emulsion. The primary and effective particle sizes of all samples are tabulated in Table 3.

As can be seen, a slightly lower primary particle size compared to an effective particle size of the droplet is obtained in all samples. This indicates minimum flocculation in the emulsions including the raw coconut milk. The natural coconut milk protein is sufficient to coat all fats in the emulsion. However, the large size of the droplet (>10 μm) leads to instability of the emulsion as the creaming rate is proportional to the diameter of the droplet. The emulsification process improves the stability of the emulsion as particle sizes reduce below 10 μm for both primary and effective particle sizes. However, only sonicated coconut milk reaches the sub-micron size (<1 μm) of the droplet. Even though a high concentration of maltodextrin is added to the high-sheared coconut milk, it cannot reach the sub-micron size of the droplet. This might be due to the low emulsifying capacity of maltodextrin and the relatively low power of high-shear homogenizer compared to the sonication process.

Table 3. Stability of coconut milk

Sample	Primary particle size, $D_{4,3}$ (μm)	Effective particle size, $D_{4,3}$ (μm)	Creaming index, %
Raw coconut milk	14.00±0.01	15.29±0.03	39.23±4.05
Diluted coconut milk	10.91±0.02	12.17±0.01	75.52±1.46
High-sheared coconut milk	5.11±0.31	6.36±0.03	51.51 ±2.12
Sonicated coconut milk	0.78±0.08	1.31±0.07	0±0.0

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The particle size distribution of the emulsion is important to indicate the uniformity of the droplets which leads to the long-term stability of the emulsion. The droplet size distribution of the coconut milk samples is illustrated in Figure 1. All samples have a bimodal distribution. Similar shape distribution was observed for raw, diluted, and high-sheared coconut milk. The peak at the smaller size corresponds to protein while the larger-sized particles correspond to the fat globules. The high-shear process improves the stability of the emulsion as the particle size shifts to a smaller range size with the narrowest distribution which indicates good uniformity of particles.

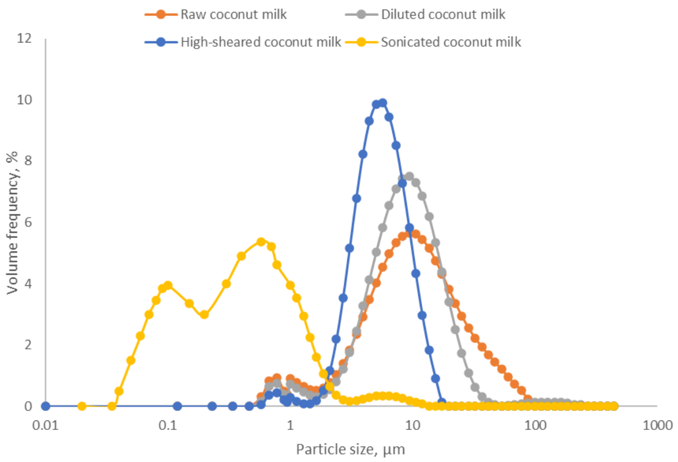

Figure 1. Particle size distribution of coconut milk

High stability of the emulsion is obtained for sonicated coconut milk. The particle size distribution of the emulsion shifted to the submicron range (<1 µm). However, it has the widest distribution which might be due to the coalescence of the fat globules (Mahdi Jafari *et al.*, 2006).

The microscopic observation of the fat globules in all samples is illustrated in Figure 2. As can be seen in Figure 2(a), raw coconut milk is filled with large-size fat globules. This is due to the high content of fat in the emulsion as found in the proximate analysis. The smaller size of fat globules is observed for the samples undergoing the emulsification process as shown in Figures 2(c) and (d). These samples have better homogeneity compared to raw and diluted coconut milk. A great reduction of fat globule size in sonicated coconut milk can be seen in Figure 2(d) compared to raw coconut milk.

