EFFECT OF EXTRACTION VARIABLES ON CONSUMER ACCEPTABILITY OF COCONUT MILK: A RESPONSE SURFACE APPROACH

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Abstract
Coconut milk is widely utilized in the food industry due to its functional roles, yet, to our knowledge, the optimal extraction conditions have not been established. The aim of this study was therefore to determine the effect of extraction variables on the sensory attributes of coconut milk with a view to determining the optimal extraction conditions. A Central Composite Design (CCD) of Response Surface Methodology (RSM) was employed to study the effect of extraction variables (extraction time, temperature and particle size of coconut meat) on the sensory attributes of coconut milk (CM). Regression models were generated and adequacy tested with lack of fit and coefficient of determination (R^2). The results showed that quadratic model as the highest order model with significant term that could describe the effect of extraction variables on sensory attributes of CM. The R^2 for appearance, taste, aroma, consistency and general acceptability were 0.9306, 0.9461, 0.9787, 0.9649 and 0.9939 respectively; which indicated that a higher proportion of variations in sensory attributes were explained by quadratic model. Extraction time, extraction temperature and particle size of coconut meat had significant effect on appearance, taste, aroma, consistency and general acceptability of CM. The optimum extraction time, extraction temperature and particle size of coconut meat were 14.755 min, 40.0 ^oC and $\leq$ 1617 µm respectively, which gave panel scores of 8.09, 8.43, 7.69, 7.16 and 8.26 for appearance, taste, aroma, consistency and general acceptability, respectively.

Keywords: Coconut milk, Coconut meat, Consumer acceptability, Optimization, Response Surface Methodology

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1. INTRODUCTION

Coconut milk (CM) is a sweet, milky, white, natural oil-in-water emulsion extracted from the endosperm of mature coconut by using mechanical force, with addition of water (Narataruka *et al*., 2010). The color and rich taste of the milk can be attributed to the high oil content and sugars. In the United States, coconut milk was one of the major sources of dietary fat, aside from dairy and animal fats (Dayrit, 2005).

CM is fast becoming an increasingly important raw material in home cooking as well as in the food processing industries (Muda, 2002). It is estimated that 25% of the world coconut output is consumed as CM (Gwee, 1988). 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 (Gwee, 1988; Gonzalez *et al*., 1990). It can also be used as a substitute for milk in some desserts such as chocolate and other confectionaries are exotically flavoured with CM (Muda, 2002).

CM also serves as an excellent source of raw material for the development of dairy-like products such as yoghurt. Its nutritional content is higher compared to cow milk (Yaakob *et al*., 2012). CM contains about 54 % moisture, 11 % solid non-fat and 35 % fat (Simuang et al., 2004; Tansakul and Chaisawang, 2006), and is high in minerals and vitamin content (Sanful, 2009 b). It is also rich in proteins such as albumin, globulin, prolamin and glutein. The fat content plays an important role in the flow property of CM (Peamprasart and Chiewchan, 2006). Unlike other nuts, CM fat is mostly in the form of medium chain saturated fatty acids (MCFAs) which is abundant in human milk, in particular lauric acid (Baldioli *et al*., 1996). 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 (Alyaqoubi, 2015).
In Nigeria, CM extraction is primarily done manually, and so time and effort consuming. Besides, the extraction process is 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 (PCA, 2014). Moreover, extraction time (Olarewaju *et al*., 2015), extraction temperature (Minh, 2014) have been identified as important factors in CM extraction. Agarwal and Bosco (2014) 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.
Response Surface Methodology (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 object is to optimize this response (Montgomery, 2005). RSM has been widely reported for the optimization of a wide range of products such as extraction of olive oil (Meziane, 2013), soybean oil (Campbell and Glatz, 2009), coconut oil (Agarwal and Bosco, 2014). RSM has also been found to be an effective tool in optimizing any process (Pishgar *et al*., 2012) wherein the interaction among factors (independent variables) has to be tailored for desired responses (dependent variables). It considers interaction among process parameters and optimizes them to a reasonable range, with the advantage of the relevant information in the shortest time with the least number of experiments (Lee and Yusof, 2006). This study was carried out to determine the effect of extraction time, extraction temperature and particle size of coconut meat on consumer acceptability of CM.

