
Optimization of Coconut (*Cocos nucifera*) Milk Extraction Using Response Surface Methodology

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Abstract: Coconut milk provides health benefits due to its medium chain fatty acids and is widely utilized in the food industry. However, there seems to be inadequate information on the optimal extraction conditions for coconut milk. In this study, a response surface methodology (RSM) based on central composite design (CCD) was employed to optimize the extraction time (X_1), extraction temperature (X_2) and particle size of coconut meat (X_3) for coconut milk extraction. Yield, pH, viscosity and total solid content of coconut milk were evaluated as responses. Regression models were generated and adequacy tested with lack of fit test and coefficient of determination (R^2). The results showed that extraction time; extraction temperature and particle size of coconut meat had significant ($p < 0.05$) effects on responses. The R^2 for yield, pH, viscosity, and total solid content of coconut milk were 0.9976, 0.7352, 0.6748 and 0.9787 respectively. Optimum extraction time, temperature and particle size of coconut meat with the highest desirability index of 0.797 was 15 min, 40°C and $\leq 1617 \mu\text{m}$ respectively, while optimum yield, pH, viscosity, and total solid content of coconut milk were estimated at 61.129%, 6.6, 2.85 cp and 16.01% respectively. The experimental results obtained validate the predicted model within the acceptable range of the responses. The results also suggest that the obtained model is acceptable for the maximum milk yield and improved quality consistency.

Keywords: Coconut Milk, Optimization, Response Surface Methodology, Central Composite Design

1. Introduction

Coconut milk (CM) is a sweet, milky-white, natural oil-in-water emulsion extracted from the endosperm of mature coconut (*Cocos nucifera*) using mechanical force, with addition of water [1]. The colour and rich taste of the milk can be attributed to the high oil content and sugars. Coconut milk is obtained from finely grated coconut meat that is steeped in hot water and then filtered. It is a refreshing beverage that provides both nutritional and health benefits. Coconut milk plays an important role in many traditional foods of many regions such as Southeast Asia, South America, Middle America, the Middle East and the Pacific region. In the United States, coconut milk was one of the major sources of dietary fat, aside from dairy and animal fats [2]. In Nigeria, it is used in preparing 'coconut rice', a very popular delicacy in the southern part of the country.

Coconut milk is fast becoming an increasingly important

raw material in home cooking as well as in the food processing industries [3]. It is estimated that 25% of the world coconut output is consumed as coconut milk [3]. It is a major and an essential ingredient in the preparation of a wide variety of food products such as curry, desserts, coconut jam, spread, coconut syrup, coconut cheese, bakery products and beverages [3, 4]. The coconut milk adds creamy taste, smooth, and aromatic flavour to these delicacies [5]. It can also be used as a substitute for milk in some desserts such as chocolate and other confectionaries are exotically flavoured with coconut milk [3].

Coconut milk also serves as an excellent source of raw material for the development of dairy-like products such as yoghurt [6]. Its nutritional content is higher compared to cow milk [7]. Coconut milk contains about 54% moisture, 11% solid non-fat and 35% fat [8, 9], and is high in minerals and vitamin content [5]. It is also rich in proteins such as albumin, globulin, prolamin and glutenin.

Coconut milk also provides health benefits. Coconut milk

fat has been reported to improve digestion and bowel function, support tissue repair and immune system functions, help protect the body from breast colon and other cancers, improve the cholesterol ratio, reduce the risk of heart disease and increase the metabolic rate of body fat, among other benefits [10]. The health benefits of coconut oil are mainly from the medium chain fatty acids (MCFAs). These MCFAs are similar to that of human milk and have corresponding nutraceutical benefits. The most predominant MCFA is lauric acid (45– 53%). This is converted in the body into a highly beneficial compound called monolaurin, an antiviral and antibacterial agent that destroys a wide variety of disease causing organisms. Furthermore, the fats present in coconuts are less likely to clog arteries, because the body does not store coconut fats which makes coconut milk a healthy alternative to cow's milk when it comes to preserving heart's health [11]. Consequently, the world market for coconut milk has increased from USD 1.2 billion in 2008 to USD 1.3 billion in 2010 [12].

In Nigeria, CM extraction is primarily done manually which is very laborious. Besides, the extraction process has not been standardized. To our knowledge, the optimal extraction conditions are not known. Different people extract under different conditions resulting in inconsistencies in product quality. The composition of CM, and by extension its quality, depends largely on the extraction procedure. It has been shown that the amount of water used for extraction, affects significantly the moisture and fat content of the milk [13]. Moreover, extraction time and temperature [14] have been identified as important factors in CM extraction. Agarwal and Bosco [15] showed that the extraction efficiency of CM was enhanced by enzyme, thus, aiding in rupture of coconut meat cell walls and subsequent leaching of the milk. It is believed that other factors such as extraction time, extraction temperature and particle size of coconut meat could have great influence on the quality of CM.

One of the recent techniques being used for development of optimum food products to enhance their nutritive and product quality is process optimization using response surface methodology (RSM). RSM is a collection of mathematical and statistical techniques useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response [16]. RSM considers interaction among process parameters and optimize them to a reasonable range, with the advantage of the relevant information in the shortest time with the least number of experiments [17]. Many researchers have employed RSM to optimize processes in the food systems as a mathematical model with the objective of achieving product excellence at the lowest possible overall cost and accelerate the transitional cycle from research and development to manufacturing [18]. RSM has been widely reported for the optimization of a wide range of products such as; extraction of olive oil [19], coconut oil [15], and has been found to be effective tool in optimizing any process [20] wherein the interaction among factors (independent variables) has to be tailored for desired

responses (dependent variables).

