Production Optimization of Fortified Foam-Mat Dried Yoghurt

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Abstract:
This experimental study examines the effect of different production parameters such as moringa seed flour, ginger extract, forming agent, mixing time and drying temperature on the selected proximate and microbiological qualities of foam-mat dried yoghurt. The design and analysis of the experiment were conducted with the central composite design technique of the Design Expert statistical software. The study aimed at fortifying and optimizing the production of foam-mat dried yoghurt, which involves powdered milk, water, starter culture and flavour which are kept constant and followed by the addition of moringa seed flour, ginger extract and forming agent (egg white). Twenty-five experimental runs with the control experiment inclusive were carried out based on the mixture-process design matrix and the nutritional properties evaluated include moisture content, crude protein, fat content, ash content, carbohydrate content, total lactic acid, bacteria and fungi. Numerical optimization, via the desirability approach, was utilized to determine the optimum production parameters for the fortified foam-mat dried yoghurt. Graphical optimization was also used to display the prediction of all responses in the mixture-process factors space. Results got revealed that foam-mat dried yoghurt with 10.79 % moisture content, 12.115% crude protein, 0.552% ash content, 2.196% fat and 16.409% carbohydrate could be produced from 80% of fresh yoghurt, 5.466% of moringa seed flour, 7.534% of ginger extract, 7% of foaming agent, mixing duration 2.53mins, drying temperature at 50oC and 0.721 desirability index gave the optimum quality. The results of this work are of great use to the food and beverage industries as they provide a basis for selecting process parameters for optimal foam-mat dried yoghurt production. Prospects for more studies were suggested.

Keywords: Foam-mat drying, fortification, quality factors, numerical optimization, yoghurt

1. Introduction

Yoghurt is a well-known fermented milk product consumed all over the world basically due to its excellent sensory properties, as well as its high nutritive and therapeutic values. Yoghurt can be fortified with bioactive components like aloe vera, caffeine, green tea, and fibre [1] and [2]. The increased intake of fruits and vegetables is an effective strategy for increasing antioxidant intake and can help to prevent chronic diseases such as cancer and cardiovascular disease.

The supplementation of yoghurt with vegetables will help provide additional health benefits concerning antioxidant properties which results in the development of functional products [3], [4] and [5].

The principal intention of a yoghurt powder manufacturer is to store the product in a stable and readily utilizable state. Yoghurt powder becomes an interesting dairy ingredient for a wide variety of food applications due to its unique flavour and nutrients. Yoghurt powder can be used to replace fresh yoghurt for beverages and can also be used in confectionery as a coating material for coating fruit, nut and cereals [6] and [7]. There is a need for powdered yoghurt which is gradually increasing, not just for increased shelf life but also to provide convenience during handling, packaging and transportation due to the weight and volume [8] and [9].

Food fortification simply involves the addition of essential nutrients such as minerals and vitamins to staple foods to improve their nutritional value [10] and [11]. Foam-mat drying simply denotes the process of drying semi-solid foods by mixing with a stabilizing agent (foaming agent) to produce stable foam which then undergoes air drying temperatures ranging from 50-80oC [12] and [13]. The foam-mat drying process can be applied to dry fruits, milk, juice, beverages and jams. The foam-mat dried product is then further milled to produce a powdered product. Foam-mat drying is a simple form of drying that is most times preferred to other methods such as freeze drying and spray drying. It is less complicated, less time-consuming and less expensive [14] and [15].

Despite all the nutritional and medical importance of yoghurt, it is a highly perishable food product of which quality stability and storage are major factors in the commercial production of the product [16], [17] and [18]. There is a need to present the product in a more shelf-stable form. The principal intention for the optimization of yoghurt powder manufacture is to maximize the production parameters and have a product stored in a stable and readily utilizable state. Thereby, making yoghurt powder become an interesting dairy ingredient for a wide variety of food applications with high nutritional value. The objective of this work is to obtain optimum conditions for the production of quality foam-mat dried yoghurt.

2. Materials and Methods

The materials used include powdered milk, water, moringa seed flour, ginger extract, foaming agent (egg white), flavour, and starter culture, and these were purchased from Kure market in Minna, Niger State. The preparation of yoghurt powder was carried out at the Department of Food Science laboratory while the analysis was done at the Department of Animal Production Technology Laboratory of the Federal University of Technology, Minna, Nigeria.

