

Full Length Research Paper

Effect of process treatments on the proximate composition of tigernut-soy milk blends

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Received 12 February, 2019; Accepted 30 September, 2019

The effect of pasteurisation parameters and formulation components on the nutritional composition (carbohydrate, protein, fat, ash and moisture contents) of tigernut-soy milk blend was investigated. Twenty-six different formulations ($F_1 - F_{26}$) were prepared from tigernut and soy milk. The process treatments employed were; pasteurisation temperature, pasteurisation duration and mixing duration which varied from 60 – 80°C, 5-20 s and 5-15 min respectively. The results showed that F_{24} with blend constituents of 37, 5 and 50% of tigernut milk, soy milk, water and process treatments of 60°C, 20 s and 5 min of pt, pd and md respectively had the highest percentage of carbohydrate (12.53%) and fat (3.181%). The highest protein value (5.69%) was found in F_{11} with blend constituents of 27, 5 and 60% of tigernut milk, soy milk, water and process treatments of 80°C, 20 s and 5 min of pt, pd and md respectively. F_{23} with blend constituents of 11, 11 and 70% of tigernut milk, soy milk, water and process treatments of 80°C, 20 s and 5 min of pt, pd and md respectively had the highest ash (4.38%) content. The most abundant in moisture content (93.065%) was F_{18} with blend constituents of 5, 17 and 70% of tigernut milk, soy milk, water and process treatments of 60°C, 5 s and 5 min of pt, pd and md respectively. Pasteurised tigernut-soy milk is rich in nutritional quality.

Key words: Pasteurisation, mixing, temperature, milk, ash, nuts, moisture content.

INTRODUCTION

Tigernut (*Cyperus esculentus* L.) belongs to the division–*Magnoliophyta*, class–*Liliopsida*, order–*cyperales* and family–*Cyperaceae*. It is a cosmopolitan, perennial crop of the same genus as the papyrus plant (Belewu and Belewu, 2007; Adejuyitan, 2011). The tubers which are about the size of peanuts are abundantly produced in Nigeria. It has other names such as ground almond, *zulu* nut, *chufa*, yellow nutgrass, edible rush and rush nut. In Nigeria, Yorubas call it *Imumu*, Hausas *Aya*, the Igbos *Aki* Hausa; whereas in the Southern part of Nigeria it is

known as *Ofo*. Since early times (chiefly in West Africa and South Europe), tigernut has been cultivated for its small tuberous rhizomes which are used as hog feed, eaten raw or roasted, or pressed for its juice to produce a beverage (Osagie and Eka, 1998).

The nuts have excellent nutritional qualities with fat composition similar to olive oil, and are also rich in mineral content especially phosphorus and potassium but with low sodium content (Martinez, 2003). According to Oladele and Aina (2007), the crude protein content of the

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Figure 1. Sample of the soya beans.



Figure 2. Sample of the Tigernuts.

nuts ranged between 7.15 and 9.7%. *Chuffa*, as it is also called is cultivated in Nigeria primarily because of its rich vegetable milk which is an alternative to cow milk among the rural poor. It is used in the production of yoghurt and *Kunnu* (beverage) to quench thirst in Northern Nigeria (Sowonola et al., 2005). Tigernut tubers have also been used as alternative to cassava in baking industry (Bosch et al., 2005).

Soybean belongs to the family leguminous, subfamily *papiliondase* and the genus *Glycine Max*. The total area cultivated when Soybean (*Glycine max*) was first introduced in Nigeria in 1908 was 401,000 ha, while the current yield is about 1270 kg per hectare (Rehman et al., 2007). Soyabean not only provides quality macronutrients but also various other micronutrients, which are otherwise required to fight against malnutrition. It is rich in protein content and can furnish protein supply to bridge up the protein deficiency gap at low-cost than any other crop (Rehman et al., 2007).

Milk has been recognized as an important food for infants and growing children. In developing countries, the cost of dairy milk and their products is prohibitive and this has led to the development of alternative source of milk from plant materials. Tigernut milk (having Spanish name *horchata*) is a refreshing purely natural vegetable drink and or dessert, which is prepared with water, sugar and

tigernuts. It is a very nutritive, energy drink both for young and old. Soymilk not only provides protein but is also a source of carbohydrate, lipid, vitamins and minerals (Chien and Snyder, 1983). It is an alternate of dairy animal milk due to the fact that it is less expensive despite it having high-quality protein. It has also been proved to be a healthy drink and is important especially for people who are allergic to cow milk protein and lactose (Rehman et al., 2007).

Tigernut-soy milk is a blended, processed commodity and is a source of quality energy, protein, minerals, and vitamins; combining the nutritional benefits of both.

Modern pasteurization is the application of adequate heat to a product for a period of time for the purpose of destroying pathogenic microorganisms, yet leaving the product acceptable from sensory and nutritional stand point (Lewis and Heppell, 2000).

In developing countries, the cost of milk and its products is prohibitive. This has led to dramatic decrease in the consumption of milk and milk products and stimulated in part the processing of milk from different seeds and nuts (Belewu and Belewu, 2007). High price of imported milk and milk products coupled with poor milk production in Nigeria and Africa in general seem to have made consumers more readily accept milk produced from plant sources.

Therefore, this study sought to evaluate the nutritive value of soy milk and tigernut milk as well as their combination in various proportions as affected by pasteurization, with a view to incorporating this into local milk production in Nigeria, taking into cognizance the importance of heat treating the milk at different temperatures.

MATERIALS AND METHODS

The soya beans and tigernuts used for this research work were purchased from Kure Market, Minna, Niger State, Nigeria. The samples of soya beans and tigernuts used for this experiment are shown in Figures 1 and 2 respectively.

Procedure for production of tigernut milk

Samples of dried tigernuts were purchased from the market and the bad nuts and other foreign materials were picked out. The tigernuts were then washed and soaked in water (6 L: 1 kg) for 18 h. Soaking of the tigernuts in water helps to soften it so as to blend with ease. The method of Belewu and Abodunrin (2006) was used. The soaked tigernuts were milled into slurry which was then pressed using muslin cloth to extract the milk and the milk extracted was divided into three parts and diluted to 50, 60 and 70% with water respectively. The flow chart for the production of tigernut milk is shown in Figure 3. The filtrate was stored in a plastic container for further processing.

Procedure for production of soy milk

Five kilograms (5 kg) of soya beans was soaked for 18 h in 15 L of potable water to give a bean-water ratio of 1:3. The soaked beans

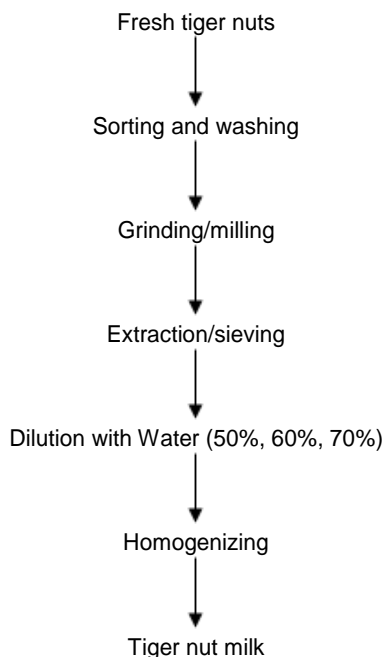


Figure 3. The flow chart for tigernut milk production.

was drained, rinsed with portable water and dehulled. Afterwards, the dehulled beans were milled. The resulting slurry was filtered through a muslin cloth and the extract (milk) obtained boiled for 2 h, after which it was divided into three parts and diluted with water to 50, 60 and 70% respectively. The flow chart for soymilk production is shown in Figure 4.

Procedure for preparation of tigernut-soy milk drink

Tigernut milk and soya milk were combined in varying proportions to obtain the final products as shown in Table 1. This was done using a LEXUS food blender operated at speed level one (450 rpm) for the duration specified for the various samples. The resulting blends were packaged in plastic bottles and were then pasteurized at the indicated temperatures and durations as specified for each of the samples in Table 1 using a water bath (Supplementary Figure 1 and 2).

After heating, they were cooled immediately to room temperature ($28 \pm 2^\circ\text{C}$). The flow chart for tigernut-soy milk drink production is shown in Figure 5.

Design of the experiment

Mixture - process design was used for the experimental design. The design matrix (Table 1) generated twenty-six experimental runs (Table 2). The mixture variables are tigernut milk, soy milk and water. The process parameters include pasteurization temperature, pasteurization duration and (constituent) mixing duration. While the responses were carbohydrate, protein, fat, moisture and ash.

Proximate analysis

The proximate composition of samples (carbohydrate, protein, fat,

ash and moisture contents) was determined according to the method described by the Association of Official Analytical Chemists (AOAC, 2000).

Statistical analysis

All experiments were carried out in triplicates. Data obtained were analyzed statistically using Design Expert 9.0 statistical package.

RESULTS AND DISCUSSION

The twenty-six separate food formulations and their corresponding results for the proximate analysis are presented in Table 3.

Effect of pasteurization and other process parameters on the proximate composition of tigernut-soy milk blends

Carbohydrate

The carbohydrate content of the samples ranged from 0.38 to 12.53% as shown in Table 3. From Figure 6, it can be observed that the carbohydrate value increased with increasing tigernut milk and decreasing soy milk in the blends when water was kept constant. Thus, the higher the percentage of tigernut milk in tigernut-soy milk, the more the carbohydrate content of the blend (Figure 7). More importantly, Figures 6 and 7 show that carbohydrate content of the various formulations generally reduced with increase in pasteurization temperature.