The two most common and popular designs in RSM are central composite design (CCD) and Box- Behnken design BBD. Shishir *et al.* [21] reported that CCD is flexible and considered as most effective for uniform precision with lower runs required, chronological investigation and reasonable information for lack of fit test. Thus the aim of the present study was to determine the optimum parameters for extraction of coconut milk using RSM based on central composite design.

2. Materials and Methods

2.1. Materials

Matured coconuts (7-8 months old) of the dwarf variety were collected directly from the trees in EmVic farm in Ibesikpo Asutan Local Government Area, Akwa Ibom State, Nigeria.

2.2. Methods

2.2.1. Extraction of Coconut Milk

The coconut was dehusked, cracked to separate the meat from the shell while the coconut water was poured into a container and stored for further use. The brown skin of the coconut meat was removed and the meat thoroughly washed and grated using manual grater. The grater was fabricated by the Department of Food Engineering, University of Uyo, Nigeria, with particle size numbers ≤ 1311.93 , ≤ 1617 , ≤ 2353.5 , ≤ 3090 and ≤ 3395.07 μm . The grated coconut meat was mixed in a ratio of 1:1 with a solution containing 75% distilled water and 25% coconut water and allowed to stand in a water bath at stipulated temperatures and time according to the CCD (Table 1). The slurry was then pressed and filtered through cheese cloth to remove the solid residue and recover the milk. The milk was pasteurized at 90°C for 30 min and allowed to assume room temperature (37°C).

Table 1. Experimental range and levels of the independent variables.

Independent Variable Symbol		Coded levels				
		$-\alpha$	-1	0	+1	$+\alpha$
Time (min)	X_1	7.92	10	15	20	22.07
Temperature (°C)	X_2	35.85	40	50	60	64.14
Particle size (μm)	X_3	1311.93	1617	2353.5	3090	3395.07

2.2.2. Physicochemical Analysis

Samples were evaluated for percentage yield, pH, viscosity and total solid content. Percentage yield was expressed as:

$$Y (\%) = W_2 / W_1 \times 100 \quad (1)$$

Where W_2 = weight of coconut milk extracted; W_1 = weight of grated coconut meat + extraction solution added

About 100 ml of sample was poured into a beaker and thoroughly mixed. pH was measured using a pH meter (Model Voltcraft pH-100 ATC, USA). The viscosity of the

coconut milk samples was determined using Fann Viscometer (Model 35SA, USA). The sample was placed in the viscometer cup. The cup was raised until the spindle was properly immersed. The Fann Viscometer was set at 600 rpm and readings were taken after 120 s of rotation and expressed in centipoise (cp).

Total solid (TS) content of the coconut milk was determined using the Association of Official Analytical Chemists [22] method. Two (2) ml of the sample was measured into a previously weighed evaporating dish. The dish containing the sample was heated in an oven at 105°C. The sample was dried to a constant weight and then cooled in a desiccator and reweighed. The weight of the solid was estimated by difference and expressed as the percentage of the sample weight. TS content was calculated as follows:

$$TS (\%) = \frac{W_2 - W_1}{W_3} \times 100 \quad (2)$$

Where W_1 = Weight of empty dish, W_2 = Weight of dish + dried sample, W_3 = weight of sample, TS = total solids.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 \quad (3)$$

Where Y is the desired value of response; X_1 , X_2 , X_3 are independent variables; β_0 is the constant; β_1 , β_2 , β_3 are coefficients of linear regression; β_{12} , β_{13} , β_{23} are coefficients of interaction regression and β_{11} , β_{22} and β_{33} are coefficients of quadratic regression. The lack of fit of the model was evaluated and the model adequacies were assessed using coefficient of determination (R^2), adjusted R^2 , predicted R^2 , adequate precision and coefficient of variation (CV). The analysis of variance (ANOVA) tables were generated and the effect and regression coefficients of individual linear, quadratic and interaction terms were determined. The significance of all terms in the polynomial were judged statistically at 5% level of probability ($p < 0.05$).

3. Results and Discussion

3.1. Model Fitting

The experimental results of the effect of extraction time,

$$Y_1 = +56.50 + 0.94X_1 + 0.35X_2 - 2.95X_3 + 1.20X_1X_2 + 0.60X_1X_3 + 1.19X_2X_3 - 0.83X_1^2 + 0.33X_2^2 + 0.58X_3^2 \quad (4)$$

$$pH = + 6.74 + 0.14X_1 + 0.15X_2 \quad (5)$$

$$\text{Viscosity} = + 2.43 - 0.45X_3 \quad (6)$$

$$\text{Total solids} = + 11.27 - 2.76X_3 + 1.92X_1X_2 - 0.43X_1^2 + 0.86X_3^2 \quad (7)$$

where Y_1 = yield, X_1 = extraction time, X_2 = extraction temperature and X_3 = particle size of coconut meat.

Table 2. Design matrix of central composite design obtained from RSM and experimental values of the responses for coconut milk extraction.

