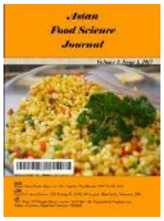

Asian Food Science Journal

4(3): 1-12, 2018; Article no.AFSJ.44137

Modelling and Optimisation of Yoghurt Production from Tigernut (*Cyperus esculentus* L.) Using Response Surface Methodology (RSM)

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Authors' contributions

This work was carried out in collaboration between all authors. Authors OJO and BO designed the study. The experiment was performed by authors BO and ORO. All the authors contributed to the statistical analysis, while author OJO wrote the manuscript from the first draft to the final draft that was accepted for publication. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2018/44137
Editor(s):
(1) Dr. Uttara Singh, Assistant Professor, Department of Foods and Nutrition Govt. Home Science College, Panjab University, India.
Reviewers:
(1) Wedad Mohamed Ahmed Ali El-kholy, Food Technology Research Institute, Egypt.
(2) A. F. Eleyinmi, Canada.
(3) Chin-Fa Hwang, Hungkuang University, Taiwan.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/26324

Original Research Article

Received 27 June 2018
Accepted 15 September 2018
Published 21 September 2018

ABSTRACT

Tigernut with its inherent nutritional and therapeutic advantage could serve as a good alternative to scarce cow milk in the production of yoghurt. This is because the crop is locally cultivated in abundant quantities and could grow in every region in Nigeria. In this study, the ingredient formulation and processing parameters for tigernut milk yoghurt production was optimised using response surface methodology (RSM), and the physicochemical properties of the product were analysed. The analyses show that the tigernut yoghurts have a pH range of 3.93 to 5.06 and acidity range of 0.45 to 2.04% during the optimisation process. The optimum acceptability of the tigernut yoghurt processing parameter is at an incubation temperature of 35°C, incubation time of 3.12 h and starter culture concentration of 2.74%. From the analysis of variance, the R^2 of all the response variables is more than 0.90, which indicates high accuracy of the model.

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Keywords: Response surface methodology; tigernut; yoghurt; incubation time; starter culture.

1. INTRODUCTION

Yoghurt is a fermented product produced by bacterial fermentation of milk from an animal source. Fermentation of the milk sugar (lactose) produces lactic acid, which acts on milk protein to give yoghurt its texture and characteristic taste [1]. Yoghurt is usually produced from whole or partially skimmed cow's or buffalo's milk. It has nutritional benefits which people who are moderately lactose-intolerant can enjoy without ill effects. This is due to the fact that the lactose in the milk precursor is converted to lactic acid by the bacteria culture [2,3]. Yoghurt is known to have medical uses, in particular for a variety of gastrointestinal conditions and in preventing antibiotic-associated diarrhoea. It has been established that drinking yoghurt containing *Lactobacillus acidophilus* helps prevent vulvovaginal candidiasis [4].

Increasing population growth and massive rural to urban migration in Nigeria in search for improved standard of living, has been one of the factors responsible for high demand for milk and milk products such as yoghurt. This has also led to insufficiency of indigenous animal milk to satisfy the local demand for milk by the teeming population. Hence, the animal milk used by industries in Nigeria are mostly imported with their attendant capital flight and negative impact on the foreign exchanging earning. This situation calls for the need to source for an alternative milk production from indigenous cultivated plant in Nigeria. Alternatives for cow milk have been explored by most industries in Nigeria to produce nutritious and affordable milk and milk products. This has led to the promotion of added-value products such as tigernut milk, coconut milk, soy bean milk, reduced fat milk, full fat milk, organic cheese probiotic and other functional yoghurts from other plant sources [5].

Tigernut (*Cyperus esculentus* L.) has been cultivated extensively in Africa, Asia and some European countries for centuries. Tigernut has high nutritional value and it helps in the treatment of indigestion, colic diarrhoea, dysentery, excessive thirst, and is often regarded as digestive tonic [6]. Tigernut has long been recognised for its health benefits as it is high in fibre, protein and natural sugars [7]. The nut was found to be useful in preventing heart attack, thrombosis and blood circulation. Therefore, tigernut, with its inherent nutritional and therapeutic advantage could serve as a good alternative to cow milk in the production of yoghurt. In addition, the inclusion of tigernut milk in the production of yoghurt could reduce the price of yoghurt and make it more affordable to many Nigerians.

Previously, some researchers have used a mixture of tigernut, soybean, coconut and cow milk as a substrate for yoghurt [8]. However, this still pose threat to lactose intolerant people because of the presence of cow milk. Several other studies have shown that incubation time, incubation temperature, and starter culture concentration are very important processing factors in the production of yoghurt from plant materials [9,10]. Moreover, the values of the parameters for optimum yoghurt production were not established. Furthermore, there is dearth of information on the attempt to produce yoghurt using tigernut as the only substrate with the application of response surface methodology (RSM) for optimisation. Hence, this study will provide useful information that can help food processing industries achieve optimum yield in yoghurt production using tigernut as sole substrate.