2. MATERIALS AND METHODS

2.1. Sample Collection

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. The coconuts were taken to the Food Processing Laboratory of Department of Food Science and Technology, University of Uyo, Uyo, Akwa Ibom State, Nigeria.

2.2. 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 $\leq$ 1311.93, $\leq$ 1617, $\leq$ 2353.5, $\leq$ 3090 and $\leq$ 3395.07 µm. The grated coconut meat was mixed in a ratio of 1:1 with a solution containing 75 % and 25 % of distilled water and coconut water and allowed to stand in a water bath at stipulated temperatures and time (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 ^{o}C for 30 min and allowed to assume room temperature (37 ^{o}C).

2.3. Optimization of Process Condition for Extraction of Coconut Milk

Optimization of CM production was performed using Design Expert (Stat-Ease Inc., Minneapolis, MN, USA) software version 9.0. 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

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

Independent Variables	Factor	Unit	$-\alpha$	-1	0	+1	$+\alpha$
			Coded levels				
Time	X_1	min	7.92	10	15	20	22.07
Temperature	X_2	^{o}C	35.85	40	50	60	64.14
Particle size	X_3	µm	1311.93	1617	2353.5	3090	3395.07

time (X_1), extraction temperature (X_2) and the particle size (X_3) of coconut meat.

Each variable had 3 different coded levels from low (-1), to medium (0) and high (+1) as well as star points ($\pm\alpha$) for efficient determination of curvature and quadratic term. The dependent variables; appearance, taste, aroma, consistency and general acceptability of extracted CM were evaluated as responses for the factors studied. The design matrix of CCD and experimental runs are shown in Table 2. Multiple regression analysis was used as tool of assessment of the effects of independent variables on the dependent variables. The full quadratic equation of the response variables for coconut milk was derived using RSM as follows:

$$Y = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_{12} X_1X_2 + \beta_{13}X_1 X_3 + \beta_{23} X_2X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 \qquad (1).$$

where Y = response, β_o = constant, β_1, β_2, β_3 = Linear regression, β_{11}, β_{22}, β_{33} = interaction regression, X_1, X_2, X_3 (independent variables) and β_{11} X_1^2, β_{22} X_2^2 and β_{33} X_3^2 = quadratic regression.

2.4. Sensory Analysis

Sensory evaluation was carried out on the CM using a 9 – point Hedonic scale where 1 represented 'dislike extremely' while 9 represented 'like extremely'. Samples were coded with 3 digits. A Panel of 20 semi-trained members was drawn from staff and students of University of Uyo, Uyo, Akwa Ibom State, Nigeria. Panelists were asked to evaluate product characteristics such as appearance, taste, aroma, consistency and general acceptability. Panelists were served a glass of water to neutralize the taste before analyzing each sample. Data obtained was analyzed using design expert software version 9.0.

3. RESULTS AND DISCUSSION

3.1 Model Fitting

The independent variables and responses were fitted to quadratic model by performing analysis of variance in order to determine the lack of fit and significance of the model and the effect of interaction between independent variables and responses. The descriptive statistics for the quality of CM as affected by extraction time (X_1), extraction temperature (X_2) and particle size of coconut meat (X_3) is presented in table 2. Sensory characteristics of CM were evaluated as responses for the factors studied. The result indicated that sensory scores for appearance of CM was between 6 and 9; while that of taste, aroma, consistency and general acceptability ranged from 4 – 9 each. The result revealed that the highest panel score of 9 (like extremely) was obtained for general acceptability of CM samples extracted at 50 ^{o}C, for 15 min using coconut meat particle size of 1311.93 µm as well as CM extracted at 60 ^{o}C, for 20 min using coconut meat particle size of 1617 µm.

