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Research Article

Empirical Modelling and Optimization of Value-Added, Foam-mat-dried Powdered Yoghourt

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Abstract

Yoghurt is one of the most popular fermented dairy products with wide acceptance worldwide due to its nutritional and health benefits. However, the commercial production of yoghurt has been limited due to the poor quality stability in storage. The present study is concerned with development and characterization of value-added foam-mat dried yoghurt powder. The effects of different ingredient formulation and processing parameters on some selected nutritional and functional properties of the developed yoghurt were evaluated. A four-component, six-processing parameters, constrained D-optimal mixture-process experimental design, with 59 randomized experimental runs, was employed. The formulation design constraints were: raw yoghurt (80%), moringa seed extract (5% - 13%), ginger extract, (5% - 13%), and foaming agent (2% - 7%). The design constraints of the processing parameters investigated were: pasteurization temperature (50°C - 80°C), pasteurization duration (5min - 30min), fermentation duration (5hr - 10hr), mixing duration (2 min - 10 min), drying temperature (50°C - 80°C), and drying duration (2hrs - 5hrs). Quality properties evaluated include moisture content, ash content, crude protein, fat content, carbohydrate content, pH, total titer acid, total lactic acid bacteria and fungi counts. Data collected were analyzed using Design Expert 11.0.0 software package. Model equations were developed to adequately relate the quality indices to the mixture component proportions and processing parameters. The adequacy of the model equations were evaluated statistically. The effects of the components formulation proportions and processing parameters on the nutritional quality of the foam-mat dried powdered yoghurt were studied and the optimum conditions for the production of foam-mat dried yoghurt were obtained. Numerical optimization, via desirability technique was utilized to determine the optimum formulation conditions for the foam-mat dried yoghurt. The result of optimization of the formulated foam-mat dried yoghurt gave optimized foam-mat dried yoghurt with overall desirability index of 0.514, based on the set optimization goals and individual quality desirability indices. The optimal foam-mat dried yoghurt was gotten from 80 % raw yoghurt, 13 % moringa seed extract, 5 % ginger extract, and 2 % foaming agent. The optimized processing conditions were: 80^0C pasteurization temperature, 30 minutes pasteurization duration, 10 hours fermentation duration, 10 minutes mixing duration, 80^0C drying temperature, and 5 hours drying duration. The quality properties of this optimal formulated foam-mat dried yoghurt are: 27.1 % moisture content, 10.1 % crude protein, 0.673 % ash content, 1.43 fat content, 58.4 % carbohydrate, 4.05 pH, 2.58 % total titre acid, 2.23E+05 CFU/g total lactic acid bacteria, and 3.81E+06 CFU/g fungi count. The result of the study showed that the optimized formulated foam-mat dried yoghurt was found to be of high quality.

1. Introduction

Yoghurt is among the most popular fermented milk products consumed all over the world because of its high nutritive and therapeutic values as well as excellent sensory properties [1]. It is offered in a variety of forms with regards to fat and total solids content and can be consumed as a snack or part of a meal, as a sweet or savory food [2, 3, 4].

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Incorporation of moringa seed extract and ginger extract into yoghurt can enhance nutritional value of yoghurt in addition to the health benefits [5]. Yoghurt is and need to be transformed into a more shelf-stable powdered form. Yoghurt powder is becoming interesting dairy ingredients for a wide variety of food application for a unique flavour and nutrients. It can be used to replace fresh yoghurt for beverage and it is also been used in confectionary as coating material for fruits, nut and cereal [6].

Foam-mat drying is a simple process of drying liquid - solid foods by being mixed with stabilizing agent and/or foaming agent to produce stable foam, which undergoes air drying temperatures ranging from 50-800C. Foam-mat drying process produces end product with favorable rehydration, controlled density and retain volatiles that would be lost when using other forms of drying methods [7]. The foam-mat dried product is then further milled to produce a powdered product. The aim of this study is to develop and optimize value added, foam-mat dried yoghurt powder using constrained optimal (custom) mixture experimental design.

2. Materials and Methods

2.1 Materials

The materials used were powdered milk, water, moringa seed flour, ginger extract, foaming agent (egg white), flavor, 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 and Technology Laboratory, Federal University of Technology, Minna.