Response surface methodology (RSM) is a statistical experimental protocol used in mathematical modelling [11,12]. This method reduces the experimental essays, improving the statistical interpretation possibility and indicates the interaction between variables [13]. The objective of this study is therefore to optimise the process factors: incubation time, incubation temperature and starter culture concentration for the production of yoghurt from tigernut tubers using response surface methodology (RSM).

2. MATERIALS AND METHODS

2.1 Materials

Fresh tigernut tuber was purchased from local market in Ile-Ife, Osun state, Nigeria. A non-dairy probiotic starter culture which contains *Lactobacillus acidophilus*, *Lactobacillus delbrueckii bulgaricus* and *Streptococcus thermophilus* was obtained from local chemical store in Ile-Ife, Nigeria. The starter culture was stored at cool temperature and dried condition until use.

2.2 Tigernut Milk Extraction

The method of Djomdi et al. [14] was employed in the extraction of the tigernut milk. Using this method, 100 g of tigernut which had been previously sorted was washed and subsequently hydrated with 400 mL demineralised water, placed in a water bath at 40°C for 12 h. This treatment was done to soften the nuts for effective milling and extraction of the milk. The hydrated tigernut were then poured into the vessel of a Kult pro mixer (WMF AG, Geislingen, Germany). Exactly 200 ml of cold and then hot demineralised water was added to the tigernut and the mixture was comminuted using household blender for 3 min to obtain the tigernut mush. The tigernut mush was quantitatively transferred by washing with 100 ml (cold) demineralised water into the hopper reservoir of a pneumatic press with its frit being layered with a Whatman (GE Healthcare Europe GmbH, Freiburg, Germany) 4 pm pore size filter membrane. The filtrate fraction which was the milk was stored in the refrigerator during analysis to prevent microbial proliferation.

2.3 Preparation of Yoghurt

Tigernut milk (1000 mL) was pre-heated at 90°C for 3 min using water bath and subsequently cooled to 42±1°C. The inoculum of yoghurt was added at the amount of 3% (w/w), mixed well, and the cultured tigernut milk was transferred into small plastic cup. The cultured tigernut milk was incubated at 35°C for 8 h. After incubation, the tigernut yoghurt was stored at 4±1°C and was used as a starter culture.

2.4 Experimental Design and Data Analysis

The statistical analysis for tigernut yoghurt production was performed using statistical software (Stat Soft, Inc 2014, version 12; Stat Soft Inc., Tulsa, USA). Box-Behnken Design (BBD) was used to study the interaction of process variables by applying response surface methodology (RSM). As shown in Table 1, the three variables considered from this study are: incubation time (A), incubation temperature (B), and amount of starter culture (C). Each variable has 3 different coded levels, from low (−1), to medium (0), and high (+1) with the range of values of 35 to 45ºC for temperature, 3 to 8 h for fermentation time and 2 to 3% for starter culture concentration. Taste, aroma, colour, appearance, pH, TTA and overall acceptability are taken as the responses of the design experiment and the full quadratic equation of the response variables is derived using RSM as:

$$\begin{aligned} Y = {} & \beta_o + \beta_1 A + \beta_2 B + \beta_3 C + \\ & \beta_{11} A^2 + \beta_{22} B^2 + \beta_{33} C^2 + \beta_{12} AB + \\ & \beta_{13} AC + \beta_{23} BC \end{aligned} \tag{1}$$

where, Y is a vector of response variables; β_o is a constant; β_1 , β_2 , β_3 are linear regression coefficients; β_{11} , β_{22} , β_{33} .. β_{23} are interaction regression coefficients; *A, B, C* are input variables.

2.5 Physicochemical Analysis of the Tigernut Yoghurt

The pH of the tigernut yoghurt was determined using a pH meter standardised and calibrated with buffer solution at 25°C. The total titratable acidity of the yoghurt sample was determined as described by Morris [15]. The total titratable acidity (TTA) was calculated as a lactic acid percentage (%) as:

$$\begin{aligned} & \text{Total Titratable Acid (TTA)} \left(\%\ \text{lactic acid}\right) \\ & = \frac{\text{ml NaOH} \times \text{N} \times 0.09}{\text{Volume of sample (ml) used}} \times 100 \end{aligned} \tag{2}$$

where N is the normality of NaOH.

All the measurements were carried out in triplicate and the mean was calculated.