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

Effect of extraction time (X_1), extraction temperature (X_2) and particle size of coconut meat (X_3) on the appearance (Y_1) of coconut milk is presented in table 3. Appearance is a critical quality attribute that plays important role in marketing and acceptance of products. Yaakob *et al.* (2012) reported that appearance, taste, aroma texture are the main criteria to assess product quality. These attributes help in defining product characteristics which are important with respect to consumer acceptability of the product.

Table 2: Design matrix and descriptive statistics for the quality of coconut milk as affected by extraction time, extraction temperature and particle size of coconut meat

Exp. run	Coded variable			Actual variable			Response				
	X_1	X_2	X_3	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4	Y_5
1	-1.000	1.000	1.000	10	60	3090	6	5	5	4	4
2	0.000	0.000	0.000	15	50	2353.5	6	6	6	6	6
3	-1.000	-1.000	-1.000	10	40	1617	8	9	8	8	8
4	0.000	0.000	α	15	50	3395.07	6	6	6	6	6
5	1.000	1.000	-1.000	20	60	1617	7	8	9	8	9
6	0.000	0.000	0.000	15	50	2353.5	7	6	6	6	6
7	α	0.000	0.000	22.0711	50	2353.5	6	6	5	6	6
8	1.000	-1.000	1.000	20	40	3090	6	4	5	6	5
9	0.000	0.000	0.000	15	50	2353.5	6	5	6	6	6
10	0.000	α	0.000	15	64.1421	2353.5	6	5	4	6	6
11	$-\alpha$	0.000	0.000	7.92893	50	2353.5	6	5	6	5	6
12	0.000	0.000	$-\alpha$	15	50	1311.93	9	9	9	9	9
13	0.000	$-\alpha$	0.000	15	35.8579	2353.5	6	5	5	5	6
14	0.000	0.000	0.000	15	50	2353.5	6	5	6	6	6
15	0.000	0.000	0.000	15	50	2353.5	6	6	6	5	6

Y_1 = Appearance, Y_2 = Taste, Y_3 = Aroma, Y_4= Consistency, Y_5 = General acceptability, X_1 = Extraction time, X_2 =Extraction temperature and X_3 = Particle size of coconut meat

Table 3: Regression coefficients, coefficient of determination, lack of fit of predicted polynomial model for appearance, taste, aroma, consistency and general acceptability of coconut milk at the design response surface

Coefficient	Appearance	Taste	Aroma	Consistency	General Acceptability
Linear					
β_o	6.19	5.45	5.89	5.78	6.04
β_1	-	-	-0.35	-	-
β_2	-	-	-0.35	-	-
β_3	-1.06	-1.06	-1.16	-1.06	-1.06
Interaction					
β_{12}	-	0.94	-	-	0.94
β_{13}	-	-	-1.10	0.85	-
β_{23}	-	0.85	-1.10	-	-
Quadratic					
β_{11}^2	-	-	-	-	-
β_{22}^2	-	-	-0.62	-	-
β_{33}^2	0.68	1.03	0.88	0.89	0.69
Lack of Fit	NS	NS	-	NS	NS
R^2	0.9306	0.9461	0.9787	0.9649	0.9939
Adjusted R^2	0.8056	0.9057	0.9574	0.9017	0.9893
Predicted R^2	0.7608	0.9165	0.7619	0.7974	0.8715
CV (%)	6.24	7.74	4.69	6.66	2.15
Adequate precision	9.326	15.875	24.992	15.333	52.554

CV, coefficient of variation; NS, not significant

The result showed that experimental data for appearance was fitted to quadratic model which was significant ($p<0.05$), adequate (lack of fit > 0.05) and reliable (CV = 6.24 %).

