Physicochemical, Nutritional, Microbiological and Sensory Qualities of the Formulated Reduced-Fat Coconut Milk Cube

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บทคัดย่อ

วิถีการดำเนินชีวิตของคนทั่วโลกที่วุ่นวายมากขึ้นเป็นแรงขับเคลื่อนทำให้ผู้บริโภคเลือกรับประทานอาหารที่ดีต่อสุขภาพและให้ความสะดวก กะทิเป็นส่วนประกอบอาหารที่ใช้กันโดยทั่วไปในเอเชียตะวันออกเฉียงใต้ รสชาติที่เข้มข้นของกะทิมาจากกรดไขมันอิ่มตัวที่มีในปริมาณสูง ที่เป็นปัจจัยเสี่ยงของการเกิดโรคหัวใจ การจัดการทดลองแบบ 2^2 แฟกทอเรียลแบบสุ่มโดยสมบูรณ์ (CRD) ถูกใช้ในการกำหนดสูตรของผลิตภัณฑ์กะทิก้อนลดไขมัน (RFCMC) ซึ่งปัจจัยสองประการที่ใช้ในการศึกษาได้แก่ อัตราส่วนของความเข้มข้นของสารที่ทำให้คงตัว (มอลโทเดกซ์ทริน) ต่อปริมาณกะทิไขมันต่ำ (35:65 และ 40:60) และอุณหภูมิที่ใช้ในการทำให้แห้ง (60°C และ 70°C) ทำการประเมินคุณสมบัติทางเคมีกายภาพ โภชนาการ จุลชีววิทยา และทางด้านประสาทสัมผัส ของผลิตภัณฑ์ RFCMC ทั้ง 4 สูตร ผลการวิจัยพบว่าสูตรที่ประกอบด้วยกะทิไขมันต่ำ 60% มอลโทเดกซ์ทริน 40% และ 0.01% BHT ที่อุณหภูมิการทำให้แห้ง 60°C เป็นเวลา 3 ชั่วโมง ได้รับคะแนนการยอมรับของผู้บริโภคโดยรวมสูงสุดที่ 6.17±0.84 โดยมีค่าความสามารถในการละลายน้ำ เท่ากับ 60.99±1.58% โดยหนึ่งหน่วยบริโภค (12.5 กรัม) ของ RFCM มีกรดไขมันอิ่มตัวเพียง 1.5 กรัม จากการวิเคราะห์ทางจุลชีววิทยาระบุว่าผลิตภัณฑ์ RFCM นี้มีความปลอดภัยสำหรับการบริโภค และถือได้ว่าเป็นส่วนผสมอาหารทางเลือกที่ดีต่อสุขภาพและให้ความสะดวกแก่ผู้บริโภค

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ABSTRACT

Globally, increasingly busy lifestyles are driving consumers toward healthy and convenience food choices. Coconut milk is a common food ingredient in Southeast Asia, with a rich taste attributed to high saturated fatty acids, a causal risk factor for heart diseases. A 2^2 factorial completely randomized design (CRD) was conducted to formulate the reduced-fat coconut milk cube (RFCMC). The two factors used were the concentration ratio of stabilizer (maltodextrin) to reduced-fat coconut milk (35:65 and 40:60) and the drying temperatures (60°C and 70°C). The four treatments of RFCMC were evaluated for physicochemical, nutritional, microbiological and sensory qualities. Results indicated that the formulation containing coconut cream 60%, maltodextrin 40% and 0.01% BHT with 60°C drying temperature for 3 h attained the highest overall consumer acceptability score of 6.17±0.84. Water solubility of this RFCMC was 60.99±1.58%. One serving (12.5 g.) of RFCM contained only 1.5 g. of saturated fatty acids. Microbiological analysis indicated that the product was safe for consumption and could be considered a healthier and more convenient alternative food ingredient for consumers.