Table 1. Experimental range and levels of independent variables

Independent variable	Symbol	Coded levels		
		-1	**0**	**+1**
Incubation time (hours)	A	3	5.5	8
Incubation temperature (°C)	B	35	40	45
Starter culture concentration (%)	C	2	2.5	3

2.6 Sensory Evaluation of the Yoghurt

A total of 20 trained-assessors drawn from Obafemi Awolowo University Ile-Ife, Nigeria assessed the sensory quality of the yoghurt samples. The hedonic rating test was used for the evaluation, analysis and the extent of the difference between the yoghurt samples for each quality was measured on a standard 9-point hedonic scale ranging from 1- dislike to 9- like extremely. The sensory qualities assessed were colour, taste, aroma, and overall acceptability.

3. RESULTS AND DISCUSSION

3.1 Effect of Incubation Time, Incubation Temperature and Starter Culture Concentration on the pH of the Tigernut Yoghurt

The results of the actual and predicted pH while varying the incubation time (A), incubation temperature (B) and starter culture concentration (C) for the fifteen samples of tigernut yoghurt produced are presented in Table 2. The pH ranging from 3.93 to 5.06 was observed. Sample 6 had the highest pH value at the incubation time, incubation temperature and starter culture concentration of 8 h, 40°C and 2%, respectively. Sample 12, on the other hand had the lowest pH value at the incubation time, incubation temperature and starter culture of 5.5 h, 45°C and 3% (w/w), respectively.

The main effects of interaction of incubation time, incubation temperature and starter culture concentration on the pH of the tigernut yoghurt was found in Fig. 1. Fig. 1a shows the interaction between incubation time and incubation temperature while holding the starter culture concentration at the centre point (0). It was observed from the figure that high incubation time and high temperature (maximum at 42.1°C), result in high pH. This observation is in agreement with the result reported by Adebayo-Tayo et al. [16] in which increasing the incubation temperature above the maximum temperature of the fermenting microorganism resulted in high pH of the food sample. Further observation showed that increasing the incubation temperature above 42.1°C with either increasing or decreasing incubation time resulted to reduction in the pH. This result could be attributed to the inhibitory effect of high temperature on the starter culture.

Fig. 1b on the other hand shows the effect of starter culture concentration, incubation time and their interaction on the pH of the yoghurt while keeping incubation temperature constant at 40°C. It was observed that increasing the incubation time coupled with low starter culture concentration increased the pH value. However, increasing both the starter culture concentration and incubation time result in low pH value of the yoghurt. An increase in starter culture concentration coupled with an increase in incubation temperature results in low pH value of the yoghurt as shown in Fig. 1c. In the production of yoghurt, a low pH is desirable and this is favoured by increase in the starter culture concentration. It has been reported in line with this result that high starter culture concentration could lead to increase in acid production thereby decreasing the pH value (increasing acidity) of the fermented food [17].

Table 2. Experimental results for tigernut yoghurt response variables

Sample	A	B	C	pH	TTA	Taste	Aroma	Colour	Appearance	Overall acceptability
1	3	35	2.5	4.29	1.22	6.95	6.76	8.24	7.50	7.01
2	8	35	2.5	4.33	0.89	6.51	6.47	7.96	6.29	7.46
3	3	45	2.5	4.25	1.13	7.08	6.48	7.53	6.70	7.63
4	8	45	2.5	4.79	0.79	7.25	6.55	8.19	6.97	6.67
5	3	40	2	4.83	0.71	6.04	6.80	7.69	6.74	6.75
6	8	40	2	5.06	0.45	6.00	6.55	8.15	5.80	6.76
7	3	40	3	4.36	1.11	6.38	6.45	8.19	6.94	7.39
8	8	40	3	4.56	0.89	6.15	6.49	8.05	6.93	6.79
9	5.5	35	2	4.28	1.72	6.78	6.72	7.90	6.97	6.72
10	5.5	45	2	4.57	0.97	6.56	6.43	7.79	7.40	6.91
11	5.5	35	3	3.95	1.50	6.33	6.26	8.30	8.29	7.54
12	5.5	45	3	3.93	2.04	7.51	6.47	7.79	7.42	6.90
13	5.5	40	2.5	4.68	0.61	6.00	6.74	7.90	6.8	6.86
14	5.5	40	2.5	4.74	0.67	6.10	6.76	7.80	6.81	6.87
15	5.5	40	2.5	4.66	0.63	6.20	6.78	7.80	6.81	6.87