Experimental run	Actual variable			Responses				
	X_1	X_2	X_3	PY (%)	Y_1^a (%)	pH ^a	Vis ^a (cp)	TS ^a (%)
1	10	60	3090	54.83	55±1.00	6.93±0.03	2.0±0.20	9.30±0.30
2	15	50	2353.5	56.50	56.5±0.20	6.66±0.10	2.5±0.10	11.60±0.30
3	10	40	1617	58.83	59.0±0.10	6.66±0.10	3.0±0.20	14.00±0.20

2.3. Experimental Design and Statistical Analysis

A Central Composite Design (CCD) of Response Surface Methodology (RSM) was used to optimize the extraction variables and to study the interaction of process variables. There were 3 independent variables; extraction time (X_1), extraction temperature (X_2) and the particle size (X_3) of coconut meat. Each variable had 5 different coded levels (Table 1) from low (-1), to medium (0) and high (+1) as well as star points ($\pm\alpha$) for efficient determination of curvature and quadratic term. Dependent variables such as yield, pH, total solid and viscosity of coconut milk were evaluated as responses for the factors studied. The experimental design in the actual levels of variables is shown in Table 2. All experiments were performed in triplicates. Statistical analysis for coconut milk extraction was performed using Design Expert (Stat-Ease Inc., Minneapolis, MN, USA) software version 9.0. The experimental data were fitted to a quadratic model to express the response variables as a function of the independent variables using equation (3).

extraction temperature and particle size of coconut meat on coconut milk yield, pH, viscosity and total solid content are presented in Table 2. These experimental data were used in RSM program to generate the best predicted model and its statistical analysis. The quadratic model with the lowest standard deviation, highest R^2 , adjusted and predicted R^2 values were observed to be significant ($p < 0.05$) and effective in describing the effect of independent variables on yield and total solid content of coconut milk. On the other hand, pH and viscosity were modelled with reduced two factor interaction (2FI) and linear model respectively. Sudamalla *et al.* [23] reported that in order to develop a regression model that is statistically significant, the insignificant terms are removed from the model thus resulting in a model's (reduced) efficiency in describing response. The fitted regression models, in terms of coded factors are shown using polynomial equations as follows:

Experimental run	Actual variable			Responses				
	X ₁	X ₂	X ₃	PY (%)	Y ₁ ^a (%)	pH ^a	Vis ^a (cp)	TS ^a (%)
4	15	50	3395.07	53.49	53.33±0.33	6.66±0.02	1.5±0.10	8.62±1.00
5	20	60	1617	57.83	58.0±0.20	6.90±0.01	3.0±0.20	14.89±0.10
6	15	50	2353.5	56.50	56.5±0.50	6.66±0.02	2.5±0.10	11.60±0.10
7	22.0711	50	2353.5	56.17	56.0±0.30	7.0±0.10	2.4±0.10	10.85±0.10
8	20	40	3090	54.83	55.0±0.10	6.66±0.01	2.5±0.20	9.38±0.10
9	15	50	2353.5	56.50	56.5±0.40	6.66±0.01	2.5±0.10	11.60±0.10
10	15	64.1421	2353.5	57.67	57.5±0.20	7.0±0.10	2.5±0.10	11.30±0.10
11	7.92893	50	2353.5	53.49	53.33±0.33	6.66±0.10	2.5±0.20	9.60±0.30
12	15	50	1311.93	61.84	61.67±0.30	6.65±0.01	3.0±0.10	17.00±0.38
13	15	35.8579	2353.5	56.67	56.50±0.40	6.59±0.01	2.0±0.10	10.62±0.10
14	15	50	2353.5	56.50	56.67±1.00	6.66±0.02	2.0±0.20	11.20±0.20
15	15	50	2353.5	56.50	56.67±1.00	6.94±0.10	2.5±0.20	11.30±0.20

PY = Predicted yield, Y₁ = Observed yield, Vis = Viscosity, TS = Total solid content, X₁ = Extraction time, X₂ = Extraction temperature and X₃ = Particle size of coconut meat, ^a mean ± standard deviation and n = 3

Table 3. Analysis of variance (ANOVA) for the fitted polynomial model of the dependent variables.

Response	Source	Df	Sum of square	Mean square	F – value	P – value
Yield (%)	Model	9	1376.27	152.92	229.38*	0.0001
	Residual	5	3.33	0.67		
	Lack of fit	1	3.33	3.33	-	-
	Pure error	4	0.000	0.000		
	Total	14	1379.60			
pH	Model	4	0.26	0.066	6.94*	0.0061
	Residual	10	0.095	9.486E-003		
	Lack of fit	6	0.032	5.357E-003	0.34	0.8839
	Pure error	4	0.063	0.016		
	Total	14	0.36			
Viscosity	Model	1	1.64	1.64	26.97*	0.0002
	Residual	13	0.79	0.061		
	Lack of fit	9	0.59	0.066	1.31	0.4248
	Pure error	4	0.20	0.050		
	Total	14	2.43			
Total solid	Model	4	69.12	17.28	114.63*	0.0034
	Residual	10	1.51	0.15		
	Lack of fit	6	1.37	0.23	6.57	0.0456
	Pure error	4	0.14	0.035		
	Total	14	70.63			

df= degree of freedom, *significant at $p < 0.05$

The fitness of the final predicted polynomial model was considered based on the results of analysis of variance (ANOVA). Result in Table 3 showed that the probability value (p-value) of the response models was less than 0.01, suggesting that the models for the responses were statistically correct and effective with insignificant lack of fit for pH and viscosity. There was no F-value for lack of fit for yield which showed that, lack of fit for the model had neither a significant nor a non-significant effect on the response [24]. In addition,

the goodness-of-fit of the model was also ascertained by the coefficient of determination (R^2) shown in Table 4. Jusoh *et al.* [25] reported that the best R^2 value for a good model fitting was estimated between 0.8 and 1.0. However, $R^2 < 0.80$ had been reported by Gupta *et al.* [24], indicating a fair fit of the model, but reliable in making predictions. Consequently, R^2 of 0.7352 and 0.6748 for pH and viscosity respectively indicated fair fit of the models. This implied that only 73.52% of variations in pH and 67.48% variations in

viscosity were explained by 2FI and linear model respectively, while over, 97% variations in yield and total solid were explained by quadratic model.