The analysis of variance (ANOVA) for the response surface combined linear \times linear model of the carbohydrate yield is shown in Table 4. The model expression developed, that relates the carbohydrate yield and the six reaction parameters (A, B, C, D, E and F) is considered suitable because its p-value is less than 0.05. The model F-value of 5.14 implies that the model is significant. The F-value is the ratio of the Model SS/Residual SS and shows the relative contribution of the model variance to the residual variance. A large number indicates more of the variance being explained by the model. The model fit was also checked with the correlation factor R^2 , which equals to 80.16%.

The significant factors from ANOVA analysis are the interactions between tigernut milk and pasteurization temperature (AD) with a p-value of 0.02 which is less than 0.05. Another significant factor is the interaction of tigernut milk and pasteurization duration with p-value of 0.03 (less than 0.05). The other factors of the model have no statistically significant effect.

In this study, the R^2 value of 0.8016 indicates that the variation of 80.16% is attributed to the independent variables while 19.84% of the total variations is not explained by the model. The value of the coefficient of

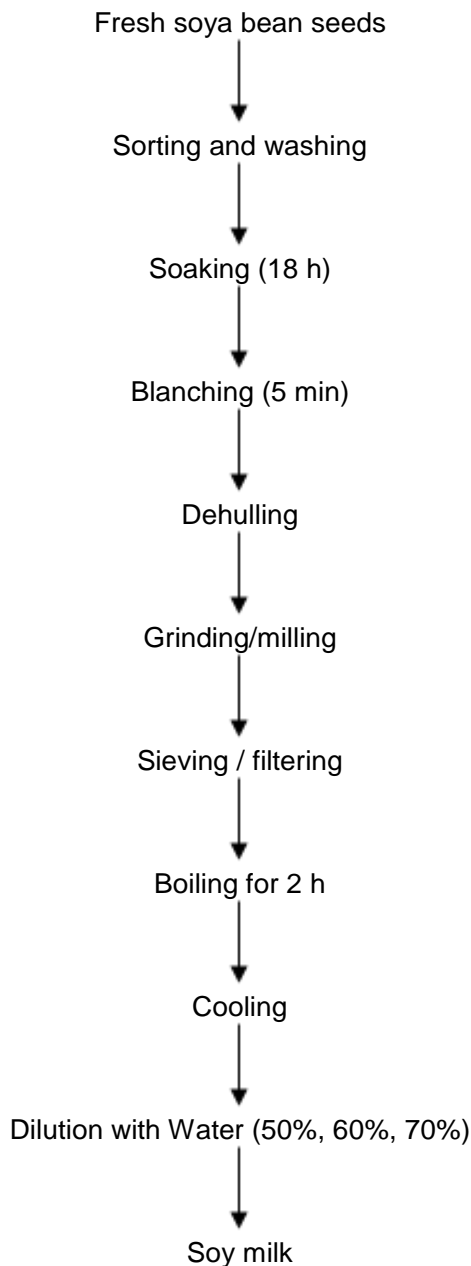


Figure 4. The flow chart for soymilk production.

variation CV%, 51.29 gives the precision and reliability of the experiment carried out where a lower value of CV indicates a better precision and reliability of the experiments carried out. Table 5 shows regression coefficients estimates of carbohydrate.

The regression analysis from Table 5 produced the following coded equation:

$$Y1: \text{Carbohydrate Content} = +6.45A + 2.55B - 1.33C - 1.60AD + 1.53AE + 0.17AF + 0.032BD + 0.05BE + 0.76BF - (9.017E - 003)CD - 0.54CE - 0.22CF \quad (1)$$

The model equation (Equation 1) shows that all the positive coefficient terms such as A, B, AE, AF, BD, BE and BF indicate synergetic or favourable effect on the carbohydrate yield, while the negative coefficients of the model terms such as C, AD, CD, CE and CF indicate antagonistic effect on the carbohydrate yield (Betiku et al., 2014).

The linear effect of A and B are the general determining factors of carbohydrate yield as they have the larger coefficients. The linear effect of C, interaction effect of AD and AE are secondary factors of the response. From this analysis, it can be seen that the tigernut milk concentration (factor A) has the highest coefficient among the three independent variables. This implies that the yield of carbohydrate from tigernut-soy milk blends relies greatly on this factor.

Protein

The protein content of the samples ranged from 3.28 to 5.89% (Table 3). There were fluctuations in the protein content of the tigernut-soy milk blends. The contour mix-process plot (Figure 8) gives a clear view of the protein yield in relations to the various process parameters, while the relationship between protein yield and the blend constituents is shown in Figure 9.

The fluctuation in the protein yield pattern may be attributed to the destructive effect of heat process involved in pasteurization on the amino acids as well as the tannin-protein complex which have contrast effects (Imafidon et al., 1997). Where amino acids are destroyed there is a consequent reduction in the total nitrogen which leads to decrease in the protein content of the resulting pasteurized milk (Oluwaniyi et al., 2009), whereas, a rise in the amount of protein may be credited to the destruction of tannin-protein complex (Belewu and Belewu, 2007).

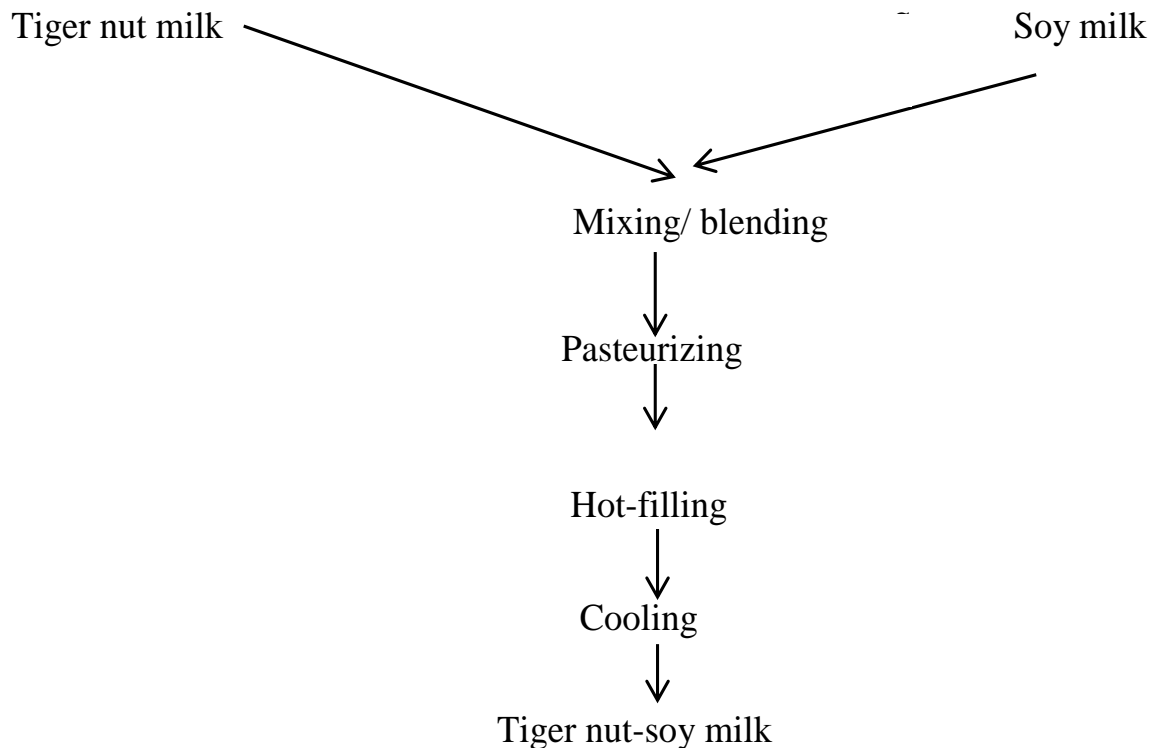
Generally, the range of protein content of the various formulations after pasteurization shows there are no serious adverse effect on the protein content as a result of pasteurizing the milk.

The analysis of the variance (ANOVA) for the response surface combined special cubic x mean model of the protein content of tigernut-soy milk bends is shown in Table 6. The model expression developed related the protein yield and the six reaction parameters considered (A, B, C, D, E, F); it has a p-value of 0.0526 greater than 0.05, which suggests there might be a more appropriate model for this experiment. The model F-value of 2.59 implies that the model is fairly significant. The model fit was also checked with the correlation factor R^2 , which equals 44.99%.

The significant factors from the ANOVA analysis were: the interactions between tigernut milk and soy milk (AB) with a p-value of 0.0186 which is less than 0.05; the interaction of tigernut milk and water (AC) with p-value of

Table 1. Design matrix of the blend constituents and process treatments.

Name	Unit	Type	Low Actual	High Actual	Low Coded	High Coded
A - Tigernut Milk	%	Mixture	5.00	37.00	0.000	1.000
B - Soya Milk	%	Mixture	5.00	37.00	0.000	1.000
C - Water	%	Mixture	50.00	70.00	0.000	0.625
D - P/ Temperature	°C	Numeric	60.00	80.00	-1.000	1.000
E - P/ Duration	s	Numeric	5.00	20.00	-1.000	1.000
F - M/Duration	min	Numeric	5.00	15.00	-1.000	1.000

**Figure 5.** The flow chart for tigernut-soy milk drink production.

0.0261<0.05; the interaction between soy milk and water (BC) with p-value of 0.0189<0.05 as well as the interactions among the three components (tigernut milk, soy milk and water) (ABC) with a p-value of 0.0056 which is less than 0.05. The other factors of the model were not statistically significant.

The value of the determination coefficient R^2 (0.4499) as shown in Table 6 indicates that the sample variation of 44.99% is attributed to independent variables and 55.01% of the total variations is not explained by the model. The value of the Coefficient of Variation (CV%) (14.95) gives the precision and reliability of the experiment carried out where a lower value of CV indicates a better precision and reliability of the experiments carried out. Table 7 shows regression coefficients of protein.