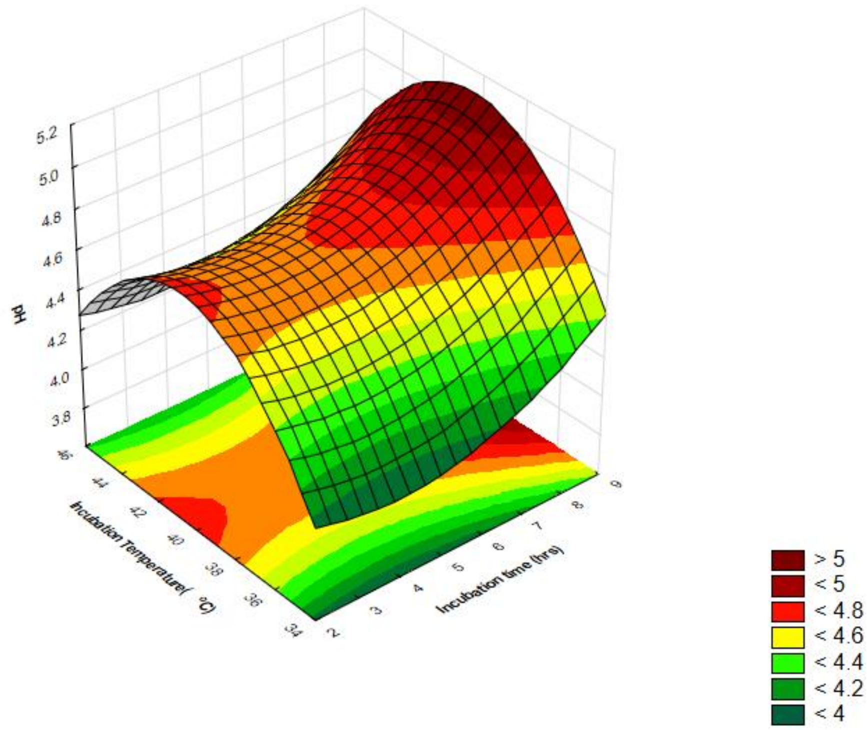

Fig. 1a. Response surface plot for the effect of incubation temperature, incubation time and their interaction on the pH of the yoghurt

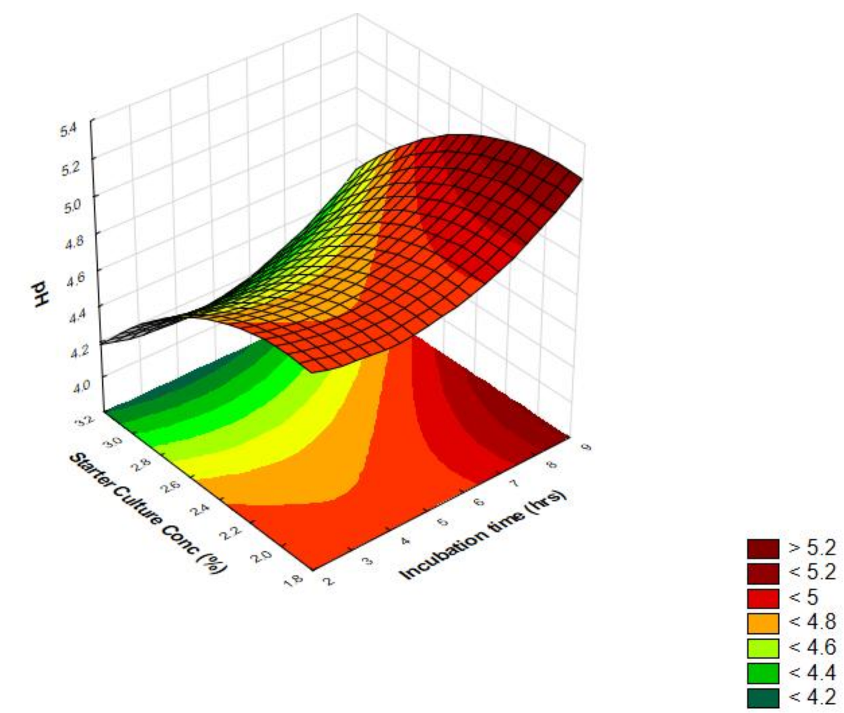

Fig. 1b. Response surface plot for the effect of starter culture concentration, incubation time and their interaction on the pH of the yoghurt