Keywords: Coconut milk, Reduced-fat product, Physicochemical quantities, Sensory evaluation, Nutritional value

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INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death and disability worldwide, with high intake of dietary saturated fats increasing CVD risk [1]. Low-fat foods are an attractive option for consumers and many food industries have developed reduced-fat products for incorporating into regular diets [2]. However, fat in food contributes to overall product quality and influences consumer acceptability, rendering the creation of reduced-fat foods with desirable sensory qualities challenging [3].

Coconut milk is produced by squeezing grated coconut meat through a cheesecloth filter. It contains fatty acids at 24%, with 90-92% saturated [4]. Although some of those saturated fatty acids are medium-chain fatty acids that provide a ready source of energy for infants, evidence suggests that coconut milk should not be used regularly in adults [5]. Nevertheless, coconut milk is widely used in the retail and household industries for direct consumption and various food preparations and accounts for around 40% of the market share value of coconut products [6]. A cross-sectional study showed that coconut milk intake at more than three times per week was associated with a 1.3 fold increase in the risk of CVD in adults [7], indicating that fat reduction in coconut milk would be beneficial. Furthermore, coconut milk also contains protein residue of approximately 2.3%. In order to maintain the protein content in reduced-fat coconut milk, isoelectric precipitation might be suitable for efficient separation of coconut milk protein and oil [8].

Coconut milk is readily available in powder and liquid form but solid cubes offering consumer convenience are not yet marketed. Therefore, this study developed reduced-fat coconut milk cubes (RFCMC) and investigated their physicochemical, nutritional, microbiological and sensory qualities.

MATERIALS AND METHODS

1. Preparation of coconut milk liquid samples

Mature coconuts (*Cocos nucifera* L.) (10-12 months) were collected from a local farm in Songkhla Province, Thailand. The procedure for preparing coconut milk followed Chetachukwu et al. (2018) [9]. Grated coconut kernels were cold-pressed using a coconut milk expeller 67 cm x 134 cm (Model RL-20N, Negombo Sri Lanka) at 29°C to obtain fresh undiluted coconut milk. The milk was then pasteurized at 90°C for 5 min and stored in a refrigerator at 4°C.

2. Reduced-fat coconut milk preparation

The isoelectric precipitation method of Chetachukwu et al. (2018) [9] was adopted to prepare reduced-fat coconut milk containing 2.8% fat from the originally 35% of total fat. Product contains at least 25% less fat per 100 g are claimed as reduced-fat product [10]. Briefly, coconut milk (pH 6.28) was destabilized by adding 6 N citric acid to reduce the pH to 4 and allowed to stand at room temperature for 3 h with intermittent agitation. The coconut milk was centrifuged at 20,000 ×g for 15 min at 25°C and the process was repeated three times. The precipitate of reduced-fat coconut milk (RFCM)

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was collected and the pH was adjusted to 5.9 by adding sodium bicarbonate ($NaHCO_3$).

3. Experimental design

A 2^2 factorial completely randomized design (CRD) was conducted to formulate the reduced-fat coconut milk cube (RFCMC). The two factors used were the concentration ratio of stabilizer (maltodextrin) to reduced-fat coconut milk (35:65 and 40:60) and the drying temperatures (60°C and 70°C). The four treatments of RFCMC are shown in Table 1.

Table 1 Formulations of the four reduced-fat coconut milk cube (RFCMC) treatments

Treatment	% RFCM	%Maltodextrin	%Butylated hydroxytoluene (BHT)	Temperature (°C)
TRT 1	65	35	0.01	60
TRT 2	65	35	0.01	70
TRT 3	60	40	0.01	60
TRT 4	60	40	0.01	70

4. Reduced-fat coconut milk cube process

In each treatment, reduced-fat coconut milk was mixed with maltodextrin and 0.01% butylated hydroxytoluene (BHT) was added to prevent rancidity. Each mixture was poured into a square aluminum mold 3*4 cm and dried in a hot air oven at 60°C or 70°C until the moisture content was lower than 10% (wet basis). The RFCMC of each treatment was determined for texture profile, color, moisture content, water solubility index analysis and sensory qualities.