The regression analysis of the data on Table 7 produced the following coded equation:

$$Y_2: \text{Protein Content} = +3.88A + 4.03B + 0.56C + 4.97AB + 11.15AC + 11.64BC - 50.29ABC \quad (2)$$

The model equation (Equation 2) shows that all the positive coefficient terms such as A, B, AB, AC and BC indicate synergetic or favourable effect on the protein yield, while the negative coefficient of the model terms ABC indicate an antagonistic effect on the protein yield (Betiku et al., 2014).

The interaction effect of ABC is the general determining factor of protein yield as it has the largest coefficient. The linear effect of A and B, interaction effect of AC and BC are secondary factors of the response.

Table 2. Formulation of Tigernut-soy milk blends.

Formulation	A (%)	B (%)	C (%)	D (°C)	E (Seconds)	F (Minutes)
1	21	21	50	60	5	5
2	37	5	50	80	20	15
3	5	37	50	60	20	15
4	5	37	50	80	5	5
5	5	17	70	80	20	15
6	5	37	50	60	20	5
7	5	37	50	80	20	5
8	16	16	60	60	5	15
9	17	5	70	60	20	15
10	37	5	50	80	5	5
11	27	5	60	80	20	5
12	37	5	50	60	5	15
13	16	16	60	60	5	15
14	5	37	50	60	5	5
15	17	5	70	80	5	15
16	37	5	50	70	12.5	10
17	37	5	50	60	20	5
18	5	17	70	60	5	5
19	17	5	70	60	20	15
20	21	21	50	60	5	5
21	5	37	50	80	5	15
22	5	27	60	70	12.5	10
23	11	11	70	80	20	5
24	37	5	50	60	20	5
25	37	5	50	80	5	5
26	17	5	70	75	8.75	7.5

Fat

The fat content of the samples ranged from 1.38 to 3.18% (Table 3). The fat value increased with increasing tigernut milk and decreasing soy milk in the blends when water was kept constant (Figure 10).

Thus, higher percentage of tigernut milk in tigernut-soy milk would increase the fat content more than having a larger portion of soy milk in the blend as seen in Figures 11 and 12. Furthermore, Figures 11 and 12 showed that fat content of the various formulations increased with increase in pasteurization temperature.

The analysis of variance (ANOVA) for the response surface combined linear x linear model of fat content of the blends is shown in Table 8. The model expression developed that relates the fat yield and the six reaction parameters (A, B, C, D, E, F) is considered suitable because its p-value of 0.0166 is less than 0.05. The model F-value of 3.43 implies the model is significant. The model fit was also checked with the correlation factor R^2 , which equals to 72.94%.

The only significant factor from the ANOVA analysis is the interaction between water and pasteurization temperature (CD) with a p-value of 0.0194 which is less

than 0.05. The other factors of the model are not statistically significant.

The value of the determination coefficient R^2 , (0.7294) indicates that the sample variation of 72.94 % is attributed to independent variables and 27.06 % of the total variations is not explained by the model. The value of the Coefficient of Variation CV % (17.67) gives the precision and reliability of the experiment carried out where a lower value of CV % indicates a better precision and reliability of the experiments carried out. Table 9 shows regression coefficients of fat.

The regression analysis of data on Table 9 produced the following coded equation:

$$Y_3: \text{Fat Content} = +2.91A + 2.00B + 1.99C - 0.19AD - 2.835(E - 003)AE + 0.090AF - 0.037BD + 0.28BE - 0.33BF + 0.76CD + 0.49CE + 0.50CF$$

The model equation (Equation 3) shows that all the positive coefficient terms such as A, B, C, AF, BE, CD, CE and CF indicate synergetic or favourable effect on the fat yield, while the negative coefficient of the model terms such as AD, AE, and BD indicate antagonistic effect on the fat yield (Betiku et al., 2014).

Table 3. Mean values of the proximate composition of the tigernut-soy milk blends.

Formulation	Carbohydrate	Moisture	Ash	Protein	Fat
1.	6.52	89.28	0.12	5.25	2.34
2.	3.58	86.39	0.30	3.50	2.77
3.	2.23	90.68	0.48	3.33	1.90
4.	1.24	90.72	0.15	4.73	2.10
5.	1.42	90.94	0.26	4.38	3.17
6.	1.21	91.39	0.55	3.51	3.11
7.	3.32	90.61	0.81	5.16	2.19
8.	1.99	91.16	0.59	3.28	1.64
9.	3.69	90.52	0.58	3.94	2.96
10.	0.54	89.04	1.06	3.50	2.70
11.	6.00	90.33	1.39	5.69	2.02
12.	2.37	85.9	0.54	4.38	3.17
13.	2.53	90.88	0.48	4.38	1.87
14.	0.81	90.52	0.98	3.94	2.01
15.	9.00	92.34	3.50	3.50	3.11
16.	7.19	83.27	0.20	4.41	3.13
17.	0.88	84.85	0.43	4.38	3.14
18.	2.78	93.06	0.06	4.59	1.38
19.	3.10	90.55	0.16	4.38	2.21
20.	2.71	88.76	0.56	5.25	2.33
21.	1.95	91.33	0.80	3.5	1.65
22.	1.20	90.66	0.28	5.47	1.62
23.	12.5	91.09	4.38	4.38	3.12
24.	3.51	84.00	0.33	3.5	3.18
25.	0.38	90.08	0.20	3.33	2.86
26.	2.99	92.43	0.35	5.25	1.56

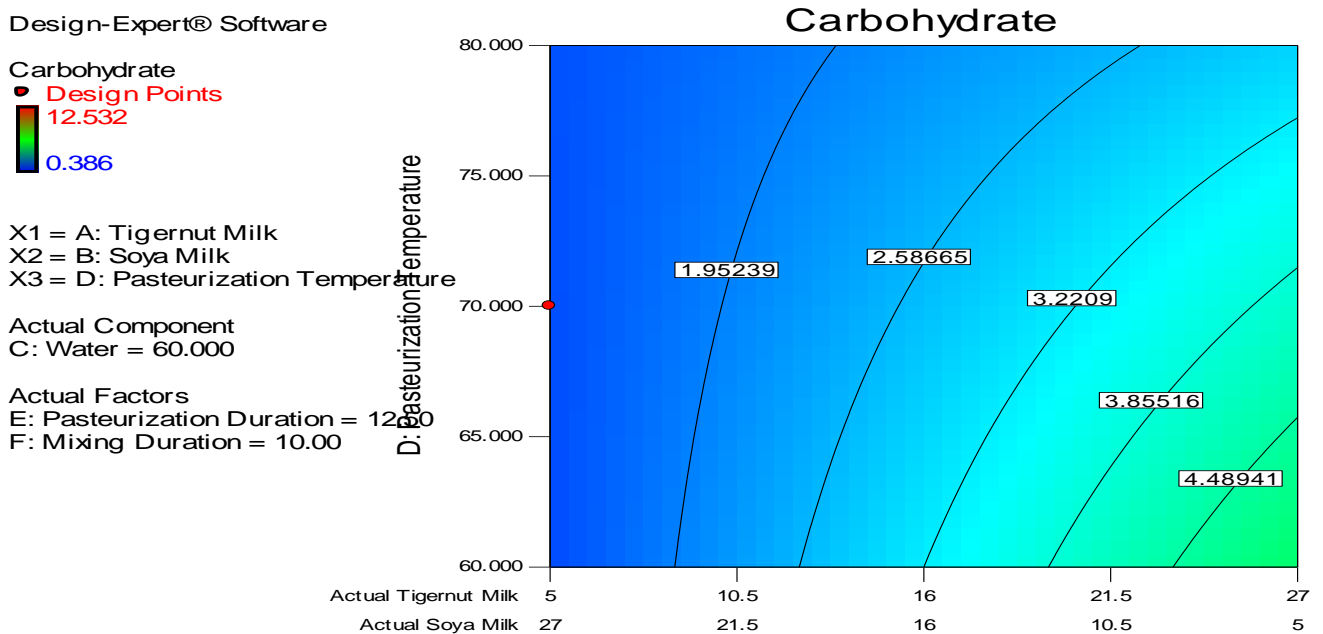


Figure 6. Contour mixed process plots showing the effect of pasteurization temperature on carbohydrate yield at different ratios of tigernut-soy milk blends.

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Carbohydrate
 12.532
 0.386

X1 = A: Tigernut Milk
 X2 = B: Soya Milk
 X3 = D: Pasteurization Temperature
 Actual Component
 C: Water = 60.000
 Actual Factors
 E: Pasteurization Duration = 12.50
 F: Mixing Duration = 10.00

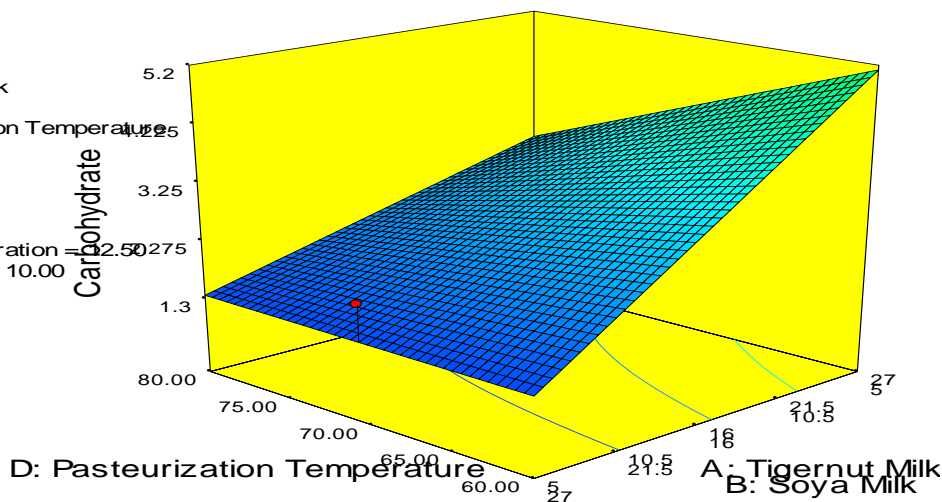


Figure 7. 3-D surface mix-process plots of the various interactions and corresponding carbohydrate yield.