2.2 Processing of the raw fresh yoghurt

Fresh Yoghurt was prepared from fresh cow milk following the procedure described by Lee and Lucey [8], after which it was refrigerated at - 4^0C pending the formulation experiments.

2.3 Methods

2.3.1 Experimental Design

A four-component, six-processing parameters, constrained D-optimal mixture-process experimental design, with 59 randomized experimental runs, was employed. The formulation design constraints were: raw fresh yoghurt (80%), moringa seed extract (5% - 13%), ginger extract, (5% - 13%), and foaming agent (2% - 7%). The processing parameters investigated were: pasteurization temperature (50°C - 80°C), pasteurization duration (5min - 30min), fermentation duration (5hr - 10hr), mixing duration (2 min - 10 min), drying temperature (50°C - 80°C), and drying duration (2hrs - 5hrs). The D-Optimal mixture – process design matrix is presented in Table 1.

Table 1. Yoghurt D-Optimal mixture- process design matrix

	x_1	x_2	x_3	x_4	z_1	z_2	z_3	z_4	z_5	z_6
Run	%	%	%	%	^0C	min	hrs	min	^0C	hrs
1	80	13	5	2	80	5	5	2	50	2
2	80	9	9	2	50	30	5	2	50	2
3	80	13	5	2	80	30	10	10	80	5
4	80	8	5	7	80	5	10	10	50	5
5	80	9	9	2	80	5	5	2	50	2
6	80	8	5	7	50	5	5	2	80	2
7	80	5	8	7	50	5	5	2	80	2
8	80	9	9	2	50	5	5	2	50	5
9	80	8	5	7	80	30	5	10	80	2
10	80	10.5	5	4.5	80	30	5	2	50	5
11	80	13	5	2	50	5	10	2	50	2
12	80	13	5	2	50	5	5	10	50	2
13	80	5	8	7	50	5	5	10	50	2
14	80	13	5	2	50	5	5	2	80	2

15	80	8	5	7	50	5	5	10	50	2
16	80	7.8	7.8	4.4	50	5	5	2	50	5
17	80	5	8	7	50	5	5	2	50	5
18	80	5	10.5	4.5	50	5	5	2	80	2
19	80	8	5	7	50	5	10	2	50	2
20	80	8	5	7	50	30	5	2	50	2
21	80	7.8	7.8	4.4	80	30	10	10	80	5
22	80	5	8	7	50	30	5	2	50	2
23	80	13	5	2	50	5	5	2	50	5
24	80	5	13	2	50	5	10	2	50	2
25	80	7.8	7.8	4.4	80	30	10	10	80	5
26	80	10.5	5	4.5	80	30	10	10	80	5
27	80	7.8	7.8	4.4	80	5	5	10	50	2
28	80	9	9	2	80	30	10	10	80	5
29	80	7.8	7.8	4.4	50	30	10	10	50	2
30	80	5	13	2	50	30	10	10	80	5
31	80	9	9	2	50	5	10	2	50	2
32	80	5	13	2	50	5	5	10	50	2
33	80	8	5	7	80	5	5	2	50	2
34	80	5	10.5	4.5	80	30	10	10	80	5
35	80	5	8	7	80	5	5	2	50	2
36	80	5	10.5	4.5	50	5	10	2	50	2
37	80	5	13	2	80	5	5	2	50	2
38	80	10.5	5	4.5	50	5	5	10	80	5
39	80	9	9	2	50	30	5	2	50	2
40	80	5	13	2	50	5	5	2	50	5
41	80	7.8	7.8	4.4	50	5	10	2	80	2
42	80	7.8	7.8	4.4	80	5	5	10	50	2
43	80	7.8	7.8	4.4	80	30	10	2	50	2
44	80	8	5	7	50	5	5	2	50	5
45	80	5	10.5	4.5	50	30	5	2	50	2
46	80	5	8	7	80	30	10	10	80	5
47	80	8	5	7	50	30	10	2	80	5
48	80	13	5	2	50	30	5	2	50	2
49	80	9	9	2	80	5	5	2	50	2
50	80	9	9	2	50	5	5	10	50	2
51	80	5	8	7	50	5	10	2	50	2
52	80	5	13	2	50	30	5	2	50	2
53	80	5	13	2	50	5	5	2	80	2
54	80	9	9	2	50	5	10	2	50	2
55	80	5	10.5	4.5	50	5	5	2	50	5