5. Physicochemical qualities of reduced-fat coconut milk cube

5.1 Hardness and color analysis

Texture analysis was carried out using a Texture Analyzer (TA-XT2i, Stable Micro System, Surrey, England) with a 50 kg load cell and P/50 probe. Pre and post-test speeds were 3 mm/s. Results were expressed as hardness, adhesiveness, cohesiveness and gumminess. The surface color of RFCMC was determined using a colorimeter (Color Flex, Hunter Lab Inc., Reston, VA, USA), with results expressed as lightness (L*), redness (a*) and yellowness (b*).

5.2 Moisture content analysis

Moisture content was determined following the gravimetric method described by the Association of Official Analytical Chemists (AOAC) [11]. Three grams of RFCMC sample were weighed into a previously weighed moisture can and dried in an oven at 105°C for 3 h. The sample was cooled in a desiccator, weighed and then returned to the oven for further drying. Drying, cooling and weighing were repeated at hourly intervals until constant weight. Moisture content was calculated using the following equation.

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$$\text{Moisture\%} = \frac{(\text{Wet Weight(g)} - \text{Dry Weight(g)})\text{x } 100}{\text{Wet Weight (g)}} \quad (1)$$

5.3 Water solubility index determination

Water solubility index (WSI) was determined as described by Singha *et al.* [12] with some modifications. RFCMC samples were ground to a fine powder and then 1 g of powder was suspended in 30 ml DI water in a tarred 50-ml centrifuge tube and vortexed for 45 s. The suspension was then centrifuged at 3,000 ×g for 15 min and the supernatant was transferred to a tarred aluminum cup and dried at 105°C for 24 h to remove the moisture. WSI was then calculated as mentioned by Singh and Muthukumarappan using the following equation [13].

$$\text{Water solubility index (\%)} = \frac{W1 - W2}{W} \times 100 \quad (2)$$

Here,

w1 =weight of dish and dried liquid

w2 =weight of dish

w=weight of dried sample

6. Sensory evaluation

Sixty consumers aged 18-65 years old were recruited from Prince of Songkla University. Testing was held on three consecutive days between 11:00 and 15:00 hours. All subjects provided informed consent and attended two sessions for i) testing the four RFCMC samples and ii) testing the four RFCMC samples after boiling in 200 ml water for 5 min and the control (RFCM without maltodextrin). The subjects indicated their degree of liking of the texture, mouthfeel and flavor (aroma and taste) of the samples on a nine-point hedonic scale (1 = dislike extremely to 9 = like extremely; 5 = neither like nor dislike). The treatment gaining the highest overall liking score was selected for further analysis of nutritional content and microbial quality.

7. Nutritional content

Nutritional content was analyzed to determine calories, total fat, saturated fat, trans fat, monounsaturated fat, polyunsaturated fat, cholesterol, total carbohydrate, dietary fiber, sugars, protein, sodium, vitamin A, thiamine (vitamin B1), riboflavin (vitamin B2), calcium and iron contents of RFCMC according to the Association of Official Analytical Chemists (AOAC) method [11].

8. Microbiological analysis

Total viable bacterial, yeast and mold counts were conducted on the RFCMC to determine the microbial load, as described by the American Public Health Association [14]. Briefly, the sample was mixed with peptone water and spread plated on nutrient agar (NA), MacConkey agar (MCA) and potato dextrose agar (PDA) to count aerobic viable bacteria, coliforms and fungi, respectively.

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The NA and MCA plates were incubated at 37°C for 24–48 h, while PDA plates were incubated at room temperature for 3–5 days. The colonies were then counted and expressed as colony forming units per gram (cfu/g) of sample.

9. Statistical analysis

The experimental data were evaluated by a completely randomized design using analysis of variance (ANOVA). Duncan's new multiple range test was used to determine the difference between means, with significance defined at $p \leq 0.05$

RESULTS AND DISCUSSION

1. Physicochemical properties of reduced-fat coconut milk cube

Texture and color characteristics of the four RFCMC treatments are shown in Table 2.