Results in Table 4 revealed that coconut milk yield, pH and TS had low coefficient of variation (CV) values (<3.5). CV is a measure of deviation from the mean values, which shows the reliability of the experiment. CV also describes the extent to which the data were dispersed as well as the reproducibility and repeatability of the model [26]. Shishir *et al.* [21] reported that a CV < 10% indicates better precision and reliability while Gupta *et al.* [24] reported that CV > 10% indicated that the experiment was less precise but

reliable. This implies that the fitted models of responses were highly reliable and can be considered reasonably reproducible. The predicted R² was in reasonable agreement with the adjusted R². This is because the difference between them was less than 0.2, which illustrated that there were excellent correlations between the independent variables in predicting the responses. Adequate precision is a comparative measure between the predicted values and the mean predicted error and measures the signal to noise ratio. A ratio greater than 4 is desirable. Our results (Table 4) showed that adequate precision values were greater than 4; therefore the respective models can be used to navigate the design space.

Table 4. Estimated regression coefficients of the fitted polynomial model representing the relationship between responses and process variables at the design response surface.

Source	Yield (%)		pH		Viscosity (cp)		Total solid (%)	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Model Constant								
β ₀	56.50	0.0001	6.74	0.0061	2.43	0.0002	11.27	0.0034
Linear X ₁	0.94	0.0001	0.14	0.0157			0.35	NS
X ₂	0.35	0.0002	0.15	0.0014	-		-	NS
X ₃	-2.95	0.0001	NS	0.8759	-0.45	0.0002	-2.76	0.0001
Interaction								
X ₁₂	-1.20	0.0043	-	-	-		1.92	0.0015
X ₁₃	0.62	0.0001	-	-	-		-	-
X ₂₃	1.19	0.0001	NS	0.0559	-		-	-
Quadratic								
X ₁ ²	-0.83	0.0001	-		-		-0.43	0.0173
X ₂ ²	0.33	0.0161	-		-		-	-
X ₃ ²	0.58	0.0002	-		-		0.86	0.0124
R ²	0.9976		0.7352		0.6748		0.9787	
Adjusted R ²	0.9932		0.6293		0.6498		0.9701	
Predicted R ²	0.8059		0.5412		0.5430		0.9339	
C.V (%)	0.24		1.44		10.16		3.37	
Adeq prec	60.00		7.607		14.22		36.985	

NS = Not significant, R² = Coefficient of determination, C.V = Coefficient of variation, Adeq prec = Adequate precision, X₁ = Extraction time, X₂ = Extraction temperature and X₃ = Particle size of coconut meat.

3.2. Effect of Extraction Time, Extraction Temperature and Particle Size of Coconut Meat on the Yield of Coconut Milk

The result in Table 2 showed that the predicted and observed coconut milk yield varied from 53.49 to 61.84% and 53.33±0.33 to 61.67±0.30% respectively. The highest yield (61.67±0.30%) of coconut milk was obtained during extraction at 50°C, for 15 min using particle size 1311.93 μm (run 12), which also had the highest total solid content (17±0.38%). The yield of coconut milk was found to be a function of the linear, interactions and quadratic effects of the independent variables. Result showed that extraction time, extraction temperature, particle size of coconut meat, interactions of extraction time and particle size of coconut meat, extraction temperature and particle size of coconut

meat, extraction time and extraction temperature, quadratic terms of extraction time, extraction temperature and particle size of coconut meat had significant (p<0.05) effects on the yield of coconut milk. A positive and negative coefficient of the independent variables in the model represents synergistic and antagonistic effects respectively.

The main effect of time (Figure 1a) indicated that increase in extraction time resulted in increased milk yield. This result is in agreement with the reports of Agarwal and Bosco [15] who reported increased coconut milk yield with increased time; and that of Deswal *et al.* [27] who reported increased milk yield during the extraction of oat milk using response surface methodology. Figure 1a also showed that increase in extraction temperature and extraction time resulted in increase in yield of coconut milk. This is because the rise in temperature with time increases the diffusion of the milk solids

while decreasing the viscosity [19]. The mass transfer coefficient of the extraction process also increases with temperature thus effecting the diffusion of the milk. The positive linear term for time and negative quadratic time suggests that the effect of time resulted in increase in milk yield until a turning point (16 min) was reached beyond which time had a negative impact on yield. The quadratic term exerted a downward force on the yield, indicating that there was less than linear increase in yield with regards to time thereby resulted in a slight tilting of the surface (Figure 1a).

The result also showed that the yield of coconut milk increased with decrease in particle size of coconut meat and increase in extraction time (Figure 1b). The increase in milk yield could be attributed to the diffusion of water-soluble components of the coconut meat [15]. Smaller particle size of coconut is an indication that the coconut meat cell walls had been ruptured in a degree that led to a larger surface area which in turn led to increase in the efficiency of the release of the components from the cells. More milk solids were extracted from smaller particle size due to the bigger interfacial area of the solid. The shorter distance the solvent has to travel to extract the milk from the solid increases the pore diffusion between solid and solvent. The larger particle has a smaller contact surface area and is more resistant to solvent entrance and milk diffusion [28]. These findings are in agreement with the report of Agarwal and Bosco [15] who also observed increase in milk yield with decrease in particle size during viscozyme - L. assisted extraction of coconut milk and virgin coconut oil.