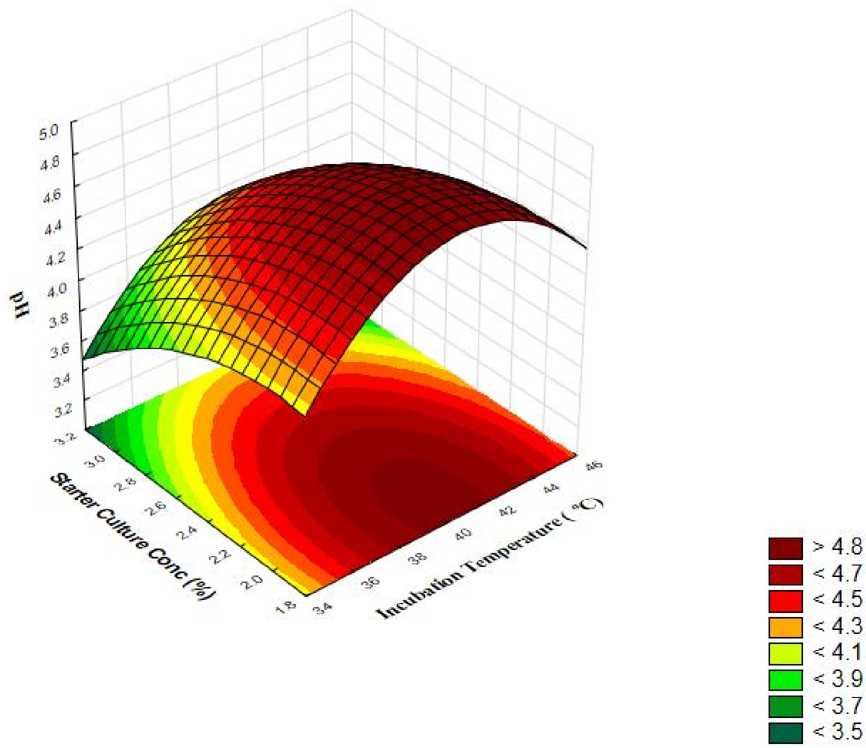

Fig. 1c. Response surface plot for the effect of starter culture concentration, incubation temperature and their interaction on the pH of the yoghurt

3.2 Effect of Incubation Time, Incubation Temperature and Starter Culture Concentration on TTA of the Tigernut Yoghurt

The results of the actual and predicted TTA while varying the incubation time (A), incubation temperature (B) and starter culture concentration (C) for the fifteen samples of tigernut yoghurt produced are also presented in Table 2. As shown in the table, the total acidity of the yoghurt product ranges from 0.45 - 2.04. According to Obi et al. [18], the International Dairy Federation recommended that the minimum value of acidity in yoghurt should be 0.70. It was observed from the results obtained in this work that more than half of the total formulations tested successfully achieve this minimum value. It was also observed from the same table that the highest acidity of 2.04 was obtained at the incubation time of 5.5 h, incubation temperature of 45°C and starter culture of 3%. As reported by Knifel et al. [19] and also in agreement with this result, controlling the incubation time, incubation temperature and culture activity are required in order to prevent over acidification of the yoghurt product.

The effects of production variables on the acidity of the tigernut yoghurt are shown in Fig. 2. As shown in Fig. 2a, an increase in incubation temperature up to 45°C and increase in incubation time increased the acidity of the yoghurt. As could be observed in Fig. 2b, the acidity of the yoghurt increase with increasing starter culture concentration and incubation temperature. This observation is in agreement with the result reported by Adebayo-Tayo et al. [16] that high starter culture concentration could bring about high acidity of fermented food products. This observation could be attributed to the fermentation of carbohydrate to organic acid thereby increasing the acidity of the fermented food products. The effect of starter culture concentration and incubation time as well as their combined effect on the acidity of the yoghurt while holding the incubation temperature constant is presented in Fig. 2c. It was observed from the figure that an increase in the starter culture concentration up to 3.2% and increase in incubation time to 9h increased the acidity of the yoghurt. The combined effect of these factors revealed that a high starter culture concentration and an increased incubation time could lead to high acidity of the yoghurt.

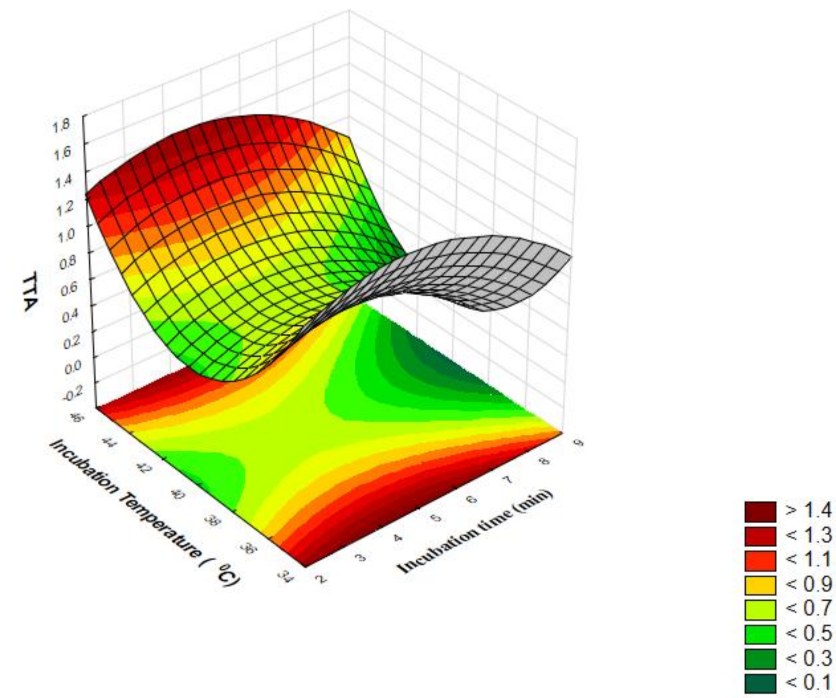

Fig. 2a. Response surface plot for the effect of incubation temperature, incubation time and their interaction on total titratable acid (TTA) of the yoghurt