Table 4. ANOVA for combined linear x linear model of the carbohydrate yield.

Source	Sum of Squares	Df	Mean Square	F-value	p-value Prob >F
Model	162.10	11	14.74	5.14	0.0027
Linear Mixture	115.31	2	57.65	20.12	<0.0001
AD	16.73	1	16.73	5.84	0.0299
AE	15.17	1	15.17	5.29	0.0373
AF	0.17	1	0.17	0.059	0.8118
BD	6.207E-003	1	6.207E-003	2.166E-003	0.9635
BE	0.015	1	0.015	5.171E-003	0.9437
BF	3.50	1	3.50	1.22	0.2879
CD	1.810E-004	1	1.810E-004	6.317E-005	0.9938
CE	0.62	1	0.62	0.22	0.6485
CF	0.100	1	0.100	0.035	0.8548
Residual	40.11	14	2.87		
Lack of Fit	25.07	9	2.79	0.93	0.5682
Pure Error	15.05	5	3.01		
Cor Total	202.22	25			
Standard Deviation			1.69		
Mean			3.30		
C.V. %			51.29		
PRESS			129.67		
R-Squared			0.8016		
Adj R-Squared			0.6458		
Pred R-Squared			0.3588		
Adeq Precision			8.172		

The linear effect of A and B are the general determining factors of fat yield as they have the larger coefficients.

The linear effect of C and the interaction effect of CD are secondary factors of the response.

Table 5. Regression coefficients estimates of the carbohydrate yield.

Coefficient component	Estimate	df	Standard error	95% CI Low	95% CI High
A-Tigernut Milk	6.45	1	0.64	5.07	7.83
B-Soya Milk	2.55	1	0.68	1.10	4.00
C-Water	-1.33	1	1.08	-3.64	0.98
AD	-1.60	1	0.66	-3.02	-0.18
AE	1.53	1	0.66	0.10	2.95
AF	0.17	1	0.70	-1.33	1.67
BD	0.032	1	0.69	-1.45	1.51
BE	0.050	1	0.69	-1.43	1.53
BF	0.76	1	0.69	-0.72	2.24
CD	-9.017E-003	1	1.13	-2.44	2.42
CE	-0.54	1	1.16	-3.02	1.94
CF	0.22	1	1.19	-2.33	2.77

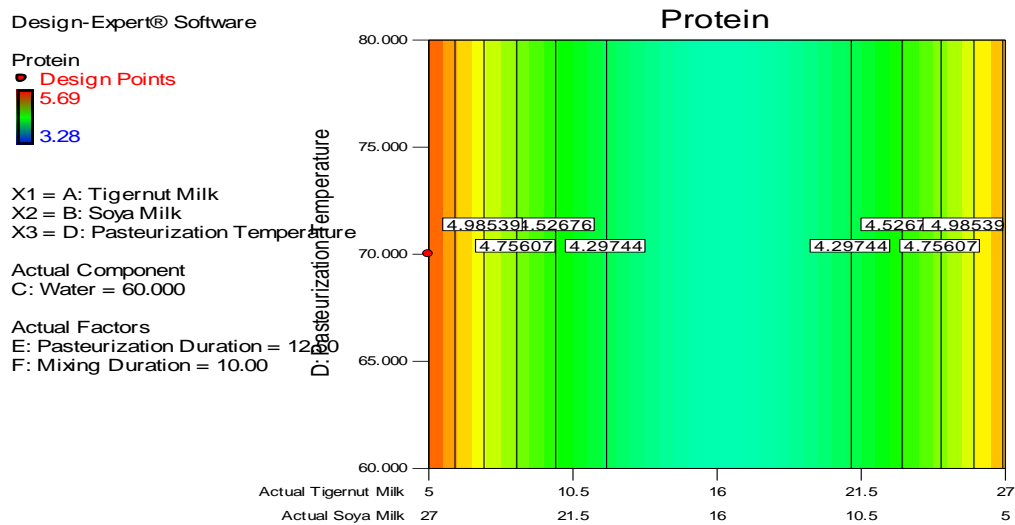


Figure 8. Contour mix-process plots showing the protein yield in relations to the effect of the process parameters.

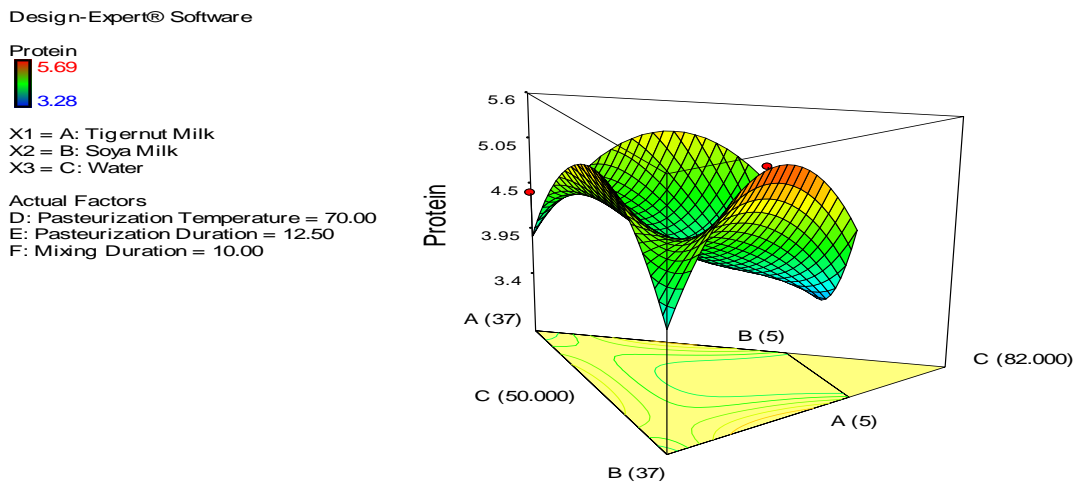


Figure 9. 3-D Surface plots showing protein yield with respect to the effect of the constituents.

Table 6. ANOVA for combined special cubic x mean model of the protein yield.

Source	Sum of Squares	df	Mean Square	F-Value	p-value Prob> F
Model	6.32	6	1.05	2.59	0.0526
Linear Mixture	0.57	2	0.29	0.71	0.5059
AB	2.69	1	2.69	6.63	0.0186
AC	2.37	1	2.37	5.82	0.0261
BC	2.68	1	2.68	6.58	0.0189
ABC	3.96	1	3.96	9.75	0.0056
Residual	7.72	19	0.41		
Lack of Fit	6.62	14	0.47	2.14	0.2052
Pure Error	1.10	5	0.22		
Cor Total	14.04	25			
Standard Deviation			0.64		
Mean			4.27		
C.V. %			14.95		
PRESS			14.04		
R-Squared			0.4499		
Adj R-Squared			0.2762		
Pred R-Squared			0.0004		
Adeq Precision			5.656		

Table 7. Regression coefficients estimates of the protein yield.

Component	Coefficient estimate	Df	Standard Error	95% CI Low	95% CI High
A-Tigernut Milk	3.88	1	0.24	3.37	4.38
B-Soya Milk	4.03	1	0.26	3.48	4.57
C-Water	0.56	1	1.77	-3.14	4.26
AB	4.97	1	1.93	0.93	9.01
AC	11.15	1	4.62	1.48	20.82
BC	11.64	1	4.54	2.14	21.14
ABC	-50.29	1	16.11	-84.00	-16.58

Furthermore, the tigernut milk concentration (factor A) had the highest coefficient among the three independent variables. This implies that the yield of fat from tigernut-soy milk blends relies greatly on this factor as may be clearly visualised in Figure 13.

Moisture content

The moisture content value of the samples ranged from 83.27 to 93.06% (Table 3). This high range of moisture content reveals that the product is highly refreshing, hence a good source of healthy natural refreshment which should be preferred to chemical (synthetic) beverages. The moisture level increased with increasing soy milk and decreasing tigernut milk in the pasteurized blends when water was kept constant (Figure 14).

Figure 15 further buttresses the point. It shows that the

higher the percentage of soy milk in tigernut-soy milk blend compared to tigernut milk, the greater the moisture content of the blend.

Furthermore, the range of moisture content of the various formulations after pasteurization shows that the moisture content generally increased with increase in pasteurization temperature (Figure 16).

The analysis of variance (ANOVA) for the response surface combined linear x linear model model of moisture content is shown in Table 10. The model expression developed that relates the moisture yield and the six reaction parameters (A, B, C, D, E, F) was considered suitable because the p-value of 0.0001 is far less than 0.05. The model F-value of 10.67 implies that the model is significant. The model fit was also checked with the correlation factor R^2 , which equals to 89.34%.