Effect of particle size of coconut and temperature on the yield of coconut milk is presented in Figure 1c. The positive coefficient of the interaction effect of extraction temperature and particle size of coconut meat resulted in increased coconut milk yield. This may be attributed to the fact that the leaching of water soluble components from coconut meat was facilitated at higher temperatures thus resulting in increased milk yield. Therefore, increase in particle size with temperature resulted in a slight increased milk yield.

3.3. Effect of Extraction Time, Extraction Temperature and Particle Size of Coconut Meat on the pH of Coconut Milk

The pH of coconut milk ranged from 6.59 ± 0.01 to 7.0 ± 0.10 (Table 2). Extraction time and extraction temperature had significant ($p < 0.05$) effect on the pH of coconut milk. The result showed that pH was found to be a function of linear terms of extraction time and extraction temperature, with a mean pH of 6.74. This result is in agreement with that of Aidoo *et al.* [29] who stated that vegetable/plant milk was slightly acidic with a pH range of 6.33 to 6.97 and more than half of the total extraction process variables tested were within this range. The positive main effect of the extraction time and temperature indicated that increase in extraction temperature from 40 – 60°C and extraction time from 10 – 20 min (Figure 2) aided in the dissolution of the coconut components, which resulted in an increased pH of coconut milk.

3.4. Effect of Extraction Time, Extraction Temperature and Particle Size of Coconut Meat on the Viscosity of Coconut Milk

The viscosity of coconut milk ranged from 1.5 ± 0.10 to 3.0 ± 0.10 cp. ANOVA showed that viscosity was significantly ($p < 0.05$) affected by particle size of coconut meat, whereas extraction time and extraction temperature had no significant ($p > 0.05$) effect on the viscosity of coconut milk. The negative coefficient of particle size indicated that particle size of coconut meat exerted an antagonistic (negative) effect on viscosity. This implied that viscosity of coconut milk is a function of linear effect of particle size of coconut meat. The 3-D plot of RSM (Figure 3) shows that increase in particle size of coconut meat led to sharp decrease in viscosity of coconut milk. Similarly, smaller particle size of coconut meat resulted in more viscous milk than larger particles.

3.5. Effect of Extraction Time, Extraction Temperature and Particle Size of Coconut Meat on Total Solid Content of Coconut Milk

Table 2 showed that the total solid content ranged from 8.62 ± 0.10 to $17.0 \pm 0.38\%$, indicating that the variation between the maximum and minimum value of total solid content was 8.38% during extraction at different process variables. Particle size of coconut meat, interaction effect of extraction time and extraction temperature, as well as the quadratic terms of time and particle size of coconut meat had significant ($p < 0.05$) effects on total solid content of coconut milk. The negative coefficient of effect of particle size of coconut meat showed that particle size of coconut meat had a negative effect on total solid content of coconut milk. Also, the positive coefficient of interaction of extraction time and extraction temperature indicated a synergistic effect on total solid content of coconut milk (Figure 4a). Figure 4a showed that increase in temperature and time of extraction resulted in an increase in the total solid content of coconut milk. Increased time and temperature of extraction may aid the dissolution of more soluble solid of coconut meat into the surrounding solution thus resulting in increased total solid of the milk. However, Murevanhama [30] reported a decrease in total solid of bambara groundnut milk with increased time and temperature. This disparity in total solids content may be as a result of differences in molecular organization of the biological material as well as the extraction time (2-6 h) employed by the different researchers. The negative quadratic time indicated that the effect of time resulted in increased total solid until a turning point (16 min) was reached beyond which time had a negative effect on total solid. This effect is seen by the tilting of the response surface plot in Figure 4a. Figure 4b revealed that particle size exerted a decline in total solid content of coconut milk. Increase in the particle size of coconut meat resulted in decrease in total solid content with time. Increase in particle size of coconut, led to a smaller surface area as some components of the coconut are locked up in the vegetative cells resulting in low total solid content. Similarly, increase in particle size also led

to decrease in total solid content of coconut milk (Figure 4c).

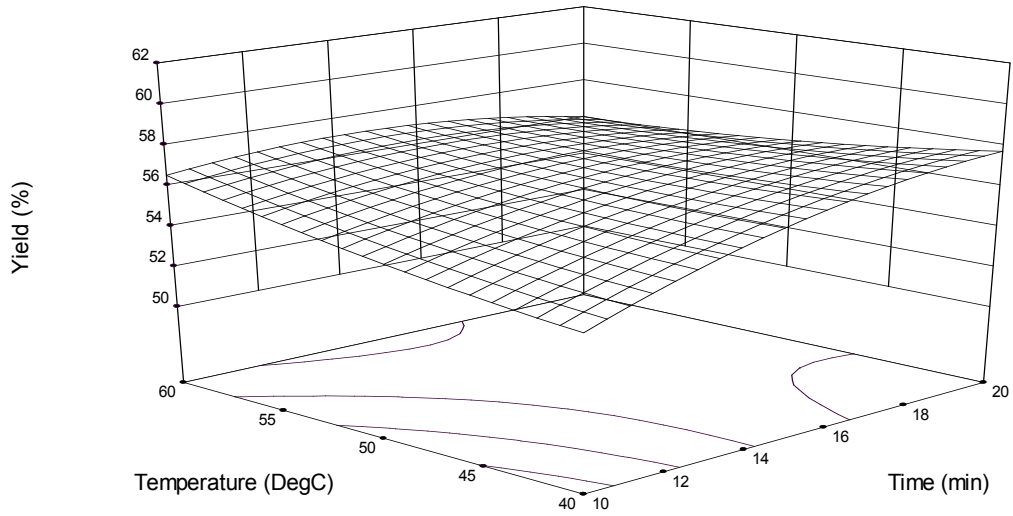


Figure 1a. Effect of time and temperature on yield of coconut milk.