56	80	9	9	2	50	5	5	2	80	2
57	80	5	10.5	4.5	80	5	5	2	50	2
58	80	7.8	7.8	4.4	50	30	5	2	80	2
59	80	5	10.5	4.5	50	5	5	10	50	2

$x_1 = Raw\ fresh\ yoghurt,\ x_2 = Moringa\ seed\ extract,\ x_3 = Ginger\ extract,\ x_4 = Foaming\ agent,$
$z_1 = Pasteurization\ temperature,\quad z_2 = Pasteurization\ duration,\quad z_3 = Fermentation\ duration,$
$z_4 = Mixing\ duration,\ z_5 = Drying\ temperature,\ z_6 = Drying\ duration.$

The formulation proportions and processing parameters were based on the constrained D-optimal mixture-process experimental design and dried samples were milled into fine particles using electric blender and the milled powder were packaged in plastic containers for quality analysis.

2.3.2 The proximate and quality analysis of the powdered yoghurt

The proximate and quality characteristic of the powdered yoghurt were carried out using the method described by the Association of Analytical Chemist [9]. The quality characteristics which were determined include moisture content, ash content, crude protein, fat content, carbohydrate, pH, total titer acid, total lactic bacteria acid, and fungi count.

3.0 Experimental Results

The mean quality properties of the foam-mat dried yoghurt are presented in Table 2.

Table 2. Quality Properties of Formulated Yoghurt

	y_{mc}	y_{cp}	y_{ac}	y_{fat}	y_{cho}	y_{ph}	y_{tta}	y_{bac}	y_{fungi}
Run	%	%	%	%	%		%	CFU/g	CFU/g
1	69	3.81	0.37	1.28	24.79	2.83	2.16	47000	2.1E+06
2	88.75	4.63	0.57	2.11	3.94	3.93	0.9	2900	3.8E+06
3	11.5	6.2	0.73	1.62	79.95	4.03	1.08	34000	2.1E+06
4	66.58	6.11	0.04	2.5	24.77	3.72	1.98	2800	3.2E+06
5	80	4.83	0.06	1.48	13.63	4.02	0.81	19000	1.9E+07
6	79	5.72	0.09	2	13.19	2.87	2.25	23000	3.2E+07
7	37.75	7.81	0.4	2.14	51.9	4.99	1.17	7000	4.2E+06
8	63.25	7.33	0.72	6.38	22.32	3.83	1.26	3900	3.8E+07
9	69	6.48	0.62	2.94	20.96	3.3	2.61	20000	2.3E+07
10	20.75	7.48	0.78	4.2	66.79	2.8	1.35	5100	3E+07
11	48.75	5.69	0.02	1.42	44.12	2.78	1.08	8400	2.7E+06
12	77.75	4.81	0.08	2.11	15.25	2.81	0.9	43000	1.8E+06
13	77.33	5.11	0.54	5.5	11.52	3.62	1.44	34000	2.1E+06
14	21.5	5.11	0.12	1.92	71.35	2.66	1.8	26000	1.6E+07
15	78.61	3.8	0.56	2.11	14.92	4.01	0.9	62000	2E+06
16	60.38	4.92	1	3.8	26.9	3.73	2.7	29000	1.8E+07
17	50.11	4.83	0.92	2.42	41.71	3.79	1.8	4000	2.7E+06
18	70.11	3.94	1.1	2.14	12.81	2.94	1.35	29000	300000
19	80.53	6.13	1.06	1.98	10.33	2.79	0.72	3E+05	2.1E+06
20	69	12.1	1.5	1.32	16.07	2.78	1.08	20000	4.1E+06
21	20.75	15.2	1.1	6	56.95	3.67	3.24	1800	4.2E+06
22	31.84	9.84	0.5	3.11	54.71	3.47	1.35	3400	1.7E+06