The significant factors from the ANOVA analysis are the interactions between tigernut milk and pasteurization

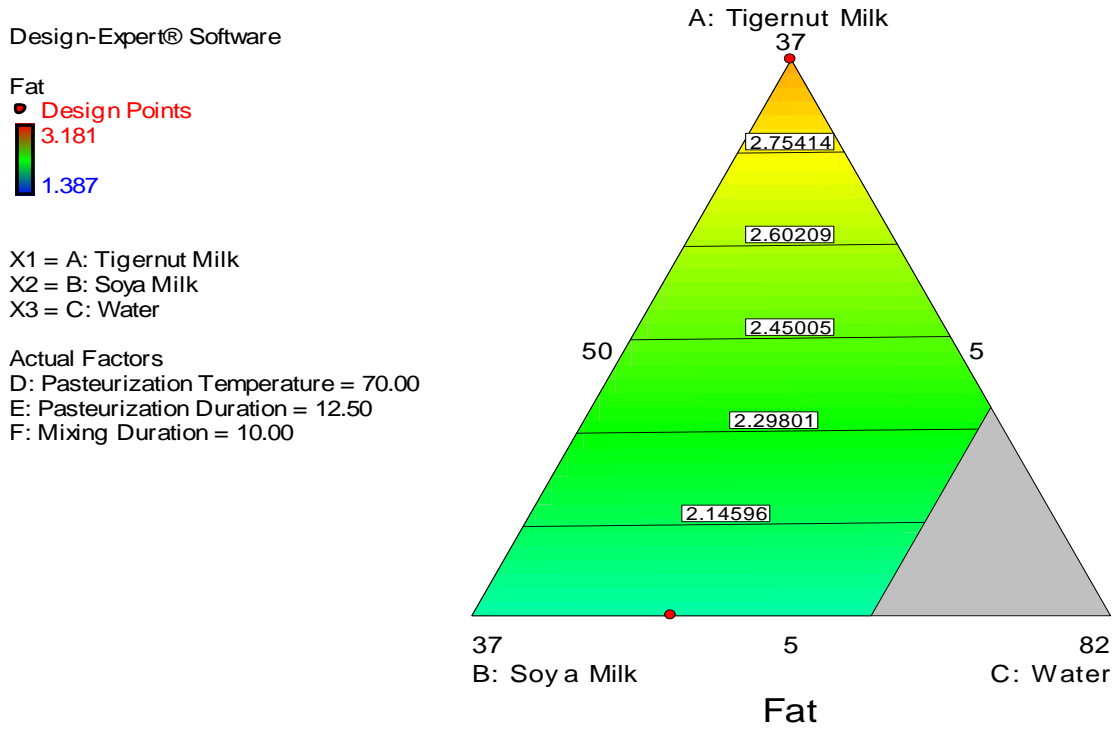


Figure 10. Contour plot showing fat yield as determined by the process constituents.

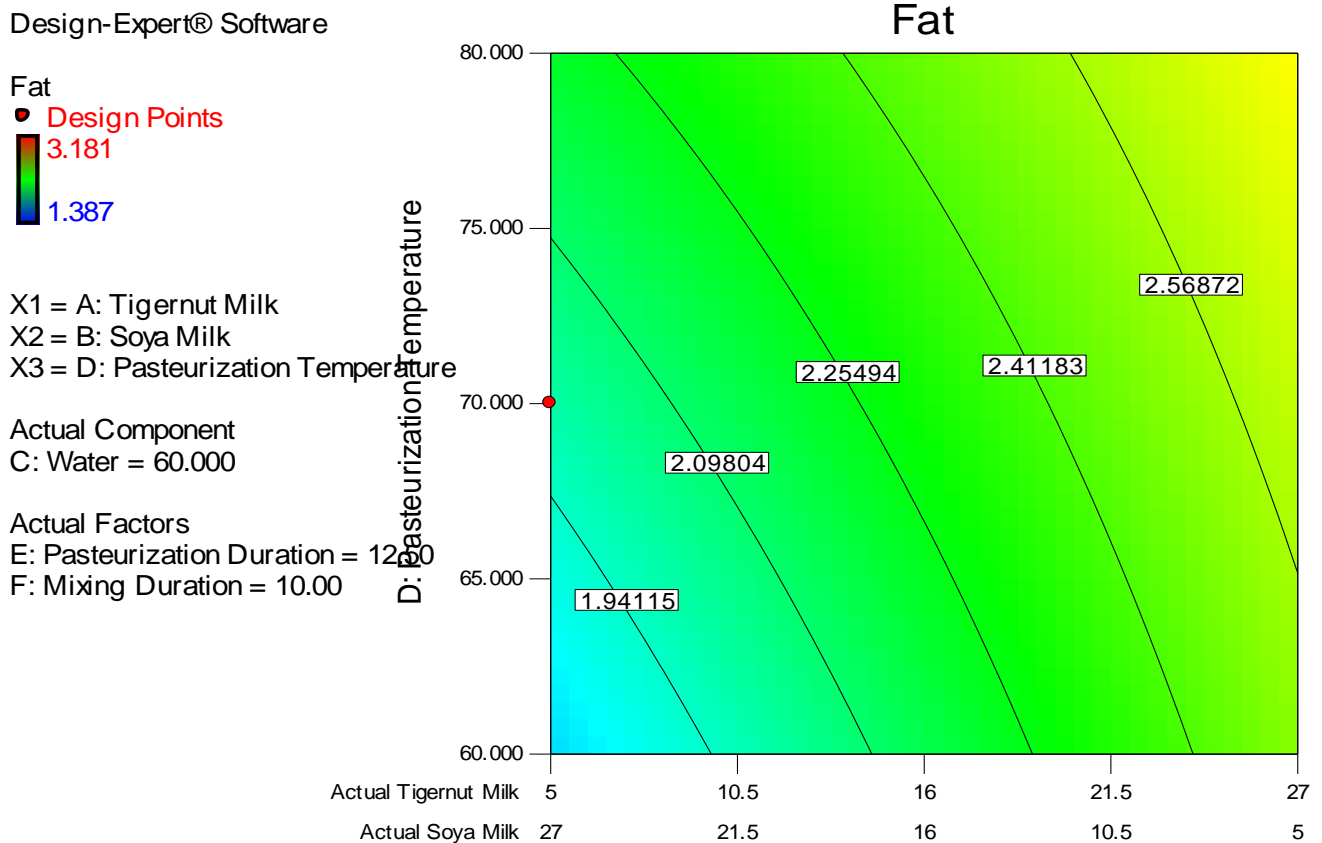


Figure 11. Contour mix-process plots showing the effect of pasteurization temperature on fat yield through the milk blends.

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Fat


X1 = A: Tigernut Milk

X2 = B: Soya Milk

X3 = D: Pasteurization Temperature

Actual Component

C: Water = 60.000

Actual Factors

E: Pasteurization Duration = 12.50

F: Mixing Duration = 10.00

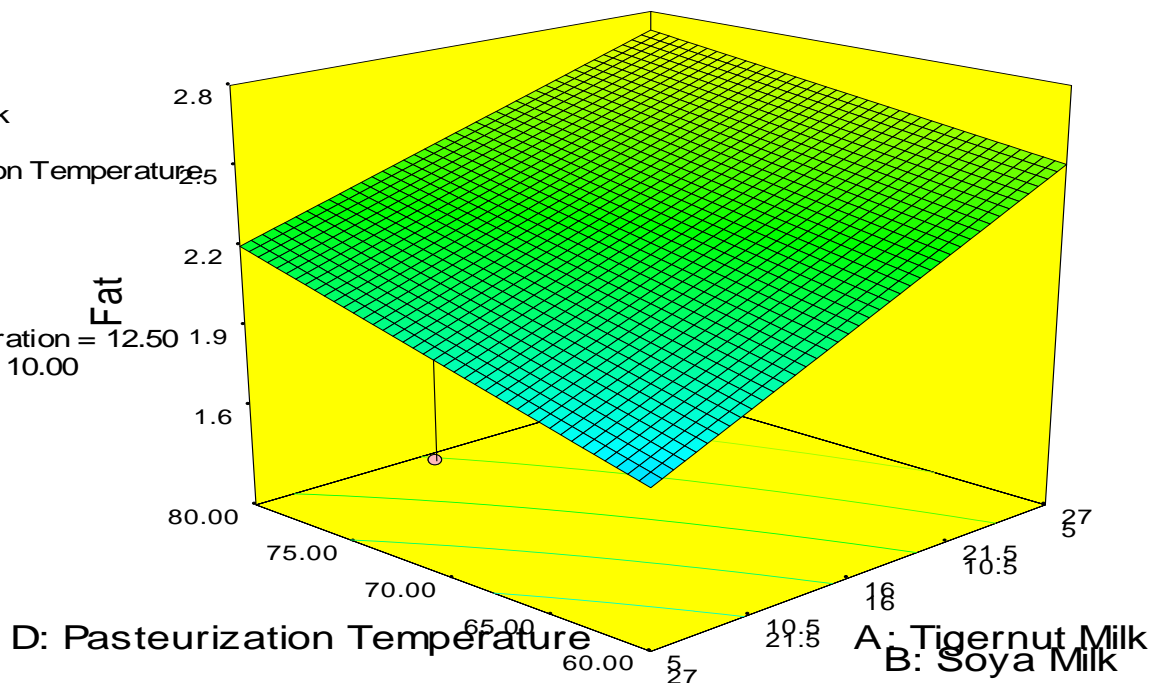


Figure 12. 3-D surface mix-process plots showing the effect of pasteurization temperature on the yield of fat with respect to the milk composition.

temperature (AD) with a p-value of 0.0045 which is less than 0.05 as well as the interaction of tigernut and pasteurization duration (AE) with p-value of 0.0308 which is also less than 0.05. The other factors of the model had no statistically significant effect.

Furthermore, the value of the determination coefficient, R^2 (0.8934) indicates that the sample variation of 89.34% is attributed to independent variables and 10.66% of the total variations is not explained by the model. The value of the Coefficient of Variation, CV % (1.26) gives the precision and reliability of the experiment carried out where a lower value of CV % indicates a better precision and reliability of the experiments carried out. Table 11 shows the regression coefficients of moisture content.