Table 2. Qualities of the four reduced-fat coconut milk cube treatments

Quality	TRT 1	TRT 2	TRT 3	TRT 4
L*	59.67 ± 0.86^{B}	55.70 ± 0.80^{C}	62.54 ± 0.89^{A}	59.54 ± 1.62^{B}
a*	3.96 ± 0.14^{AB}	4.23 ± 0.16^{A}	3.68 ± 0.46^{B}	3.88 ± 0.25^{AB}
b*	19.67 ± 0.58^{A}	20.50 ± 0.77^{A}	19.16 ± 0.69^{A}	19.83 ± 1.08^{A}
Hardness (g)	1465.57 ± 59.79^{C}	1846.54 ± 29.76^{A}	1658.05 ± 20.32^{B}	1851.41 ± 27.23^{A}
Adhesiveness (g.s)	51.34 ± 0.90^{D}	56.39 ± 1.70^{C}	58.22 ± 0.92^{B}	65.08 ± 0.71^{A}
Cohesiveness	0.36 ± 0.02^{A}	0.36 ± 0.01^{A}	0.35 ± 0.02^{A}	0.35 ± 0.02^{A}
Gumminess (g)	654.43 ± 29.90^{A}	635.31 ± 32.37^{A}	659.73 ± 26.56^{A}	637.97 ± 5.30^{A}
Moisture content (%)	6.27 ± 0.71^{A}	6.20 ± 0.82^{A}	6.24 ± 0.67^{A}	6.17 ± 0.53^{A}
WSI (%)	60.67 ± 1.64^{A}	60.78 ± 1.48^{A}	60.99 ± 1.58^{A}	61.87 ± 1.36^{A}

[1]Three replicates of each treatment were conducted.

[2]Means ± SD with different capital letters in the same row represent significantly different variances during treatments ($p \leq 0.05$).

[3] L*, Lightness (L = 100; white and L = 0; black); a*, green chromaticity (−60) to red (+60); b*, blue chromaticity (−60) to yellow (+60).

[4] Trt =RFCM: Maltodextrin and temperature; TRT1 = 65:35 and 60°C; TRT2 = 65:35 and 70°C; TRT3 = 60:40 and 60°C; TRT4 = 60:40 and 70°C

All four RFCMC treatments were white, with L* values greater than 50. The L* value was dependent on the concentration ratio of maltodextrin to RFCM and drying temperature. Increase in RCFM concentration and drying temperature significantly decreased L* values ($p \leq 0.05$). Butylated hydroxytoluene (BHT) was added at 0.01% to prevent lipid auto-oxidation. RFCM experienced a browning reaction or the Maillard reaction of amino acids and sugars in the tray dryer at high temperature [15], while greenness to redness (a*) and blueness to yellowness (b*) of RCFMC obtained using different treatments ranged 3.68±0.46 to 4.23±0.16 and 19.16±0.69 to 20.50±0.77, respectively. No significant differences ($p > 0.05$) were observed (Table 2), implying that changing RFCM concentration ratio and temperature did not significantly ($p > 0.05$) impact a* and b* color profiles.

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Hardness and adhesiveness values of RFCMC increased at higher drying temperature and percentage of maltodextrin (Table 2). Similar findings are mentioned in Ghodki et al.'s study (2016) that an increasing trend in RFCMC hardness occurred with decreasing moisture content during the drying process [16]. Protein denaturation temperature contributed to an increase in product gel hardness [17]. Higher percentages of maltodextrin rendered the product network more intense, leading to strengthening of the structure [18, 19], while the cohesiveness and gumminess of the four different treatments did not differ significantly.

The ability of RFCMC to dissolve in water, termed solubility, indicated complete rehydration of the cubes. There was no significant difference in water solubility index between all treatments ($p > 0.05$). At the reduced-fat coconut milk preparation stage, insolubility particles such as fat remained at 2.8%; consequently, the WSI of all treatments ranged 60.99±1.58% to 61.87±1.36%. Solubility increased at higher temperature [20, 21], with boiling possibly required before consuming the product.