2.1 Reagent and Apparatus

The following reagents and apparatus were used during the experiment; Ferric Chloride, Ammonium thiocyanate, Ammonium solution, concentrated H_2SO_4, Sodium hydroxide, Ethanol, petroleum ether, HCL, N-hexane and distilled water, Electric Oven, Mixer, thermometer, aluminium pot, gas cooker, turner, sieve, electric weighing balance, electric blender, conical flask, plastic containers and fridge.

2.2 Methodology

Fresh Yoghurt was produced as described by [19]. Powdered milk was dissolved in warm water, and sugar and the water were added at a ratio of 1:10 was pasteurized at 85ºC for 30 min, and then held for 5min. It was cooled rapidly to 45ºC and starter culture was introduced. It was set aside to ferment for 9 hours and shaken to break the fermentation after which it was refrigerated at <4ºC. The formulation was subjected to oven drying using specified drying temperature and drying duration respectively. The dried foam-mat dried samples were milled into fine particles using an electric blender. The milled powder was packaged in a plastic container for analysis. The mixture-process variable design for this research is shown in Table 1. Interaction between composition variables and process factors can be better revealed by experiments that combine mixture components with process factors. A mixture-process design is used for a mixture of fresh yoghurt and three other components (moringa seed flour, ginger extract and foaming agents). It has a total of twenty-five runs or twenty-five different ingredient combinations with a control. The quality characteristics of powdered yoghurt, which were measured include moisture content, ash content, crude protein, fungi count, bacteria count, fat content and carbohydrate which is similar to the report by [20]. The mixture process variable design is shown in Table 1.

2.3 Optimization of Production Process

An approach of response surface with multi-variable numerical optimization with Design-Expert®Software (version 11.0) was adopted for the determination of the quality characteristics of powdered yoghurt. The numerical optimization has the desirability index by minimizing the response parameters (moringa seed flour, ginger extract, foaming agents, mixing duration and drying temperature). The values of the desirability index for each of the response parameters as well as the combined optimization with a Dn-value were determined.

2.4 Proximate Analysis

The nutritional properties evaluated include moisture content, ash content, crude protein, fat content, carbohydrate content, total lactic acid, bacteria and fungi.

2.5 Percentage Moisture

The moisture content of the foam-mat dried sample was carried out by oven drying as reported by [22]. W1 was taken as the initial weight by weighing 2 grams of the foam-mat dried sample in a dry crucible thereafter; the crucible was taken to the oven for 8 hours and at 1000ºC until a steady weight was obtained. After 8 hours, the crucible was taken out from the oven and allowed to cool for 35 minutes in a desiccator. The crucible was weighed again after cooling as the final weight (W_2). The Percentage of moisture was derived using the formula below:

$$\%\ \text{moisture} = \frac{W_1 - W_2}{w_0} \times 100 \qquad (1)$$

Where W_0 = weight of the empty crucible, g

W_1 = weight of foam-mat dried sample and crucible before heating, g

W_2 = weight of foam-mat dried sample and crucible before heating, g

2.6 Percentage Ash

The ash content of the foam-mat dried sample was determined by the use of a muffle furnace. An empty crucible was placed in a muffle furnace at 6100C for 1 hour and later cooled in a desiccator. The initial weight was determined and recorded as W_1. Two grams of the foam-mat dried sample were taken in the crucible and labelled as W_2. The foam mat-dried sample was ignited over a burner. After ignition, the crucible was then placed in a muffled furnace at 6100C for 3 hours. After ashing, the crucible was removed and grey-white ash was observed, which indicates complete oxidation of all organic matter in the foam-mat dried sample which was placed in a desiccator to cool. After cooling, the weight was determined as (W_3).

Percentage ash was calculated as:

$$\%\ \text{Ash} = \frac{W_3 - w_1}{w_2} \times 100 \qquad (2)$$

Where W_1 = initial weight of crucible empty, g

W_2 = weight of foam-mat dried sample and crucible before heating, g

W_3 = weight of foam-mat dried sample and crucible after heating, g

Table 1 Mixture-process variable design

Runs	Moringa seed Flour (%) X_1	Ginger Extract (%) X_2	Foaming Agent (%) X_3	Mixing Duration(min) X_4	Drying Temp.ºC X_5
1	13	15	12	10	50
2	18	15	7	12	50
3	13	5	2	10	80
4	8	5	7	10	50
5	9	9	2	2	50
6	8	5	7	2	80
7	5	8	7	2	80
8	9	9	2	2	50
9	8	5	7	10	80
10	10.5	5	4.5	2	50
11	13	5	2	2	50
12	13	5	2	10	50
13	5	8	7	10	50
14	13	5	2	2	80
15	8	5	7	10	50
16	7.8	7.8	4.5	2	50
17	5	8	7	2	50
18	5	10.5	4.5	2	80
19	8	5	7	2	50
20	8	5	7	2	50
21	7.8	7.8	4.5	10	80
22	5	8	7	2	50
23	13	5	2	2	50
24	5	13	2	2	50
25	7.8	7.8	4.5	10	80