23	48.75	8.11	0.57	6	36.57	3.75	2.25	3000	2E+07
24	77.75	6.38	1	2.33	12.54	3.95	0.99	46000	1.9E+08
25	21.5	17.5	1.5	4.68	54.82	3.65	3.15	3E+07	2.8E+07
26	11.5	10.1	1	2.5	74.89	3.72	2.34	27000	2.7E+07
27	34.11	8.24	0.76	2.28	54.61	3.94	0.81	3000	1.9E+07
28	21	14.5	0.94	6	57.56	3.68	2.31	19000	2.3E+07
29	86	9.84	0.68	1.11	2.37	3.98	0.9	20000	1.6E+07
30	23.25	12.5	1	5.5	57.75	3.66	3.6	20000	3.6E+07
31	63.88	7.22	0.48	2.26	28.16	3.97	0.9	19000	1.9E+06
32	70.11	6.18	0.02	1.38	22.31	2.72	0.81	17000	1.3E+06
33	68.32	7.32	0.09	1.43	22.84	3.61	1.44	1600	1.8E+06
34	84.5	6.33	0.26	2.9	6.82	3.03	1.08	2000	2.4E+06
35	28.24	5.48	0.38	1.43	64.47	4.03	0.72	13000	190000
36	65.11	4.84	0.09	1.38	28.58	3.41	1.44	16000	2E+06
37	48.11	3.33	0.32	2.33	45.91	2.98	1.34	34000	1.9E+06
38	13.5	11.5	0.47	2	72.53	3.75	3.78	19000	3.4E+07
39	80.63	4.38	0.5	5.5	8.99	4.17	3.11	22000	1.6E+06
40	80.11	4.04	0.39	3.4	12.06	3.78	1.35	18000	2E+06
41	77.65	4.32	0.5	2.14	15.39	2.99	1.62	21000	1.8E+06
42	37.84	3.28	0.54	3	55.34	3.68	1.62	4400	1.8E+06
43	82.25	3.59	0.61	2.11	11.44	2.68	0.72	39000	1.2E+06
44	71.11	4	0.72	1.32	22.85	3.88	1.98	20000	1.3E+06
45	81.75	4.9	0.09	1.94	11.32	3.24	1.62	2600	2.9E+06
46	27	5.11	0.04	2.77	65.08	3.66	2.88	19000	1E+06
47	15.25	4.32	0.51	2.5	77.42	3.71	4.05	28000	4.8E+07
48	78.75	6.33	0.72	2.72	11.48	2.73	0.54	31000	1.6E+06
49	66.48	6.48	0.48	1.38	25.18	4.17	0.54	20000	1.9E+06
50	66.58	12.5	0.28	0.94	19.7	2.82	1.35	43000	3.8E+07
51	79.48	11.1	0.63	1.38	20.27	3.63	0.99	1600	1E+07
52	80.25	8.32	1.04	2.04	9.35	2.87	1.62	4300	1.7E+07
53	60.11	8.11	0.78	1.93	29.07	3.63	1.44	2800	2E+06
54	69	6.38	0.61	2.34	21.67	3.41	1.32	24000	1.9E+07
55	71.68	7.11	0.58	2.14	18.49	3.89	2.25	1700	2E+06
56	79.25	5.38	0.5	3.14	11.73	2.94	0.81	1400	1.9E+06
57	80.28	6.11	0.38	1.38	11.85	3.75	1.81	2200	1.6E+07
58	78.75	5.48	0.38	1.94	13.45	4.22	1.8	1600	2E+06
59	77.25	4.96	0.78	2.63	14.38	3.89	0.8	2800	1.9E+06

$y_{mc} = Moisture\ content,\ y_{ac} = Ash\ content,\ y_{cp} = Crude\ protein,\ y_{fat} = Fat\ content,$

$y_{cho} = Carbohydrate,\ y_{tta} = Total\ titre\ acid,\ y_{bac} = Total\ lactic\ acid\ bacteria,\ y_{ph} = pH\ level,$

$y_{fungi} = Fungi\ count.$

3.1 Statistical analysis of experimental results

The experimental results were analyzed and appropriate Scheffe canonical models were fitted to the mean quality data. The statistical significance of the terms in the Scheffe canonical regression models were examined and the adequacy of the models were evaluated by coefficient of determination, F-value, and model p-values at the 0.05 level of significance. The models were also subjected to lack-of-fit and adequacy tests. The fitted models for all the responses were used to generate 3-D response surfaces as well as their contour plots using the DESIGN EXPERT 11.0 statistical software.