The regression analysis from Table 11 produced the following coded equation:

$$Y4: \text{Moisture Content} = +86.33A + 90.73B + 94.27C + 1.50AD - 1.07AE - 0.63AF - 0.14BD - 0.14BE + 0.023BF - 0.82CD - 0.76CE + 0.22CF$$

The model equation (Equation 4) shows that all the positive coefficient terms such as A, B, C, AD, BF, and CF indicate synergetic or favourable effect on the moisture yield, while the negative coefficient of the model terms such as AE, AF, BD, BE, CD and CE indicate

antagonistic effect on the moisture yield (Betiku et al., 2014).

Ash content

The ash content, which is the approximate total mineral or inorganic matter of the samples ranged from 0.069 to 4.38% (Table 3).

From the model graph (Figure 17, contour mix-process plot), it may be deduced that the ash content initially reduced drastically, then began to increase as the pasteurization temperature increased.

Statistically, Tables 12 and 13 as well as the contour plots (Figure 18) show that the various components of the blends had no influence whatsoever on whether the ash value increased or decreased.

The 3 D Surface Mix-Process Plot (Figure 19) also revealed clearly that the ash value remained unaltered by the various proportions of tigernut milk and soy milk in the tigernut-Soya milk blends, but it increased with increase in pasteurization temperature.

The analysis of the variance (ANOVA) for the response surface combined mean x 2FI model of the ash yield is shown in Table 12. The model expression developed that relates the ash yield and the six reaction parameters

Table 8. ANOVA for combined linear x linear model of the fat yield.

Source	Sum of Squares	df	Mean Square	F-value	p-value Prob > F
Model	7.00	11	0.64	3.43	0.0166
Linear Mixture	2.60	2	1.30	7.01	0.0078
AD	0.24	1	0.24	1.30	0.2728
AE	5.236E-005	1	5.236E-005	2.823E-004	0.9868
AF	0.047	1	0.047	0.25	0.6223
BD	8.067E-003	1	8.067E-003	0.043	0.8378
BE	0.47	1	0.47	2.56	0.1322
BF	0.68	1	0.68	3.64	0.0770
CD	1.29	1	1.29	6.97	0.0194
CE	0.51	1	0.51	2.74	0.1204
CF	0.51	1	0.51	2.73	0.1204
Residual	2.60	14	0.19		
Lack of Fit	2.27	9	0.25	3.92	0.0735
Pure Error	0.32	5	0.065		
Cor Total	9.60	25			
Standard Deviation			0.43		
Mean			2.44		
C.V. %			17.67		
PRESS			11.97		
R-Squared			0.7294		
Adj R-Squared			0.5167		
Pred R-Squared			-0.2470		
Adeq Precision			7.711		

Table 9. Regression coefficients estimates of the fat yield.

Component	Coefficient Estimate	Df	Standard Error	95% CI Low	95% CI High
A-Tigernut Milk	2.91	1	0.16	2.56	3.26
B-Soya Milk	2.00	1	0.17	1.63	2.37
C-Water	1.99	1	0.27	1.40	2.58
AD	-0.19	1	0.17	-0.55	0.17
AE	-2.835E-003	1	0.17	-0.36	0.36
AF	0.090	1	0.18	-0.29	0.47
BD	-0.037	1	0.18	-0.41	0.34
BE	0.28	1	0.18	-0.096	0.66
BF	-0.33	1	0.18	-0.71	0.041
CD	0.76	1	0.29	0.14	1.38
CE	0.49	1	0.29	-0.14	1.12
CF	0.50	1	0.30	-0.15	1.15

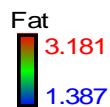
considered (A, B, C, D, E, F) may not be considered suitable because its p-value of 0.2687 is greater than 0.05. The model F-value of 1.39 further implies that the model may not be suitable. The model fit was also checked with the correlation factor R^2 , which equals 30.52%.

It was also observed that all the factors had p-values greater than 0.05, thus they are not considered

significant. Therefore, it suffices to say that the entire factors of the model have no statistically significant effect.

The value of the determination coefficient, R^2 (0.3052) indicates that the sample variation of 30.52% is attributed to independent variables and 69.48% of the total variations is not explained by the model. The value of the coefficient of variation, CV % (126.24) gives the precision and reliability of the experiment carried out where a lower

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X1 = A: Tigernut Milk
 X2 = B: Soya Milk
 X3 = C: Water

Actual Factors
 D: Pasteurization Temperature = 70.00
 E: Pasteurization Duration = 12.50
 F: Mixing Duration = 10.00

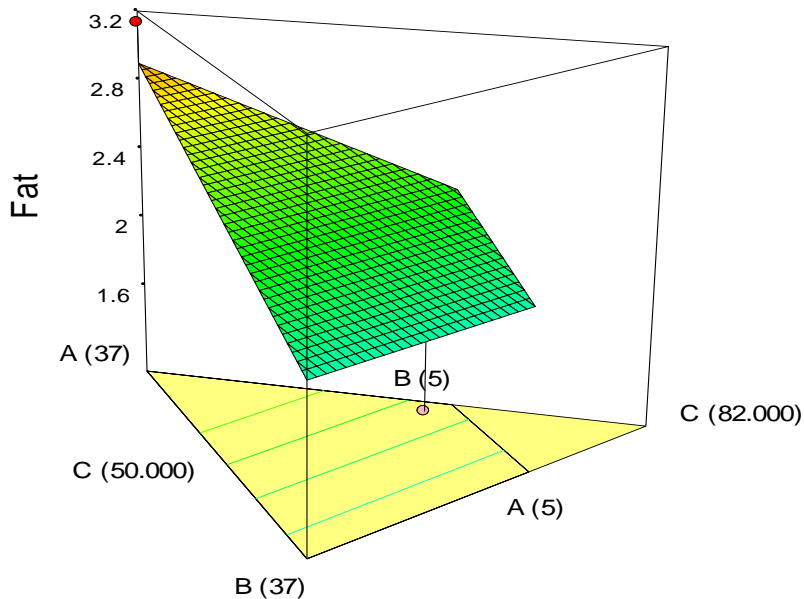


Figure 13. 3-D surface plots showing the relationship between the various constituents and fat yield.

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X1 = A: Tigernut Milk
 X2 = B: Soya Milk
 X3 = C: Water

Actual Factors
 D: Pasteurization Temperature = 70.00
 E: Pasteurization Duration = 12.50
 F: Mixing Duration = 10.00

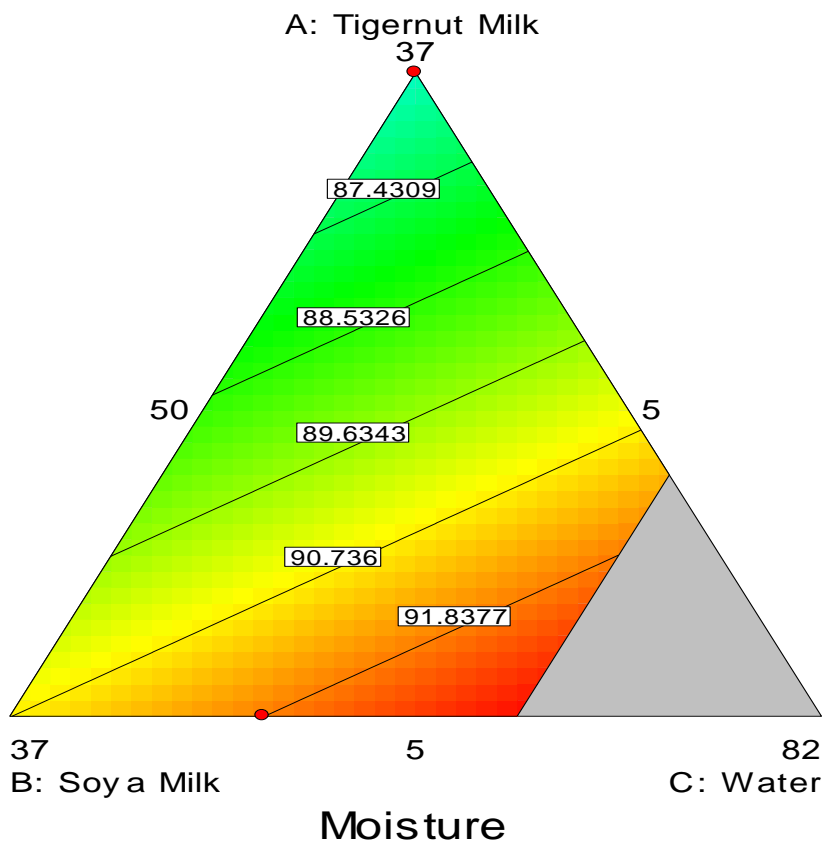
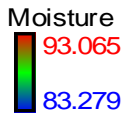


Figure 14. Contour plots showing the relationship between moisture content and the various blend components.

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X1 = A: Tigernut Milk
 X2 = B: Soya Milk
 X3 = C: Water

Actual Factors
 D: Pasteurization Temperature = 70.00
 E: Pasteurization Duration = 12.50
 F: Mixing Duration = 10.00

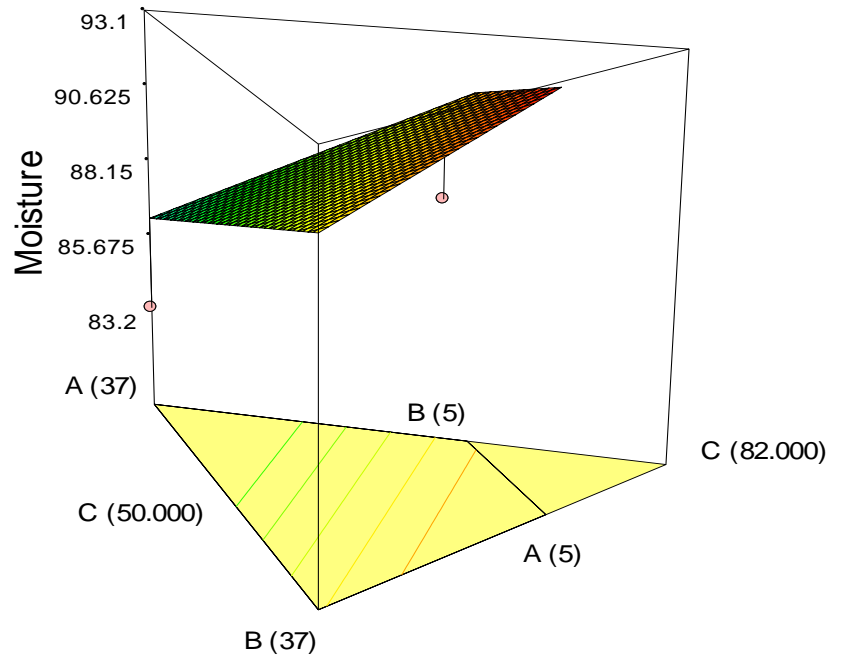


Figure 15. 3-D surface plot showing the relationship between moisture content and the blend components.