2. Sensory evaluation

Determination of good physical qualities of RFCMC should be done concurrently with sensory evaluation to determine the treatment preferred by consumers [22]. Mean sensory property scores of the four RFCMC samples are shown in Table 3. No significant differences were observed between samples for appearance, color and overall acceptability ($p > 0.05$). Sensory scores indicated that consumers liked the RFCMCs, with overall acceptability ranging 6.9 to 7.2.

Table 3 Mean liking scores of the four reduced-fat coconut milk cube treatments

Attribute	TRT 1	TRT 2	TRT 3	TRT 4
Appearance	7.33±0.66^{A}	7.17±0.79^{A}	7.90±0.77^{A}	7.33±0.80^{A}
Color	6.90±0.84^{A}	6.75±0.76^{A}	7.03±0.64^{A}	6.83±0.65^{A}
Overall acceptability	7.08±0.78^{A}	6.90±0.69^{A}	7.20±0.85^{A}	7.13±0.86^{A}

Sensory characteristics were graded as 1 = dislike extremely to 9 = like extremely; 5 = neither like nor dislike.
Mean values in the same column with different letters are significantly different ($p \leq 0.05$).
Trt =RFCM: Maltodextrin and temperature; TRT1 = 65:35 and 60°C; TRT2 = 65:35 and 70°C; TRT3 = 60:40 and 60°C; TRT4 = 60:40 and 70°C.

For further testing, RFCMCs were boiled in 200 ml of water for 5 min. Sensory evaluation profiles of melted RFCMCs and controls of each group are presented in Figure 1. Results in the control (100% RFCM) group showed that lowering fat content decreased sensory acceptability by consumers [3].

Incorporation of maltodextrin concentrations into RFCM (40:60) produced higher overall acceptability, appearance, color and texture. Previous studies reported that addition of

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maltodextrin improved the texture, with a smoother and creamier product mouthfeel [23]. Maltodextrin acts as a fat replacer by gel formation that traps substantial quantities of free water in food systems [24]. TRT 3, with 40% maltodextrin and 60°C drying temperature gave optimal liking scores. The product prototype of TRT 3 is shown in Figure 2.