The goodness-of-fit of the model was also ascertained by the coefficient of determination (R^2). The R^2 value of 0.9306 implies that the model fit the data and 93. 06 % variations in the observed values of appearance were explained by the quadratic model. Jusoh *et al*., (2013) reported that the best R^2 value for a good model fitting was estimated between 0.8 and 1.0. The predicted R^2 of 0.7608 was in reasonable agreement with the adjusted R^2 of 0.8056 which illustrated that there were excellent correlations between independent variables. Adequate precision (9.326) which measures the signal to noise ratio indicated an adequate signal. A ratio greater than 4 is desirable. Therefore the model can be used to navigate the design space.

The linear main effect and quadratic term of particle size of coconut meat were the only significant ($P<0.05$) terms affecting the appearance of CM. However, extraction time, extraction temperature, interaction of extraction time and extraction temperature, interaction of extraction time and particle size of coconut meat, interaction of extraction temperature and particle size of coconut meat, quadratic effects of extraction time and temperature had no significant ($P>0.05$) effect on the appearance of CM and were removed, thus, resulting in a regression model that is statistically significant as shown in equation (2).

$$\text{Appearance} = +6.19 - 1.06\, X_3 + 0.68X_3^2 \qquad (2)$$

where X_3 = Particle size of coconut meat

The negative linear and positive quadratic effects of particle size of coconut meat indicated an accelerated decline in panel rating for appearance from 8 (like very much) towards 5 (neither like nor dislike) with increase particle size of coconut meat as shown in fig 1.

3.3. Effect of extraction time, extraction temperature and particle size of coconut meat on taste of coconut milk

The significant ($p<0.05$) terms in the fitted quadratic model as shown in table 3 are the linear effect of particle size of coconut meat, interaction effect of extraction time and extraction temperature, interaction effect of extraction temperature and particle size of coconut meat and quadratic term of particle size of coconut meat. The quadratic model was significant ($P<0.05$), adequate (lack of fit > 0.05), reliable (CV = 7.74 %), predictable (R^2= 0.9461) and explained 94.61 % of observed variability. The regression model showing the effect of extraction time (X_1), extraction temperature (X_2) and particle size of coconut meat (X_3) is shown in equation (3).

$$\text{Taste} = +5.45 - 1.06X_3 + 0.94X_1X_2 + 0.85X_2X_3 + 1.03X_3^2 \qquad (3)$$

The positive coefficient of interaction of extraction time and extraction temperature resulted in synergistic effect on taste (fig.2a). Increase in extraction temperature (from 40-60 ^oC) and time (from 10-20 min) resulted in increase in panel score for taste from 4 (dislike slightly) towards 6.8 (between like slightly and moderately). It seems likely that more soluble flavor components were released into the milk as the temperature and time of extraction increased.

The negative linear coefficient and positive quadratic coefficient of particle size indicated that increase in particle size of coconut meat resulted in decrease in panel score of taste from 7 to 4.5 at 40 ^oC (fig. 2b) and the response surface curve is convex, showing that there was a maximum turning point (2500.8 µm) beyond which the panel rating for taste increased. The implication is that there was less than linear decrease in panel score for taste with regards to particle size. This is because the quadratic term of particle size of coconut was exerting an upward force on the equation. Possibly, the leaching of greater amount of the coconut meat components was facilitated at higher temperatures, more fats, minerals and sugars were released into the milk resulting in the gradual increase in panel score for taste.

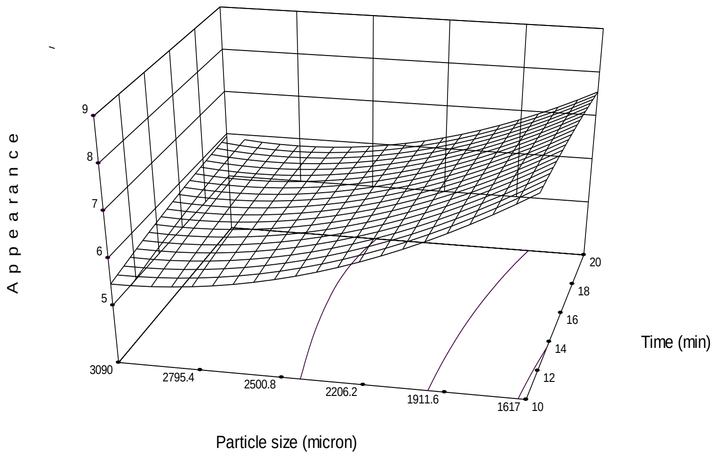

Fig. 1: Effect of particle size of coconut meat and extraction time on appearance of coconut milk