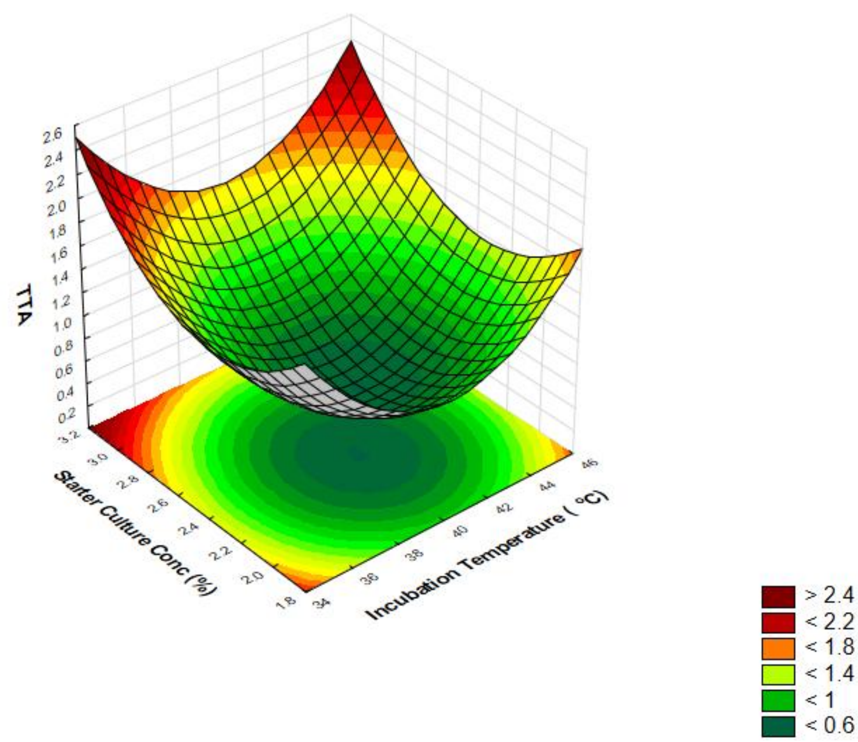

Fig. 2b. Response surface plot for the effect of starter culture concentration, incubation temperature and their reciprocal interaction on total titratable acid (TTA) of the yoghurt

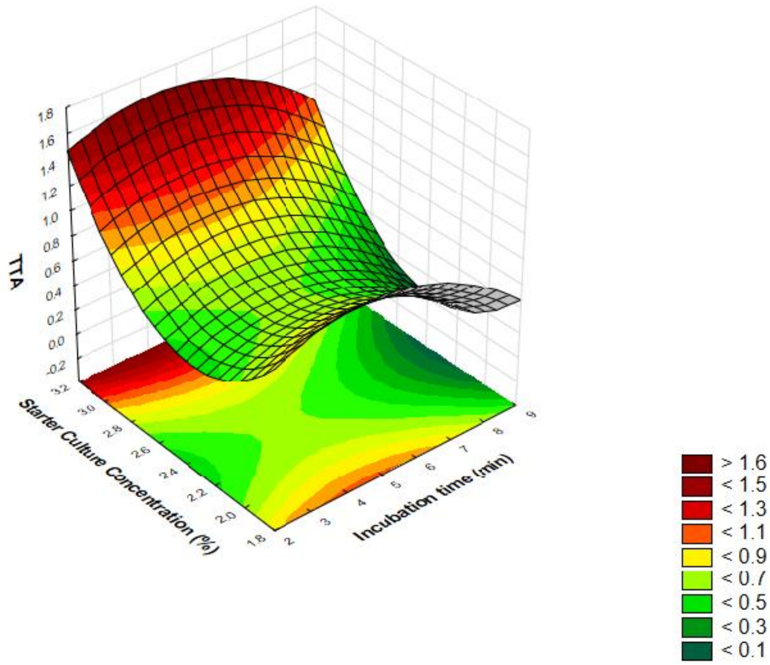

Fig. 2c. Response surface plot for the effect of starter culture concentration, incubation time and their interaction on total titratable acid (TTA) of the yoghurt

3.3 Effect of Incubation Time, Incubation Temperature and Starter Culture Concentration on the Sensory Attributes of the Tigernut Yoghurt

The results of the sensory analysis which include taste, aroma, colour, appearance and overall acceptability of the yoghurt produced from tigernut are presented in Table 2. The results from the table revealed that the sensory analysis ranged between 6.04 –7.51 for taste, 6.26– 6.80 for aroma, 7.53–8.30 for colour, 5.8–8.29 for appearance and 6.67–7.63 for overall acceptability. Sensory analysis helps in defining the product characteristics with respect to acceptability and customer acceptance. They are the main criteria to assess product quality [20].