The creaming index is used to determine the stability of the emulsion based on the formation of 2 distinct layers i.e., serum layer and cream layer due to the separation of water and oil. As tabulated in Table 3, diluted coconut milk is the most unstable emulsion as the creaming index is >70%. It is also found that the emulsification process helps to improve the stability of the emulsion. The presence of maltodextrin in high-sheared coconut milk slightly reduces the creaming index to 51.51%. Even though the particle size of this emulsion has been reduced to around 6 µm but high stability of the emulsion cannot be achieved. This might be due to the particle size of the emulsion that does not reach the sub-micron range of size as found in particle size analysis. Only the sub-micron range of particle size (sonicated coconut milk) has high stability as the creaming index reaches 0%. Interestingly, pure coconut milk has a creaming index of 39.23%. This indicates that raw coconut milk has a better creaming index compared to high-sheared coconut milk. This is due to the high-fat content in pure coconut milk compared to diluted coconut milk. However, the addition of water to the grated coconut meat that leads to diluted coconut milk is important as it increases the percentage yield of coconut milk by about 10% during the extraction process (Cancel *et al.*, 1971).

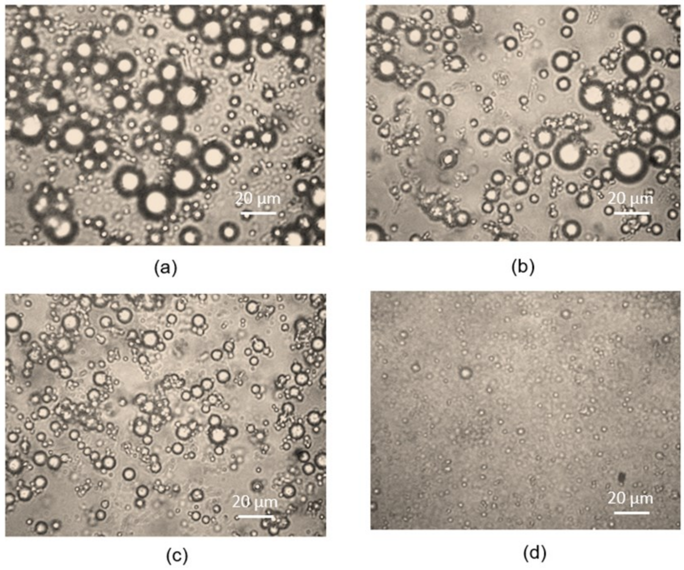

Figure 2. Microscopic observation of (a) raw coconut milk, (b) diluted coconut milk, (c) high-sheared coconut milk and (d) sonicated coconut milk under 100× magnifications

4. Conclusion

The addition of water and additives, i.e., SC and maltodextrin to coconut milk increased the carbohydrate and protein content and lower the calories. The emulsification process using a sonicator and high-shear homogenizer improves the stability of coconut milk by reducing the primary particle size of the droplet to less than 1 µm and 6 µm, respectively. With a creaming index of >50%, the high-shear homogenization failed to produce high stable emulsion, even though the particle size was reduced to less than 10 µm and formed the homogenous size of the droplet. Combined additive (SC and maltodextrin) with high power homogenizer i.e., sonicator provides better stability in coconut milk as the fat droplets reached the submicron range size and creaming index of 0%.

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References

Abdolmaleki, K., Mohammadifar, M.A., Mohammadi, R., Fadavi, G. and Meybodi, N.M. (2016). The effect of pH and salt on the stability and physicochemical properties of oil-in-water emulsions prepared with gum tragacanth. *Carbohydrate Polymers*, 140, 342-348. https://doi.org/10.1016/j.carbpol.2015.12.081

Abdullah, Z., Taip, F.S., Kamal, S.M.M. and Rahman, R.Z.A. (2020). The effect of drying temperature and sodium caseinate concentration on the functional and physical properties of spray-dried coconut milk. *Journal of Food Science and Technology*, 58 (8), 3174–3182. https://doi.org/10.1007/s13197-020-04820-9

Abdullah, Z., Taip, F.S., Mustapa Kamal, S.M. and Abdul Rahman, R.Z. (2018). Effect of sodium caseinate concentration and sonication amplitude on the stability and physical characteristics of homogenized coconut milk. *Journal of Food Processing and Preservation*, 42(11), e13773. https://doi.org/10.1111/jfpp.13773