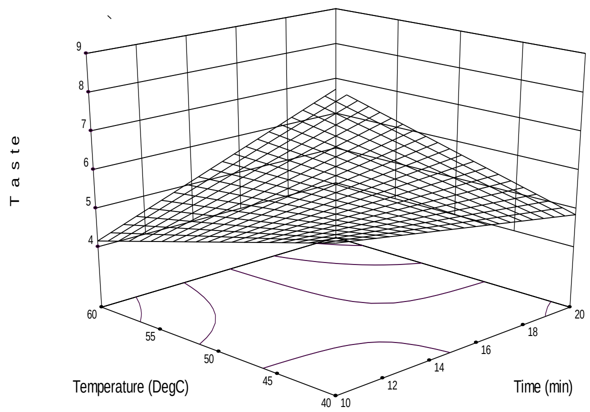

Fig. 2a. Effect of extraction time and temperature on the taste of coconut milk

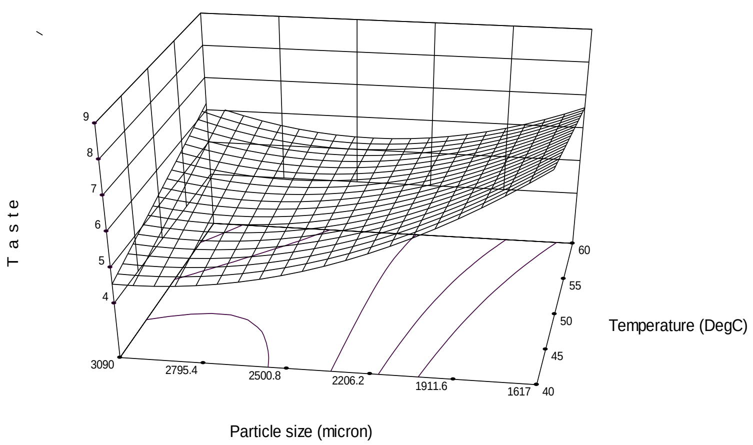

Fig.2b. Effect of particle size of coconut meat and extraction temperature on the taste of coconut milk

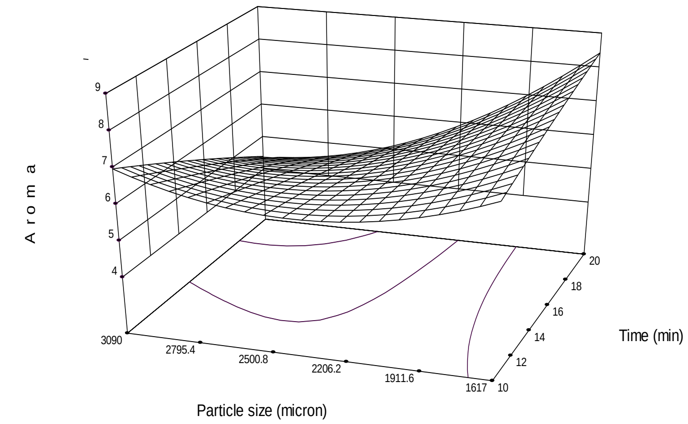

Fig.3a. Effect of particle size of coconut meat and extraction time on the aroma of coconut milk