2.7 Percentage Crude Protein

The percentage of crude protein was determined by measuring 2g of the foam-mat dried sample which was taken into the digestion flask and concentrated H_2SO_4 of 10ml along with 8g of digestion mixture (K_2SO_4 and $CuSO_4$ of ratio 8:1) were added, mixed and swirled to maintain homogeneity. The flask was then heated to start digestion until the mixture turned blue-green. After 2 hours of digestion, the digest was cooled and transferred to a 100ml volumetric flask adding distilled water to make up the volume to the mark. After the digestion, distillation was then carried out and then 10ml of the digest was added to the distillation tube before 10ml of 0.5N NaOH was gradually added in the same way leaving it for 10 minutes. Ammonium produced was processed in a conical flask containing 20ml of 4% boric acid solution with a few drops of modified methyl red indicator and collected as ammonium hydroxide (NH_4OH, yellow). The distillate was then titrated against standard 0.1NHCl solution until the pink colour appearance was observed. The percentage of the crude protein content of the foam-mat dried sample was calculated and multiplied by a factor of 6.25.

% Crude Protein = 6.25 × % N

$$\% N = \frac{(S-B)\times N\times 0.014\times D\times 100}{weight of Sample} \qquad 3$$

Where: S = foam-mat dried sample of titration reading B = blank titration reading
N = normality of HCL D = dilution of the foam-mat dried sample after digestion
V= Volume taken for distillation 0.014= milli equivalent weight of nitrogen.
The general procedure for yoghurt making comprised of mixing-up the original composition of milk, pasteurizing the yoghurt mix, and fermentation at temperatures between 40 and 45 ºC. Cooling and addition of fruits and flavours. The production steps in the manufacturing process of set and stirred yoghurt are shown in Figure 1.

3. Results and Discussion

The mean nutritional composition for the fortified foam-mat dried yoghurt based on the experimental design is presented in Table 2 while the ANOVA of the various qualities and microbial properties are summarized in Table 5. The proximate composition for the foam-mat dried yoghurt based on the experimental design is presented in Table 1 while the mean score of the sensory qualities is presented in Table 3.