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X1 = A: Tigernut Milk
 X2 = B: Soya Milk
 X3 = D: Pasteurization Temperature

Actual Component
 C: Water = 60.000

Actual Factors
 E: Pasteurization Duration = 12.50
 F: Mixing Duration = 10.00

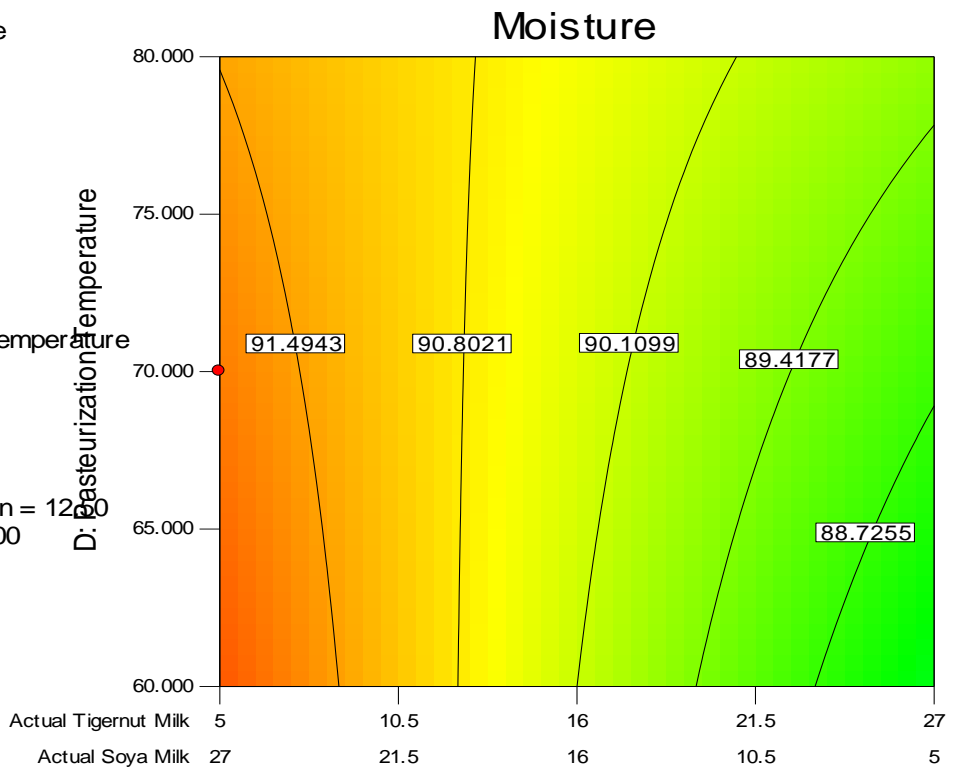


Figure 16. Contour mix-process plots showing the yield of moisture with regards to pasteurization temperature.

Table 10. ANOVA for combined linear x linear model of the moisture yield.

Source	Sum of Squares	Df	Mean Square	F-value	p-value Prob >F
Model	150.80	11	13.71	10.67	0.0001
Linear Mixture	116.04	2	58.02	45.17	0.0001
AD	14.69	1	14.69	11.44	0.0045
AE	7.40	1	7.40	5.76	0.0308
AF	2.31	1	2.31	1.80	0.2016
BD	0.12	1	0.12	0.094	0.7634
BE	0.11	1	0.11	0.086	0.7739
BF	3.112E-003	1	3.112E-003	2.423E-003	0.9614
CD	1.49	1	1.49	1.16	0.2992
CE	1.23	1	1.23	0.96	0.3442
CF	0.096	1	0.096	0.074	0.7889
Residual	17.98	14	1.28		
Lack of Fit	16.91	9	1.88	8.75	0.0139
Pure Error	1.07	5	0.21		
Cor Total	168.78	25			
Standard Deviation			1.13		
Mean			89.65		
C.V. %			1.26		
PRESS			2.67		
R-Squared			0.8934		
AdjR-Squared			0.8097		
Pred R-Squared			0.6879		
Adeq Precision			12.331		

Table 11. Regression coefficients estimates of the moisture yield.

Component	Coefficient Estimate	Df	Standard Error	95% CI Low	95% CI High
A-Tigernut Milk	86.33	1	0.43	85.41	87.25
B-Soya Milk	90.73	1	0.45	89.75	91.70
C-Water	94.27	1	0.72	92.72	95.81
AD	1.50	1	0.44	0.55	2.45
AE	-1.07	1	0.44	-2.02	-0.11
AF	-0.63	1	0.47	-1.63	0.38
BD	-0.14	1	0.46	-1.13	0.85
BE	-0.14	1	0.46	-1.13	0.86
BF	0.023	1	0.46	-0.97	1.01
CD	-0.82	1	0.76	-2.45	0.81
CE	-0.76	1	0.77	-2.42	0.90
CF	0.22	1	0.80	-1.49	1.92

value of CV% indicates a better precision and reliability of the experiments carried out.

The regression analysis from Table 13 produced the following coded equation:

$$Y_5: \text{Ash Content} = +0.38D + 0.014E - 0.032F + 0.068DE - 0.027DF - 0.41EF \quad (5)$$

The model equation (Equation 5) shows that all the

positive coefficient terms such as D, E, and DE indicate synergetic or favourable effect on the ash yield, while the negative coefficients of the model terms such as F, DF and EF indicate an antagonistic effect on the ash yield (Betiku et al., 2014). Also, it shows that the linear effect of D and the interaction effect of EF are the general determining factors of ash yield as they have the larger coefficients.

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Ash
 ● Design Points
 4.38
 0.069

X1 = A: Tigernut Milk
 X2 = B: Soya Milk
 X3 = D: Pasteurization Temperature

Actual Component
 C: Water = 60.000

Actual Factors
 E: Pasteurization Duration = 12.00
 F: Mixing Duration = 10.00

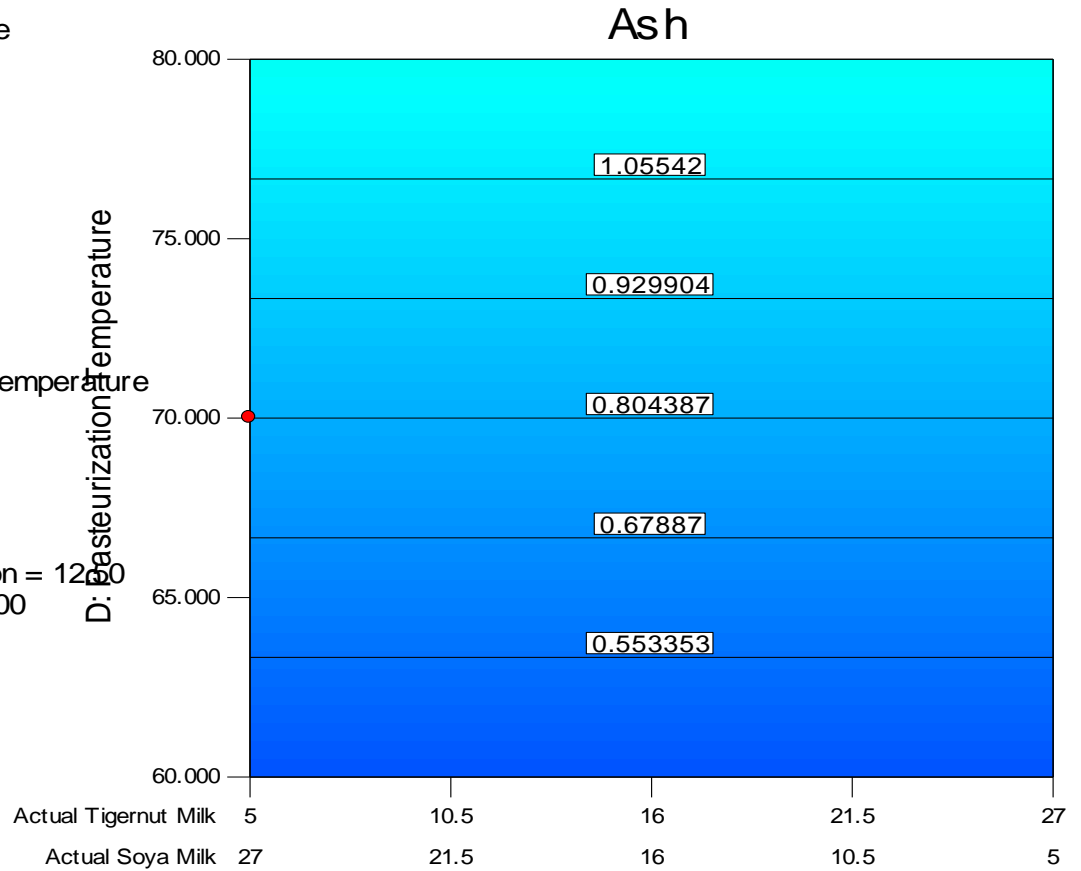


Figure 17. Contour mix-process plots showing fat yield with respect to pasteurization temperatures.