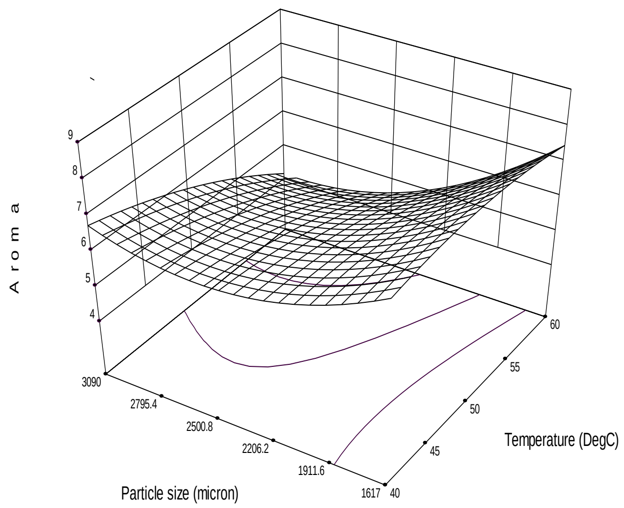

Fig. 3b. Effect of particle size of coconut meat and extraction temperature on the aroma of the coconut milk

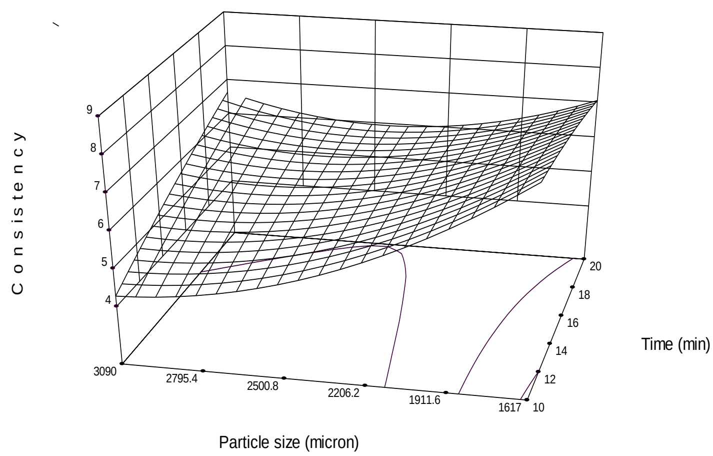

Fig 4a. Effect of particle size of coconut meat and extraction time on the consistency of coconut milk

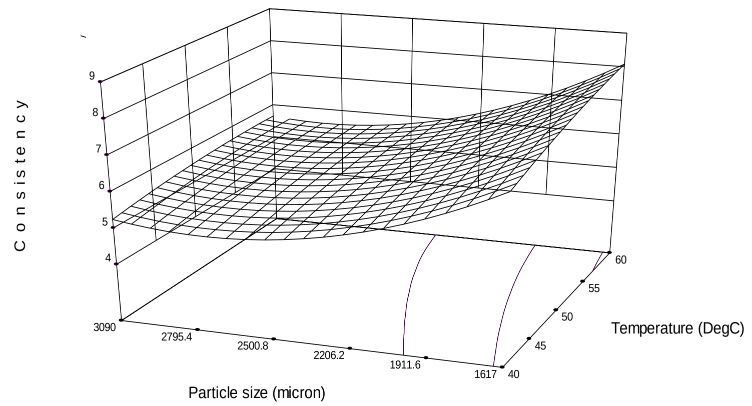

Fig. 4b: Effect of particle size of coconut meat and extraction temperature on the consistency of coconut milk

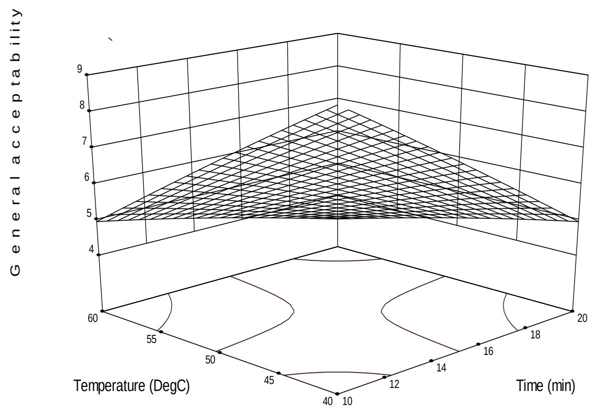

Fig.5a. Effect of time and temperature on the general acceptability of the coconut milk