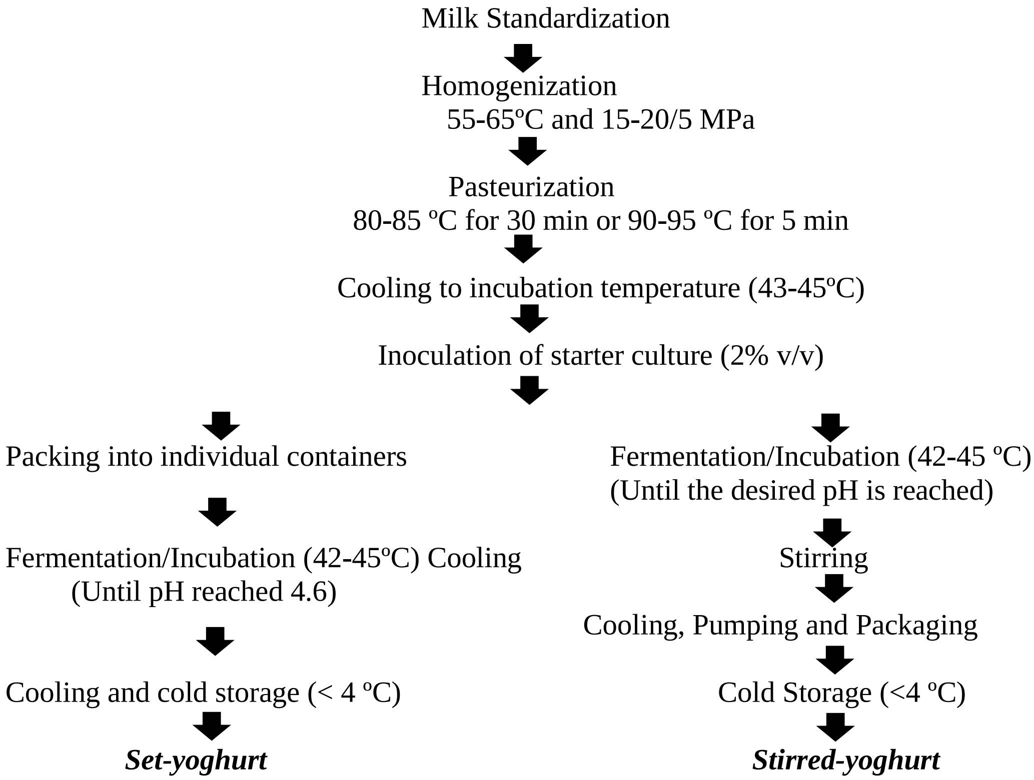

Figure 1: Manufacturing process of the set- and stirred-yoghurt [23].

Table 2 Mean of nutritional composition for the fortified foam-mat dried powder yoghurt

Runs	Moisture Content %	Crude Protein %	Ash Content %	Fat Content %	Carbohydrate Content %	Total Lactic Acid Bacteria CFU/G	Fungi CFU/G
1	69.75	3.81	0.37	1.28	24.79	4.7×10^{4}	$2.1\ X10^{6}$
2	88.75	4.63	0.57	2.11	3.94	2.9×10^{3}	$3.8\ X10^{6}$
3	11.5	6.2	0.73	1.62	79.95	3.3×10^{3}	$1.6\ X10^{7}$
4	66.58	6.11	0.04	2.5	24.77	2.8×10^{3}	$3.2\ X10^{6}$
5	80	4.83	0.06	1.48	13.63	1.9×10^{4}	$1.9\ X10^{7}$
6	79	5.72	0.09	2	13.19	2.3×10^{4}	$3.2\ X10^{7}$
7	37.75	7.81	0.4	2.14	51.9	7×10^{3}	$4.2\ X10^{6}$
8	63.25	7.33	0.72	6.38	22.32	3.9×10^{3}	$3.8\ X10^{7}$
9	69	6.48	0.62	2.94	20.96	2×10^{4}	$2.3\ X10^{7}$
10	20.75	7.48	0.78	4.2	66.79	5.1×10^{3}	$3.0\ X10^{7}$
11	48.75	5.69	0.02	1.42	44.12	8.4×10^{3}	$2.7\ 610^{7}$
12	77.75	4.81	0.08	2.11	15.25	4.3×10^{4}	$1.8\ X10^{6}$
13	77.33	5.11	0.54	5.5	11.52	3.4×10^{4}	$2.1\ X10^{6}$
14	21.5	5.11	0.12	1.92	71.35	2.6×10^{4}	$1.6\ X10^{7}$
15	78.61	3.8	0.56	2.11	14.92	6.2×10^{4}	$2.0\ X10^{6}$
16	60.38	4.92	1	3.8	26.9	2.9×10^{4}	$1.8\ X10^{7}$
17	50.11	4.83	0.92	2.42	41.71	4×10^{3}	$2.7\ X10^{6}$
18	70.11	3.94	1.1	2.14	12.81	2.9×10^{4}	$3.0\ X10^{6}$
19	80.53	6.13	1.06	1.98	10.33	3×10^{5}	$2.1\ X10^{6}$
20	69	12.11	1.5	1.32	16.07	2×10^{4}	$4.1\ X10^{6}$
21	20.75	15.2	1.1	6	56.95	1.8×10^{3}	$4.2\ X10^{6}$
22	31.84	9.84	0.5	3.11	54.71	3.4×10^{3}	$1.7\ X10^{6}$
23	48.75	8.11	0.57	6	36.57	3×10^{3}	$2.0\ X10^{7}$
24	77.75	6.38	1	2.33	12.54	4.6×10^{4}	$1.9\ X10^{8}$
25	21.5	17.5	1.5	4.68	54.82	3×10^{7}	$2.8\ X10^{7}$

Table 3. Mean score for the sensory quality of fortified foam-mat dried powder yoghurt