Alyaqoubi, S., Abdullah, A., Samudi, M., Abdullah, N., Addai, Z.R. and Musa, K.H. (2015). Study of antioxidant activity and physicochemical properties of coconut milk (pati santan) in Malaysia. *Journal of Chemical and Pharmaceutical Research*, 7(4), 967–973. https://doi.org/10.19026/ajfst.7.1301

Campelo, P.H., Junqueira, L.A., Resende, J.V.D., Zacarias, R.D., Fernandes, R.V.D.B., Botrel, D.A. and Borges, S.V. (2017). Stability of lime essential oil emulsion prepared using biopolymers and ultrasound treatment. *International Journal of Food Properties*, 20(Suppl. 1), S564-S579. https://doi.org/10.1080/10942912.2017.1303707

Cancel, L.E., Rivera-Ortiz, J.M. and Santos-Sanchez, M. (1971). Effect of the amount of water on the extraction of coconut milk at two temperature ranges. *The Journal of Agriculture of the University of Puerto Rico*, 55(2), 167-173. https://doi.org/10.46429/jaupr.v55i2.11047

Fatimah, F., Gugule, S. and Tallei, T. (2017). Characteristic of coconut milk powder made by variation of coconut-water ratio , concentration of tween and guar gum. *Journal of Applied Science Research*, 13(6), 34–44.

Fox, M., Akkerman, C., Straatsma, H. and De Jong, P. (2010). Energy reduction by high dry matter concentration and drying. New Food Magazine, p. 60-63. Retrieved from New Food Magazine website: https://www.newfoodmagazine.com/article/474/energy-reduction-by-high-dry-matter-concentration-and-drying/

Goodarzi, F. and Zendehboudi, S. (2019). A comprehensive review on emulsions and emulsion stability in chemical and energy industries. *The Canadian Journal of Chemical Engineering*, 97(1), 281-309. https://doi.org/10.1002/cjce.23336

Grande, F. and Vincent, A. (2020). The importance of food composition data for estimating micronutrient intake: what do we know now and into the future? *Global Landscape of Nutrition Challenges in Infants and Children*, 93, 39-50. https://doi.org/10.1159/000503355

Hofman, D.L., Van Buul, V.J. and Brouns, F.J. (2016). Nutrition, health, and regulatory aspects of digestible maltodextrins. *Critical Reviews in Food Science and Nutrition*, 56(12), 2091-2100. https://doi.org/10.1080/10408398.2014.940415

Mahdi Jafari, S., He, Y. and Bhandari, B. (2006). Nano-emulsion production by sonication and microfluidization—a comparison. *International Journal of Food Properties*, 9(3), 475-485. https://doi.org/10.1080/10942910600596464

Market Research Future (2019). Coconut milk market research report: information by category (conventional and organic), form (powder, and liquid), packaging type (bottles, cans, pouches, and others) distribution channel (store-based and non-store-based), and region – global forecast till 2023. Retrieved on May, 2020 from Market Research Future Website: https://www.marketresearchfuture.com/reports/coconut-milk-market-3024.

Santana, A.A., Martin, L.G.P., de Oliveira, R.A., Kurozawa, L.E. and Park, K.J. (2017). Spray drying of babassu coconut milk using different carrier agents. *Drying Technology*, 35(1), 76–87. https://doi.org/10.1080/07373937.2016.1160111

Seow, C.C. and Gwee, C.N. (1997). Coconut milk: chemistry and technology. *International Journal of Food Science and Technology*, 32(3), 189–201. https://doi.org/10.1046/j.1365-2621.1997.00400.x

Suyitno, T. (2003). Health benefit of coconut milk. *Indonesian Food and Nutrition Progress*, 10 (2), 106-112.

Tangsuphoom, N. and Coupland, J.N. (2005). Effect of heating and homogenization on the stability of coconut milk emulsions. *Journal of Food Science*, 70 (8), e466-e470. https://doi.org/10.1111/j.1365-2621.2005.tb11516.x

Viet Delta. (2015) Coconut milk powder. Retrieved on April, 2019 from Coconut Vietnam Website http://www.coconutvietnam.com.vn/news/coconut-milk-powder/511.html.

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