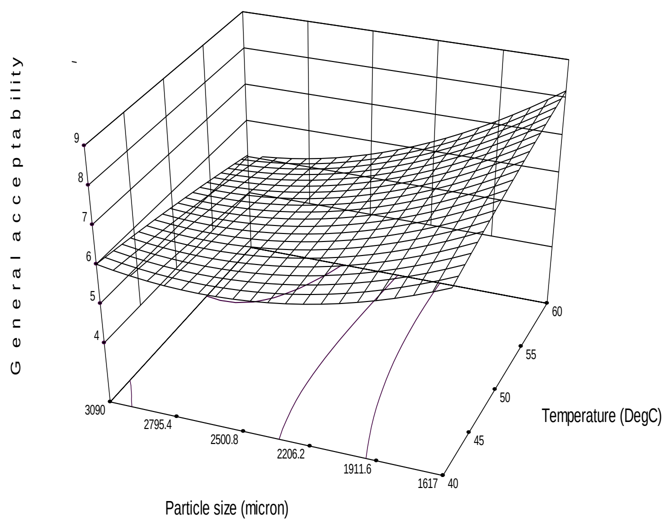

Fig.5b. Effect of particle size of coconut meat and extraction temperature on general acceptability of coconut milk

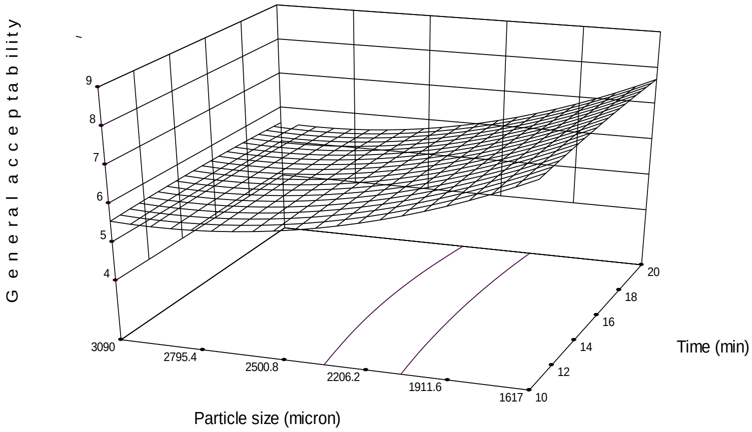

Fig.5c. Effect of extraction time and particle size of coconut meat on general acceptability of the coconut milk

3. 4. Effect of extraction time, extraction temperature and particle size of coconut meat on the aroma of coconut milk

The fitted quadratic model for aroma of coconut milk (table 3) was adequate, reliable (CV = 4.69 %), predictable (R^2= 0.9787) and explained 97.87 % of observed variability. The regression model showing the effects of process variables is shown in equation (4).

$$\text{Aroma} = +5.89 - 0.35X_1 - 0.35X_2 - 1.16X_3 - 1.10X_1X_3 - 1.10X_2X_3 - 0.62X_2^2 + 0.88X_3^2 \quad (4).$$

The linear main effect of extraction time, extraction temperature, particle size of coconut meat, interaction effects of extraction time and particle size of coconut, interaction of extraction temperature and particle size of coconut meat, quadratic term of temperature as well as quadratic term of particle size of coconut meat significantly ($P< 0.05$) affected the aroma of CM. However, interaction effects of extraction time and extraction temperature and quadratic term of time had no significant ($P>0.05$) effect on aroma of CM.
The negative coefficients of extraction time, extraction temperature and particle size of coconut meat implied that extraction time, extraction temperature and particle size of coconut meat had a negative effect on aroma of CM. This also implied that interaction terms exerted a negative effect on aroma of CM. Panel rating for aroma decreased from 8.5 (like very much) to about 4.5 (between dislike very much and neither like nor dislike) with increase in particle size of coconut meat (fig. 8 a). Similarly, increased in particle size of coconut meat with temperature led to decrease in panel rating for aroma from 7 (like moderately) to 4 (dislike slightly) (fig. 8 b). This decrease may be attributed to the non-leaching of most aromatic compounds present in coconut meat due to increased particle size of coconut meat.