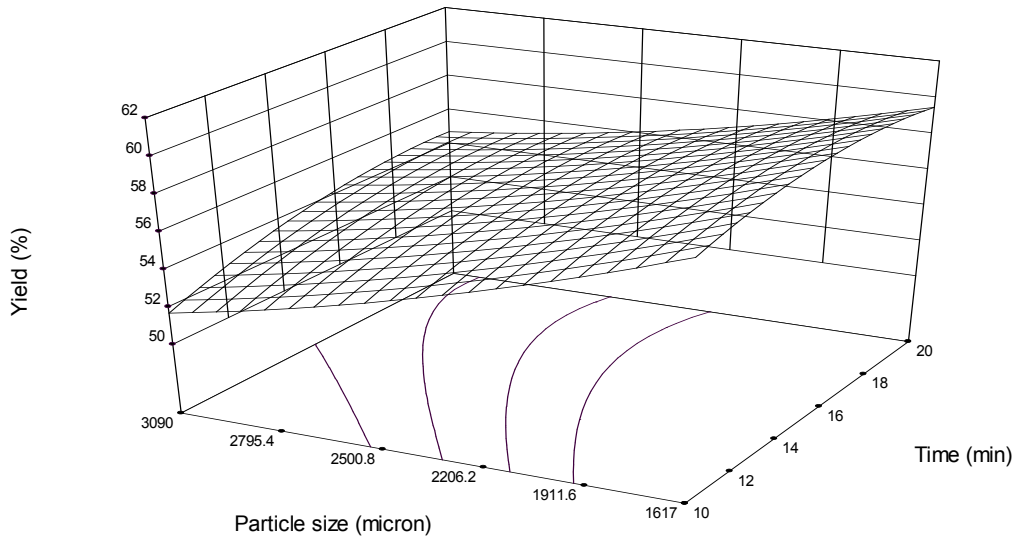


Figure 1b. Effect of time and particle size of coconut on yield.

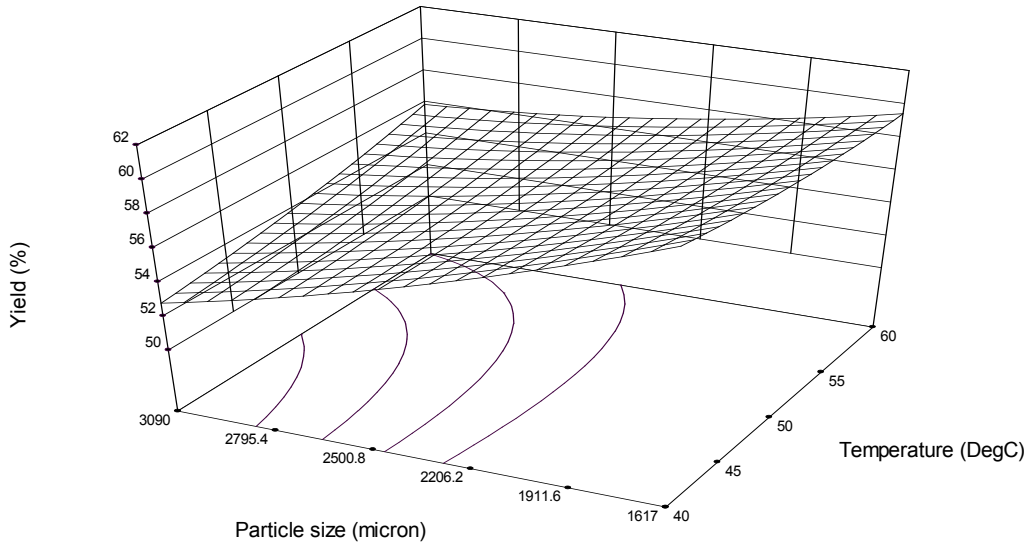


Figure 1c. Effect of particle size of coconut meat and temperature on the yield of coconut milk.

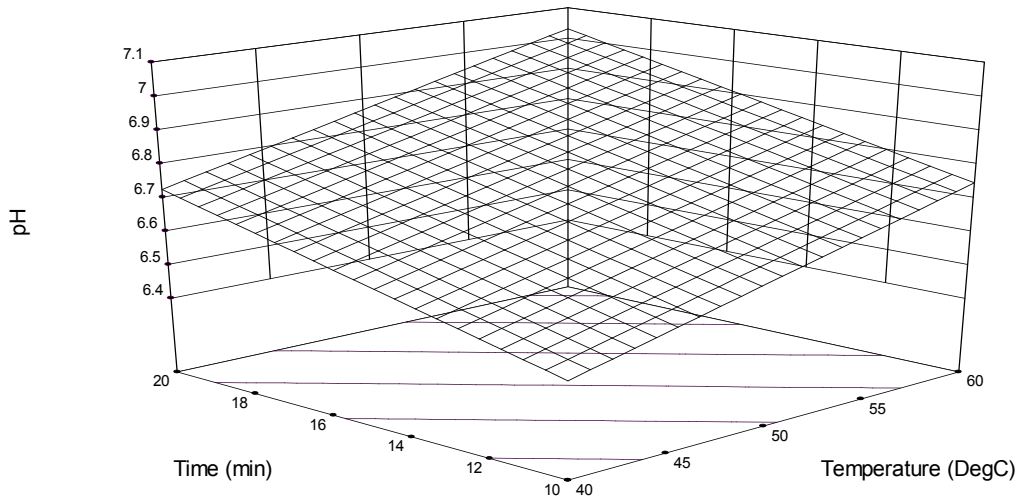


Figure 2. Effect of time and temperature on the pH of coconut milk.