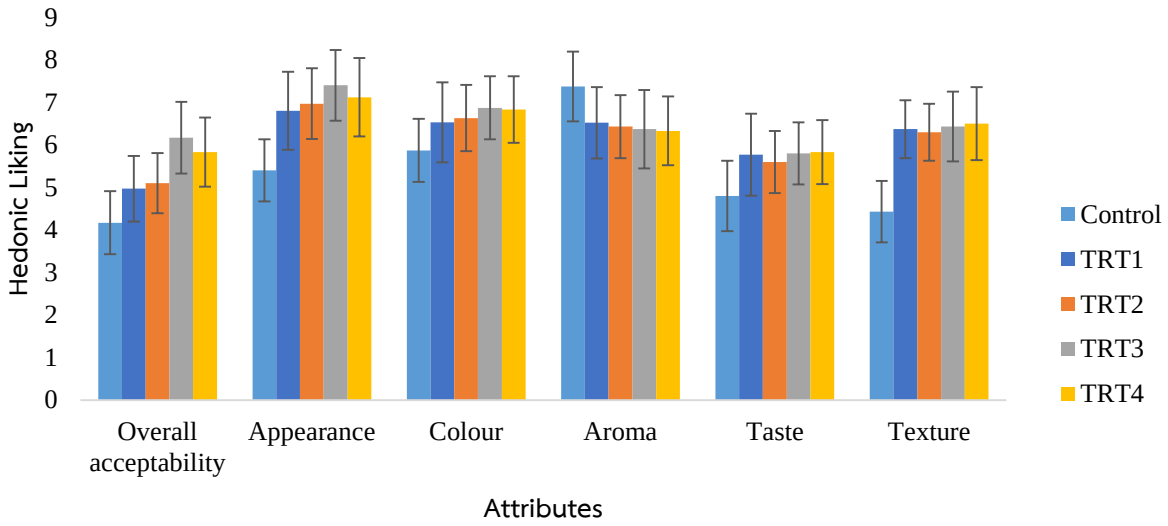

Figure 1. Sensory quality evaluation by attributes of overall acceptability, appearance, color, aroma, taste and texture of the control and four treatments of reduced-fat coconut milk cube. Bar charts labeled with varying subscripts in the same group are significantly different ($p \leq 0.05$). Trt =RFCM: Maltodextrin and temperature; TRT1 = 65:35 and 60°C; TRT2 = 65:35 and 70°C; TRT3 = 60:40 and 60°C; TRT4 = 60:40 and 70°C.

Figure 2. Product prototype of reduced-fat coconut milk cube.

3. Nutritional value of selected reduced-fat coconut milk cube

The nutritional composition of RFCMC depicted in Figure 3 indicated that one serving of food (12.5 g) provided 48 kcal contained 4 g of protein and 1.5 g of saturated fat, with percentage daily value (%DV) 8%. While domestic coconut milk and commercially available coconut milk powder contained 3.1 g/100 g and 1.83/ 100 g of total fat, respectively[25]. The protein content in this product was from the using of isoelectric precipitation to remove the coconut milk fat. Frequent intake of high saturated fatty acid coconut milk increases the risk of cardiovascular disease in adults [7]; therefore, a low amount of saturated fat in RFCMC would be a good alternative low-fat ingredient substitute for full-fat coconut milk as a food product. Other nutrients such as vitamins and minerals are low; therefore,

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additional nutrients would add more value to this product.

Figure 3. The Nutrition Facts label of reduced-fat coconut milk cube.

Nutrition Facts			
Serving size: 4 cubes (50 g)			
Servings per container: 4			
Amount per serving			
Calories 48			
Calories from Fat 15			
			% Daily Value*
Total Fat 2 g			**3%**
Saturated fat 1.5 g			**8%**
Monounsaturated fat 0.5 g			
Polyunsaturated fat 0 g			
Trans Fat 0 g			
Cholesterol 0 mg			**0%**
Protein 2 g			
Sodium 30 mg			**1%**
Total Carbohydrate 6 g			**4%**
Dietary fiber 0 g			**0%**
Sugar 1 g			
% Daily Value *			
Vitamin A	0%	**Vitamin B1**	0%
Vitamin B_2	0%	**Calcium**	0%
Iron	4%		
*Percent daily values based on a 2,000 calorie diet. Daily values may be higher or lower depending on individual calorie needs:			
	Calories:	2,000	2,500
Total fat	Less than	65 g	80 g
Saturated fat	Less than	20 g	25 g
Cholesterol	Less than	300 mg	300 mg
Sodium	Less than	2,400 mg	2,400 mg
Total carbohydrate		300 g	357 g
Dietary fiber		25 g	30 g
Calories per gram:			
Fat 9 · Carbohydrate 4 · Protein 4			

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4. Microbiological characteristics of the selected reduced-fat coconut milk cube

Microbiological counts of molds, yeasts and total coliforms of RFCMC were undetectable under the conditions applied for sensory evaluation (100℃ for 5 min). The heating process eliminated harmful microbes [26] and RFCMC was safe for consumption. The shelf life of a food product is dependent on microbiological quality and should be further assessed [27].

CONCLUSIONS

The TRT 3 formulation containing coconut cream 60%, maltodextrin 40% and 0.01% BHT with 60℃, 3 h drying temperature and time gained the highest consumer acceptability score. One serving of this formulation contained 1.5 g of saturated fat and significantly less saturated fat than commercial full-fat coconut milk. The TRT 3 formulation adequately met consumer acceptance. Coconut milk formulation in cube form is convenient and the product can be completely rehydrated. Reduced-fat coconut milk cube products showed promise for use by consumers in the manufacture of processed healthy food products.

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