It could be observed from Table 3 that the panel set up to assess the sensory quality of the product gave the highest average acceptability of 7.51 to the taste of the yoghurt produced at highest concentration of starter culture of 3%, highest incubation temperature of 45°C and incubation time of 5.5 h. The observed trends could imply that high starter culture concentration and high incubation temperature favour the microbial activities responsible for the production of lactic acid which is responsible for the sour taste of the yoghurt. In addition, according to Kneifel et al. [19], high incubation temperature can result in a more acidic product. However, the sour taste in yoghurt does not come only from the presence of lactic acid but from other metabolic products produced during the culture.

The highest average acceptability of 6.80 was given to aroma of the yoghurt produced at medium incubation temperature of 40°C, lowest starter culture concentration of 2% and lowest incubation time of 3 h. This result indicates that medium incubation temperature and lowest incubation time could provide favourable conditions for fermenting microorganism (starter culture) that synthesise aromatic compounds such as aldehyde and ketones that give good aroma to fermented food products.

Colour plays an important role in product acceptability and marketing purposes. Food product that is highly nutritious and beneficial to human may not be marketable if visual attraction is bad. The highest average acceptability of 8.30 was given to the colour of the yoghurt produced at the lowest incubation temperature of 35°C, highest starter culture concentration of 3% and lowest incubation time of 3 h. This result implies that controlling these variables could highly improve the colour of the product for acceptable marketability. The colour of the yoghurt produced

Table 3. Estimated coefficients of the fitted second-order polynomial model for all response variables

Regression coefficient	Response						
	pH	**TTA**	**Taste**	**Aroma**	**Colour**	**Appearance**	**Overall acceptability**
Intercept	4.69[a]	0.64[a]	6.10[a]	6.79[a]	7.83[a]	6.81[a]	6.87[a]
Linear							
A	0.13[a]	-0.15[a]	-0.069[a]	-0.054[a]	0.089[a]	-0.24[a]	-0.14[a]
B	0.089[a]	-0.052[a]	0.23[a]	-0.036[a]	-0.14[a]	-0.068[a]	-0.077[a]
C	-0.24[a]	0.21[a]	0.12[a]	-0.10[a]	0.10[a]	0.33[a]	0.19[a]
Interaction							
AB	0.13[a]	-4.24×10^{-3}[ns]	0.15[a]	0.092[a]	0.24[a]	0.37[a]	-0.35[a]
AC	-7.50×10^{-3}[ns]	0.011[ns]	-0.048[ns]	0.073[a]	-0.15[a]	0.23[a]	-0.15[a]
BC	-0.078[a]	0.32[a]	0.35[a]	0.13[a]	-0.10[a]	-0.32[a]	-0.21[a]
Quadratic							
A^2	0.12[a]	-0.20[a]	0.10[a]	-0.043[a]	0.11[a]	-0.43[a]	0.12[a]
B^2	-0.40[a]	0.57[a]	0.75[a]	-0.15[a]	0.039[ns]	0.49[a]	0.21[a]
C^2	-0.11[a]	0.35[a]	-0.052[ns]	-0.14[a]	0.078[a]	0.23[a]	-0.056[ns]

[a] Significant at $p<0.05$ level. [ns] Not significant at $p>0.05$ level

Table 4. Correlation between experimental (actual) and predicted values of pH and TTA

Sample	A	B	C	pH		TTA	
				Actual	Predicted	Actual	Predicted
1	3	35	2.5	4.29	4.33	1.22	1.20
2	8	35	2.5	4.33	4.33	0.89	0.92
3	3	45	2.5	4.25	4.25	1.13	1.11
4	8	45	2.5	4.79	4.76	0.79	0.81
5	3	40	2	4.83	4.81	0.71	0.73
6	8	40	2	5.06	5.08	0.45	0.42
7	3	40	3	4.36	4.34	1.11	1.13
8	8	40	3	4.56	4.58	0.89	0.86
9	5.5	35	2	4.28	4.26	1.72	1.72
10	5.5	45	2	4.57	4.59	0.97	0.98
11	5.5	35	3	3.95	3.93	1.50	1.50
12	5.5	45	3	3.93	3.95	2.04	2.04
13	5.5	40	2.5	4.68	4.69	0.61	0.63
14	5.5	40	2.5	4.74	4.69	0.67	0.63
15	5.5	40	2.5	4.66	4.69	0.63	0.63

is slightly different from the formulations, which is light brown. As shown in Table 2, the highest average acceptability of 8.29 for the appearance of yoghurt produced is achieved at the lowest incubation temperature of 35°C, highest starter culture concentration of 3% and lowest incubation time of 3 h. The starter culture in the formulation could have acted not only as lactic acid producing agent but also as a texturising agent that gives good appearance to the fermented product [21].