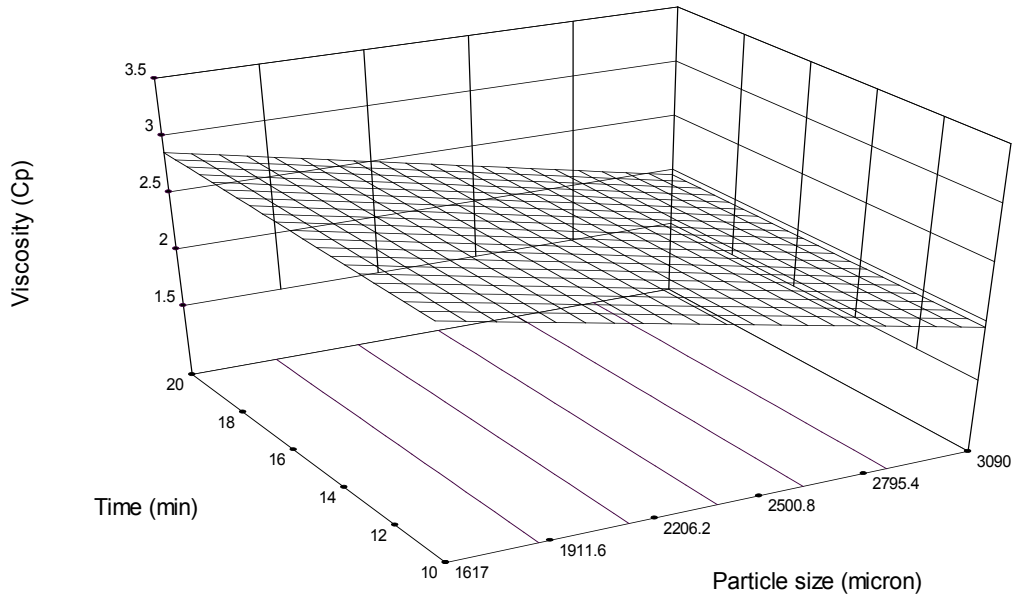


Figure 3. Effect of extraction time and particle size of coconut meat on the viscosity of coconut milk.

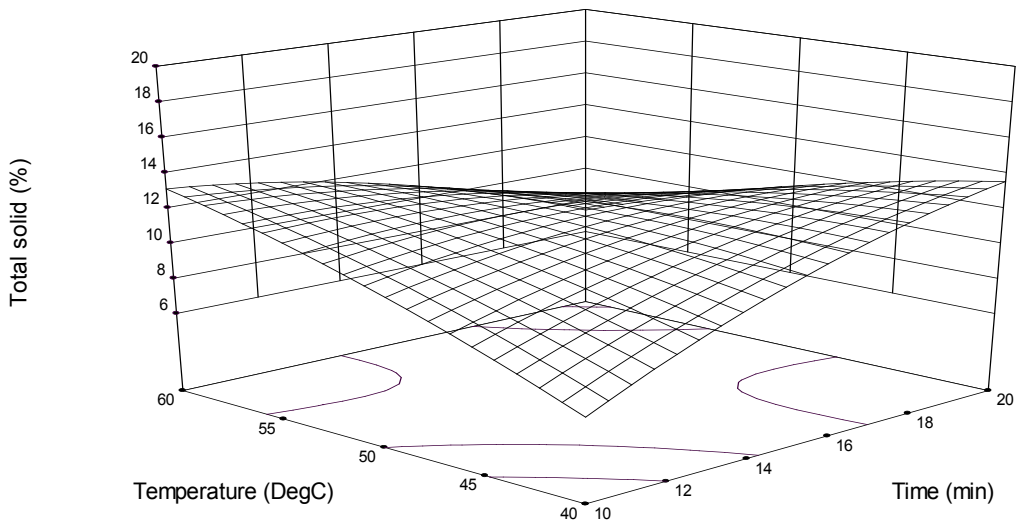


Figure 4a. Effect of time and temperature on the total solid content of coconut milk.