Runs	Taste	Colour	Texture	Flavour	Acceptability
1	5.8	5.8	6.9	8.6	5.8
3	7.4	9.2	8	8.1	6.2
6	6.8	8	8.4	7.6	7.4
9	8.2	7.3	8.6	7.7	7.7
12	6	8.4	8.6	7.8	7.7
15	7.8	6.9	8.6	8.1	8.2
18	7	7.9	8	8.2	7
21	8	8.3	9	8.6	9.2
25	7.4	7.9	7.9	8.2	8.1

The result of the sensory analysis was performed by using a 9-point hedonic scale and 20 panellists' acceptance of the foam-mat dried samples indicated by the high points the panellists gave (Table 3). This shows that the different formulations for the fortified foam mat dried powder yoghurt seem to be appealing to the panellists nonetheless with slight variances. The ANOVA of the various nutritional properties is summarized in Table 3. Organoleptic profiles of powder yoghurt containing flavour, taste, colour, texture and acceptability of the powder yoghurt produced were normal when compared to the fresh product. The flavour was generated by L. bulgaricus which resulted in an acceptable flavour as reported by [24]. The taste of powder yoghurt possessed a sour taste similar to fresh yoghurt. [25] noted that the powder colour was altered slightly from yellowish due to the drying temperature. Table 4 shows the ANOVA for the mean proximate composition of the foam-mat dried sample.

Table 4. ANOVA for the mean proximate composition of fortified foam-mat dried powder Yoghurt

Nutrient	**SS**	**MS**	**F**	**Sig**
M/C	32916.16	621.06	21.46	0.0400
Protein	534.03	10.27	2.19	0.0306
Ash	1.45	0.15	1.19	0.3226
Fat	101.79	2.48	3.64	0.0028
CHO	11136.03	1856.00	5.48	0.2002
Bacterial	4.335	8.179	0.091	0.010
Fungi	3.983	7.515	5.18	0.0361

The ANOVA table above shows that the moisture content value of the foam-mat dried yoghurt powder is 0.04 indicating a significant difference from the fresh foam-mat dried sample. The mean moisture content of the yoghurt powders was significant. Water was removed during drying from the yoghurt foam which forms the three-dimensional structure of yoghurt and resulted in an amorphous structure of the yoghurt powder [26]. This is similar to the report by [27] and [28]. Another factor that affects moisture content in processing yoghurt powder is the use of egg white which tends to decrease the moisture content by reducing the water activity of the yoghurt. The ash and carbohydrate content values are $P \geq 0.05$ showing that there is no significant difference among the formed dried foam-mat samples. Several components of food undergo drastic reduction through the thermal process through this process does not affect the mineral content in yoghurt which includes sodium, potassium, calcium, potassium, magnesium and iron ions. The ash content in the foam-mat dried sample contains minerals resulting in the ash content of the dried yoghurt. The protein content value increased ($P \leq 0.05$) and this was suspected to be mostly due to the egg white which contains protein, so the higher concentration of egg white will cause the higher protein content in yoghurt powder. In addition, the high temperature could also increase the kinetic energy and lead the molecules of protein to vibrate faster. For the fat content, there is a significant decrease which is largely caused by the moisture reduction due to drying. More so, the drying process could also decrease fat content due to the oxidation of the fat. Oxidation is an interactive process between oxygen molecules and all different substances. The bacteria and fungi load reduced significantly by $P \leq 0.05$ which is in line with the report by [29] and [30]. This is also similar to the values reported by [22] who found that the total LAB of powder yoghurt was 5.6 × 107 CFU/ml. The addition of egg white foam can reduce bacterial viability due to egg white foam prevents bacteria from synthesizing their food. So, the bacteria will not get enough energy to thrive in the yoghurt. However, the treatments showed low bacterial viability, and it was suspected that the capability of egg white as a foaming agent to maintain bacterial viability.

Table 5: Optimization of the proximate composition of foam-mat dried yoghurt

No	Moringa Seed Flour	Ginger Extract	Foaming Agent	Mixing Duration	Drying Temp	MC	CP	Ash	Fat	CHO	Bacterial	Fungi	Desirability	
1	5.46	7.53	7	2.53	50	10.79	12.11	0.55	2.96	16.40	-262929	- 51154	0.721	**Selected**
2	5.97	7.02	7	3.07	50	11.50	11.35	0.47	2.25	16.27	-231318	-1.3E07	0.720	
3	5.22	7.74	7	4.05	50	11.49	11.69	0.61	2.68	16.71	163387	171945	0.719	
4	6.20	6.79	7	3.08	50	12.76	11.32	0.54	2.26	16.46	-358690	-1.7E07	0.719	
5	5.64	7.39	7	4.79	50	11.50	10.82	0.56	2.78	16.99	277430	-25944	0.717	