Table 12. ANOVA for combined mean x 2FI model of the ash yield.

Source	Sum of Squares	Df	Mean Square	F-value	p-value Prob > F
Model	7.59	6	1.27	1.39	0.2687
D-Pasteurization Temperature	3.16	1	3.16	3.48	0.0777
E-Pasteurization Duration	4.257E-003	1	4.257E-003	4.681E-00	30.9462
F-Mixing Duration	0.023	1	0.023	0.025	0.8760
DE	0.10	1	0.10	0.11	0.7390
DF	0.016	1	0.016	0.017	0.8967
EF	3.71	1	3.71	4.08	0.0576
Residual	17.28	19	0.91		
Lack of Fit	16.71	14	1.19	10.49	0.0085
Pure Error	0.57	5	0.11		
Cor Total	24.87	25			
Standard Deviation			0.95		
Mean			0.76		
C.V. %			126.24		
PRESS			37.31		
R-Squared			0.3052		
Adj R-Squared			0.0858		
Pred R-Squared			-0.5002		
Adeq Precision			3.571		

Table 13. Regression coefficients estimates of the ash yield.

Component	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High
Intercept	0.80	1	0.19	0.40	1.20
D-Pasteurization Temperature	0.38	1	0.20	-0.046	0.80
E-Pasteurization Duration	0.014	1	0.20	-0.41	0.44
F-Mixing Duration	-0.032	1	0.20	-0.46	0.39
DE	0.068	1	0.20	-0.35	0.49
DF	-0.027	1	0.20	-0.45	0.40
EF	-0.41	1	0.20	-0.83	0.015

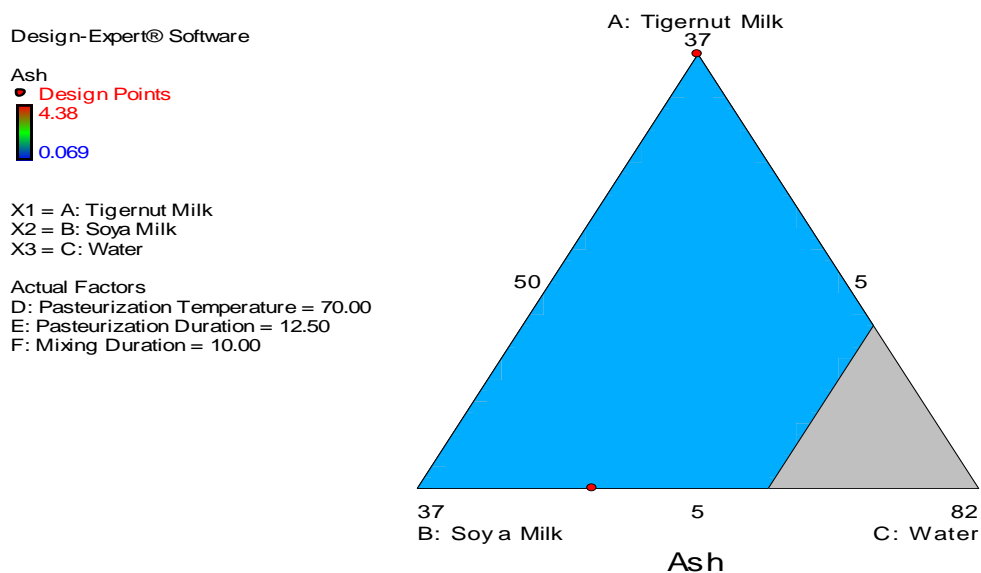


Figure 18. Contour plots showing the relationship between ash content and the various blend components.

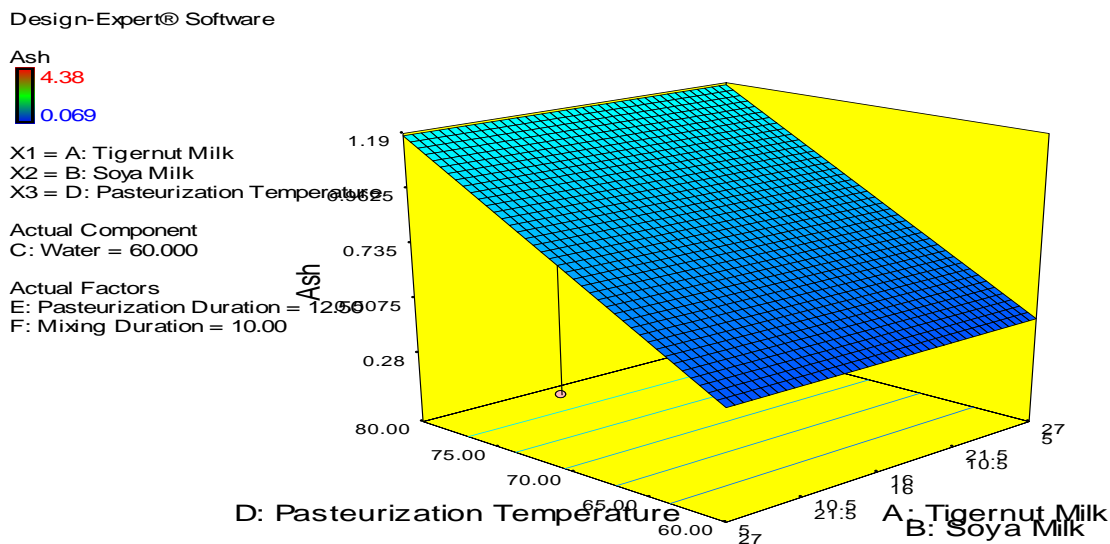


Figure 19. 3-D surface mix-process plots showing the effect of pasteurization temperature on the yield of ash with respect to the milk composition.

Conclusion

This study has shown that pasteurized tigernut-soy milk blend is rich in proximate qualities. When water was kept constant, the higher the percentage of tigernut milk in tigernut-soy milk, the more the carbohydrate and fat content. Moisture content increased with increase in soy milk proportion of the blends while ash values remained unaffected by variations in the tigernut and soy milk ratio. There was no clear-cut direction as to how protein value could be increased or reduced in the tigernut-soy milk blends as the yield of protein fluctuated between increasing and decreasing contents of the blends. Increase in pasteurization temperature reduced the carbohydrate content but favoured increase in fat, ash and moisture content of the blends. There was fluctuation in the protein yield pattern which could be attributable to the destructive effect of heat process involved in pasteurization on the amino acids as well as the tannin-protein complex which had contrast effects.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- Adejuyitan JA (2011). Tigernut processing: its food uses and health benefits. *Food Technology* 6(3):197-201.
- AOAC International (2000). Official methods of analysis of AOAC International. 17th Edition; Gaithersburg, MD, USA, Association of Analytical Communities.
- Belewu MA, Belewu KY (2007). Comparative Physico- Evaluation of Tigernut, Soybean and Coconut Milk Sources. *International Journal of Agriculture and Biology* 9:785-787.
- Belewu MA, Abodunrin OA (2006). Preparation of Kunnu from unexploited rich food source: Tigernut (*Cyperus esculentus*). *World Journal of Dairy and Food Sciences* 1:19-21.
- Betiku O, Omilakin OR, Ajala SO, Okeleye AA, Taiwo AE, Solomon BO (2014) Mathematical Modelling and Processes Parameter Optimization Studies by Artificial Neural Network and Response Surface Methodology: a Case of Non-Edible Neem (*Azadiracta Indica*) Seed Oil Biodiesel Synthesis. *Energy* 72:266-273.
- Bosch L, Alegria A, Farre R (2005). Determination of Tigernut and Orgeat Amino Acid Contents. *Food Science Technology International* 11:33-40.
- Chien JT, Snyder HE (1983). Detection and control of soymilk astringency. *Journal of Food Science* 48:438-440.
- Imafidon GI, Farkye NY, Spanier AM (1997). Isolation, purification and alteration of some functional groups of major proteins: a review. *Critical Review Food Science and Nutrition* 7:663-689.
- Lewis M, Heppell N (2000). *Continuous Thermal Processing of Foods; pasteurization and UHT Sterilization*. ASPEN Publishers, Gaithersburg, MD. P 447.
- Martinez V (2003). Scientific analysis of effects of Tigernut on heart diseases and related aspects In: *Tigernut and Health* pp. 1-2.
- Oladele AK, Aina JO (2007). Chemical Composition and Functional Properties of Flour Produced from Two Varieties of Tigernut (*Cyperus esculentus*). *African Journal of Biotechnology* 6(21):2473-2476.
- Oluwaniy OO, Dodumu OO, Awolola GV, Abdulraheem AF (2009). Nutritional Analysis and Stability Studies of Some Natural and Synthetic Food Colourants. *American Journal of Food Technology* 4(5):218-225.
- Osagie AU, Eka SA (1998). Lipid from plant source, structure and distribution. *Procedure of the 1st Agricultural Conference on Biochemistry of lipids* 103:21-26.
- Rehman S, Hussain S, Nawaz H, Ahmad MM, Huma N, Virk WA (2007). Preparation and quality evaluation of lathyrus sativus L- bovine milk blend. *Pakistan Journal of Nutrition* 6:134-137.
- Sowonola OA, Tunde-Makinde TY, Adedeji F (2005). Nutritional and Sensory Qualities of Soymilk-Kunnu Blends. *African Journal of Food Agriculture Nutrition and Development* 5(2):1-12.

Supplementary Figures

Figure 1. The LEXUS blender used for mixing the milk and the different milk samples.



Figure 2. The samples set in Water Bath for pasteurization.