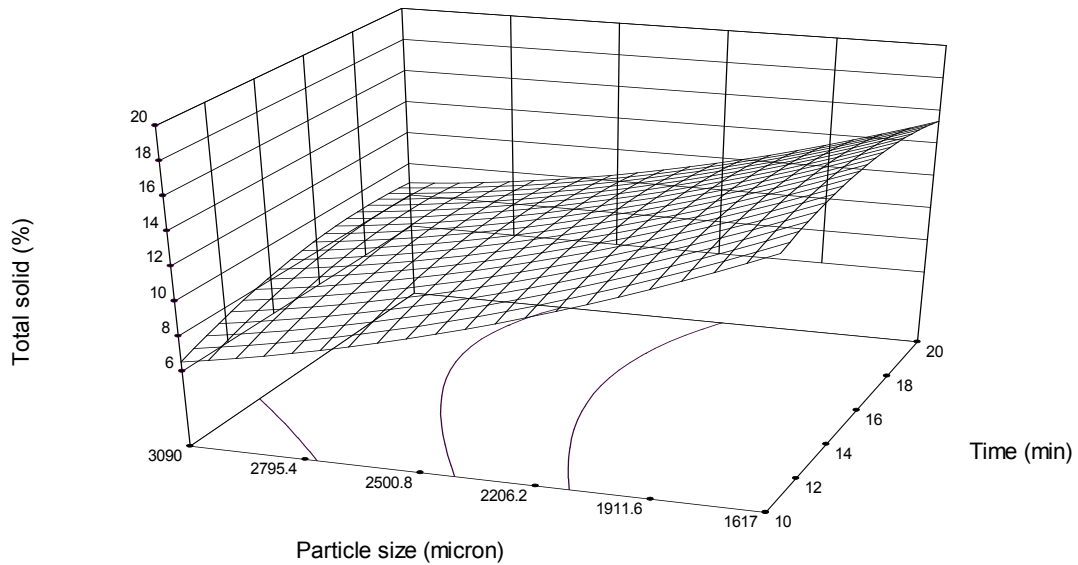


Figure 4b. Effect of particle size of coconut meat and extraction time on the total solid content of coconut milk.

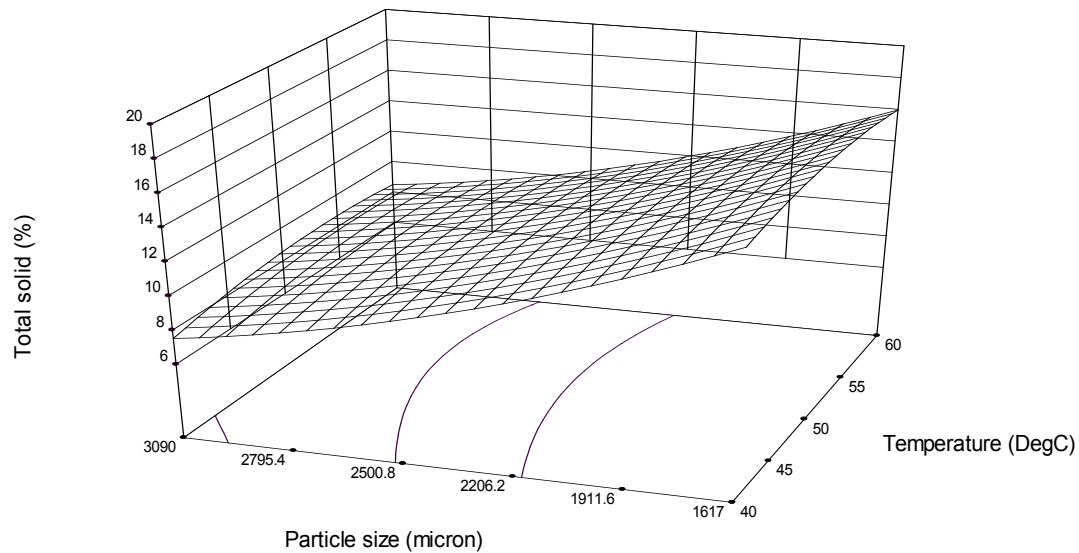


Figure 4c. Effect of particle size of coconut meat and extraction temperature on total solid content of coconut milk.

3.6. Optimization of Coconut Milk Extraction

Numerical optimization option was employed; the desirability function was generated after limiting the preferred goal of extraction variables and responses, such as minimizing particle size of coconut meat and extraction temperature, maximizing milk yield, viscosity and total solid content while the extraction time and pH were allowed to be in range. According to the desirability function, the software generated several solutions of process variables with the predicted values of responses. The predicted optimum condition at maximum desirability index of 0.797 (79.70%) was obtained as 14.755 min extraction time, 40°C extraction temperature and a particle size of coconut meat $\leq 1617.00\mu\text{m}$. The predicted optimal yield, pH, viscosity, total solids were estimated to be 61.129%, 6.608, 2.851cp and 16.013% respectively.

3.7. Validation of Optimization of the Extraction Process

To validate optimization of extraction time, extraction temperature and particle size of coconut meat, three experiments were carried out under the recommended optimum condition with a slight modification in extraction time to 15 min as against 14.755 min. The predicted and experimental values are presented in Table 5. The result showed that there were no significant difference ($p > 0.05$) on the corresponding experimental values between the predicted (simulated) and actual properties of coconut milk. This result attests to the effectiveness of this framework for optimum and effective coconut milk extraction. In general, the optimized values of process variables (extraction time of 14.755 min, extraction temperature of 40.0°C and particle size of coconut meat $\leq 1617.00\mu\text{m}$) obtained from RSM is different from calculated data in Table 2. This is because the

optimization has been carried out by software and the variable in range has been selected to obtain the optimum response.

Table 5. Predicted and actual responses for optimized process.

Response	Values	
	Predicted	Experimental ^a
Yield (%)	61.129	60.90± 0.28
pH	6.608	6.65±0.05
Viscosity (cp)	2.851	3.00±0.50
Total solids (%)	16.013	14.00±0.50

^amean ± standard deviation, $n=3$

4. Conclusion

The optimization of extraction process conditions for coconut milk was effectively implemented using a response surface methodology. Results showed that extraction time, extraction temperature and particle size of coconut meat markedly affect the yield, pH, viscosity and total solids of the coconut milk. The multiple response optimization revealed the optimum conditions to maximize the yield, viscosity and total solids of coconut milk. The experimental results validated the optimized model in terms of 60.90±0.28% of yield, 6.65±0.05 of pH, 3.0±0.50 cp of viscosity and 14.0±0.50% of total solids at the optimum conditions of extraction time of 15 min (modified), extraction temperature of 40°C and particle size of coconut meat ≤ 1617.00 µm. The results of this study suggest that the obtained model is acceptable for the maximum milk yield, improved quality consistency and standardized coconut milk for production of dairy-like products.

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