3.5. Effect of extraction time, extraction temperature and particle size of coconut meat on consistency of coconut milk

The consistency of CM was modeled using quadratic model. The model with a non significant lack of fit, was adequate, reliable (CV = 6.66 %), predictable (R^2= 0.9649) and explained over 90 % of observed variability. Particle size of coconut meat, interaction of time and particle size as well as quadratic term of particle size were the only significant ($P <0.05$) terms influencing the consistency of CM. The regression model showing the effect of extraction time (X_1), extraction temperature (X_2) and particle size of coconut meat (X_3) is shown in equation (5).

$$\text{Consistency} = +5.78 - 1.06X_3 + 0.85X_1X_3 + 0.89X_3^2 \quad (5).$$

The negative linear coefficient of particle size of coconut meat showed that increase in particle size of coconut meat resulted in decrease in panel rating of consistency of CM (figure 4a). However, a positive coefficient of the interaction of particle size of coconut meat and time resulted in synergistic effect (figure 4a); increase in particle size of coconut meat with time aided the leaching and dissolution of soluble solids of coconut meat which resulted in subsequent increase in panel rating of consistency of CM. Figure 4b shows that the consistency of CM was greatly influenced by the particle size of coconut meat. Effect of particle size of coconut meat and extraction temperature indicated a negative effect on the consistency.

3.6. Effect of extraction time, extraction temperature and particle size of coconut meat on general acceptability of coconut milk

The quadratic model for the effect of process variables on general acceptability of CM was reliable (CV = 2.15 %), predictable (R^2= 0.9939), significant ($P<0.05$) and effective in explaining 99.39 % of observed variability in general acceptability. The significant terms influencing general acceptability of CM were; particle size of coconut meat, interaction of extraction time and extraction temperature and quadratic term of particle size of coconut meat. The regression model showing the effects of extraction time (X_1), extraction temperature (X_2) and particle size of coconut meat (X_3) on general acceptability of CM is shown in equation (6).

$$\text{General acceptability} = + 6.04 - 1.06X_3 + 0.94X_1X_2 + 0.69X_3^2 \quad (6).$$

Positive and negative coefficients in the model represent synergism and antagonism between process variables respectively. Increase in extraction temperature (from 40 - 60 ^oC) and extraction time (from 10-20 min) led to increase in panel rating for general acceptability from about 5.5 to 6.8 (between like slightly and like moderate) (fig. 5a). Increase in extraction time and temperature aided the leaching of components from the coconut meat into the milk thus, influencing the quality of the milk (Kaptso *et al.*, 2007) and subsequent increase in panel rating.

Figure 5b shows that particle size contributed more significantly to the effect on the general acceptability than temperature. Extraction temperature and particle size of coconut meat had a negative effect on general acceptability of CM; this resulted in a drop in panel rating for general acceptability from 8.2 (like very much) towards 5 (neither like nor dislike). The figure shows that panelists preferred milk extracted from smaller particle size of coconut meat than those of larger particle size. Similar result was also observed in figure 5c. This shows that particle size of coconut meat is an important factor for consumer acceptability of CM.

4. CONCLUSION

This study has clearly shown the applicability of RSM in the study of effect of extraction time, extraction temperature and particle size of coconut meat on sensory attributes of CM. Results indicated that extraction time, extraction temperature and particle size of coconut meat had significant effect on sensory attributes of CM, with the optimum extraction time, extraction temperature and particle size of coconut meat being 14.755 min, 40.0 ^oC and $\leq$ 1617 µm respectively.

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