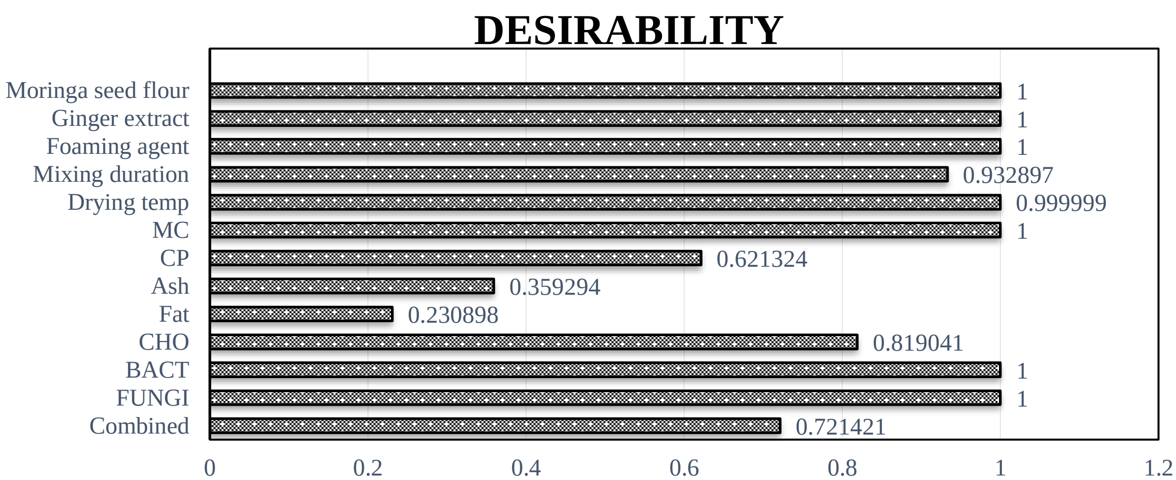

Figure 2: Desirability index plot of fortified foam-mat dried yoghurt.

The optimum moisture content of powder yoghurt obtained was 10.79%. This result is similar to the value reported by [13] who found the moisture content of powder yoghurt dried at 50-70℃ was 8.5-8.6%, and [15] reported that the moisture content was 11% while [4] reported that the moisture content of the commercial product was 3.0-5.0%. A numerical optimization method exploiting the desirability technique was utilized to generate a new formulation with the anticipated responses. The ideal formulation was chosen based on the criteria of achieving minimum moisture content, maximum protein, minimum carbohydrate, minimum drying duration, minimum drying temperature, maximum fat and maximum ash content. The goal of this optimization is to obtain an excellent series of conditions that will meet the objectives. It can be deduced from the optimization process that a yoghurt of 0.721 desirability index can be obtained from the optimal conditions selected based on the chosen criteria. Figures 2 to 8 show the surface plot of the proximate and microbial properties of the fortified foam-mat dried yoghurt.

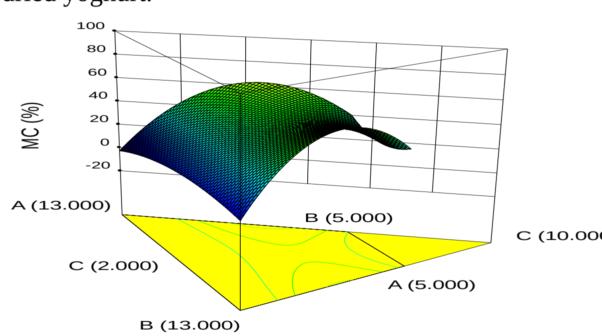

Figure 3: 3D surface plot of the moisture content

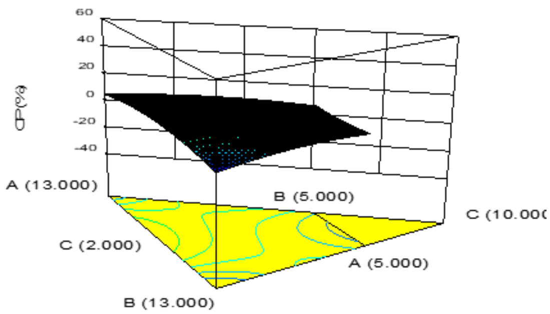

Figure 4: 3D surface plot of the protein content.