3.4 Statistical Analysis and Modelling of Variables for Production of Yoghurt

The results for the analysis of the model for the production of yoghurt from tigernut milk are listed in Table 3. The regression coefficient of the intercept, linear, quadratic and interaction terms of the model were calculated using the least square technique. It was observed from this result that the linear terms (A, B, and C), two interaction terms (AC and BC) and all the quadratic terms (A^2, B^2 and C^2) were found to be significant at the level of $p<0.05$ for pH, whereas the linear terms, quadratic terms and one interaction term (BC) were significant at the level of ($p<0.005$) for TTA. Three linear (A, B and C), and two quadratic parameters (A^2 and B^2) and two interaction terms (AB and BC) were found to be significant at the level of ($p<0.05$) for taste. Also, all the linear, interaction and quadratic terms were significant for aroma and appearance. Only one quadratic term (B^2) was found not to be significant at the level of $p>0.05$ while only the quadratic term (C^2) was observed not to be significant at the level of $p>0.05$. The fitted quadratic model for pH, TTA, taste, aroma, colour, appearance and overall acceptability are shown in Equations (3) – (9):

$$pH = 4.64 + 0.13A + 0.089B - 0.24C + 0.13AB - 7.50\times10^{-5}AC - 0.078BC + 0.12A^2 - 0.40B^2 - 0.11C^2 \quad (3)$$

$$TTA = 0.64 - 0.15A - 0.052B + 0.21C - 4.24\times10^{-3}AB + 0.011AC + 0.32BC - 0.20A^2 + 0.57B^2 + 0.35C^2 \quad (4)$$

$$Taste = 6.10 - 0.069A + 0.23B + 0.21C + 0.15AB - 0.048AC + 0.35BC + 0.10A^2 + 0.57B^2 - 0.052C^2 \quad (5)$$

$$Aroma = 6.79 - 0.054A - 0.036B - 0.10C + 0.092AB + 0.073AC + 0.13BC - 0.043A^2 - 0.15B^2 - 0.14C^2 \quad (6)$$

$$Colour = 7.83 + 0.089A - 0.14B + 0.10C + 0.24AB - 0.15AC - 0.10BC + 0.11A^2 + 0.039B^2 + 0.078C^2 \quad (7)$$

$$Appearance = 6.81 - 0.24A - 0.068B - 0.33C + 0.37AB + 0.23AC - 0.32BC - 0.43A^2 + 0.49B^2 + 0.23C^2 \quad (8)$$

$$Overall\ Acceptability = 6.87 - 0.14A - 0.077B + 0.19C - 0.35AB - 0.15AC - 0.21BC + 0.12A^2 + 0.21B^2 - 0.056C^2 \quad (9)$$

The experimental data were analysed to check the correlation between the experimental (actual) and predicted values of pH and TTA for different combinations of production variables and the results are presented in Table 4. The results of the analysis of variance (ANOVA) for both the pH and TTA indicate good model performance with correlation coefficient (R^2) values of 0.9943 for pH and 0.9977 for TTA. The results for other variables also indicate a good model performance with correlation coefficient (R^2) values of 0.9938 for taste, 0.9925 for aroma, 0.9860 for colour, 0.9973 for appearance and 0.9909 for overall acceptability. These results indicate that the statistical models are adequate for the prediction of the production of yoghurt from tigernut milk.

3.5 Process Optimisation

The optimal value of the independent variables for the production of yoghurt from tigernut were determined using the maximum desirability. The result of optimal conditions to obtain the minimum pH, maximum acidity, and maximum sensory attributes were incubation time of 3.12 h, incubation temperature of 35°C and starter culture concentration of 2.74%, at which the values for the pH, TTA, taste, aroma, colour, appearance, and overall acceptability were 4.22, 1.24, 6.83, 6.72, 8.43, 7.82 and 7.03, respectively. The maximum desirability was 0.672.

4. CONCLUSION

The optimum combination of production parameters for tigernut yoghurt was determined using response surface methodology. It was shown from the results that the incubation time, incubation temperature and starter culture have significant effects on the pH, TTA, taste, aroma, colour, appearance and overall acceptability of the tigernut yoghurt produced. The multiple response optimisation provided the optimal conditions to obtain the minimum pH, maximum acidity, and maximum sensory attributes for the product. The regression models obtained perfectly described the process and can be used to predict the optimal conditions for tigernut yoghurt production with minimum pH, maximum acidity, and maximum sensory attributes.

ACKNOWLEDGEMENT

The authors wish to acknowledge the Departments of Chemical Engineering and Food Science and Technology, Obafemi Awolowo University Ile-Ife for providing the laboratory facilities to carry out this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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