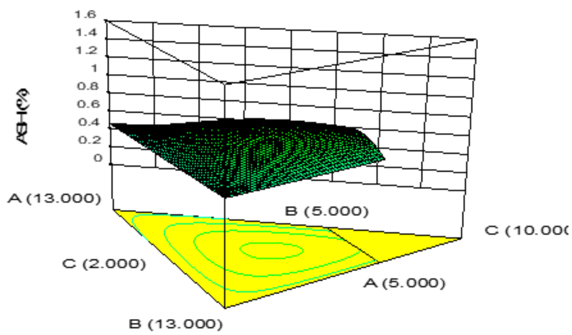

Figure 5: 3D surface plot of the ash content.

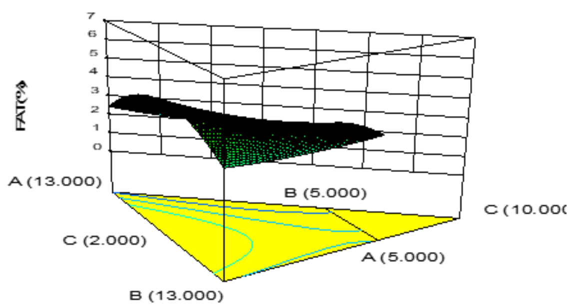

Figure 6: 3D surface plot of the fat content.

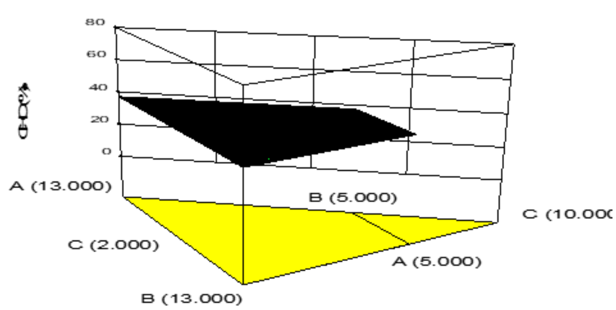

Figure 7:3D surface plot of the carbohydrate content.

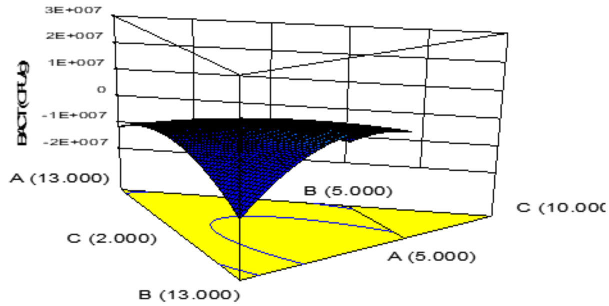

Figure 8:3D surface plot of the bacteria content.

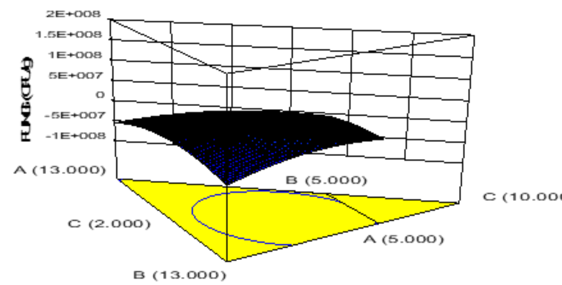

Figure 9: 3D surface plot of the fungi content.

4. Conclusion

Optimization analysis based on the proximate and microbial properties revealed that yoghurt of 10.79 % moisture content, 12.115% crude protein, 0.552% ash content, 2.196%fat, 16.409% carbohydrate could be produced from 80% of fresh yoghurt, 5.466% of moringa seed flour, 7.534% of ginger extract, 7% of foaming agent, drying temperature at 50oC, drying duration at 2hours 0.721 desirability index could be obtained. This experimental study provides a basis for selecting process parameters for the optimal condition in the production of foam-mat dried yoghurt. Statistical analysis of the variance of the result showed that the production variables have a significant effect on the proximate composition and microbial quality of fortified foam-mat dried yoghurt with the level of probability ($p<0.05$). Further studies may explore the influence of more process variables on the production of dried foam-mat yoghurt using other methods of design of experiment and further research should be carried out to determine the shelf-life of foam mat-dried yoghurt using suitable packaging material. Moreover, improvements should be made to the use of other conventional methods of drying the foam-mat dried yoghurt.

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