3.2 Generation of the Optimal Formulation

A Numerical optimization approach, exploiting the desirability function technique, was utilized to generate the optimal formulation with the anticipated responses. Numerical optimization maximizes, minimizes, or targets desired response based on set criteria for all variables, including components proportions. Optimization goals are assigned to parameters and these goals were used to construct desirability indices (di). A goal may be to maximize, minimize, or target specific quality parameter to satisfy the dietary needs of the consumers of the formulated food product. On the aspect of the component and process variables, a goal may be to keep in the design range or a specified range. Components can be allowed to range within their pre-established constraints in the design or they can be set to desired goals. Also, components can be set equal to specified levels. Desirabilities range from zero to one for any given response and individual desirability for all the responses, in the case of multi-response optimization, are combined into a single number known as overall desirability index. A value of one represents the case where all goals are met perfectly. A zero indicates that one or more responses fall outside desirable limits.

Numerical optimization solutions are given as a list in their order of desirability, detailing the components proportions and process variables values that satisfies the set criteria and the overall desirability. The numerical solution can also be presented in the form of bar graph, desirability contour and desirability mix-process graphs. Furthermore, optimization can also be achieved through graphical method. Graphical optimization yields the overlay contour and the overlay mix-process plots [10]. A contour graph of overall desirability indicates the desirable formulation. Overlay plots of the responses indicates regions that meet specifications.

3.3 Empirical Modeling of Proximate Compositions of Formulated Value-Added Custard

Empirical models in terms of L-pseudo components were fitted to the proximate and physicochemical properties of the formulated composite gari. The fitted models for the quality properties in terms of L_Pseudo Components are given as

equations 1 – 9. The contour and mix-process plots for the proximate and microbiological characteristics of the powdered yoghurt are summarized in Figure 1.

$$\left.\begin{aligned} y_{ac} &= 0.453x_2 + 0.50x_3 - 0.342x_4 + 1.07x_2x_3 + 2.39x_2x_4 + 0.0592x_2z_1 \\ &+ 0.234x_2z_2 - 0.101x_2z_3 - 0.0694x_2z_4 - 0.0481x_2z_5 + 0.145x_2z_6 + 1.43x_3x_4 \\ &- 0.233x_3z_1 + 0.212x_3z_2 + 0.154x_3z_3 - 0.260x_3z_4 + 0.128x_3z_5 - 0.136x_3z_6 \\ &- 0.655x_4z_1 + 0.694x_4z_2 + 0.215x_4z_3 - 0.730x_4z_4 - 0.962x_4z_5 - 0.207x_4z_6 \\ &+ 0.233x_2x_3z_1 - 0.474x_2x_3z_2 + 0.377x_2x_3z_3 + 0.374x_2x_3z_4 - 0.0467x_2x_3z_5 \\ &+ 0.958x_2x_3z_6 + 0.703x_2x_4z_1 - 0.483x_2x_4z_2 - 0.0289x_2x_4z_3 + 1.99x_2x_4z_4 \\ &+ 1.21x_2x_4z_5 - 0.274x_2x_4z_6 + 1.47x_3x_4z_1 - 2.58x_3x_4z_2 - 1.23x_3x_4z_3 \\ &+ 2.18x_3x_4z_4 + 1.93x_3x_4z_5 + 1.22x_3x_4z_6 \end{aligned}\right\} \quad (1)$$

$$\left. y_{mc} = \quad - \quad z_1 + 0.433z_2 + 0.292z_3 - 1.41z_4 - 7.86z_5 - 9.43z_6 \right\} \quad (2)$$

$$\left.\begin{aligned} y_{fat} &= 2.12x_2 + 3.43x_3 + 3.41x_4 + 6.64x_2x_3 - 2.24x_2x_4 - 0.730x_2z_1 \\ &+ 0.0229x_2z_2 - 0.714x_2z_3 - 0.407x_2z_4 - 0.481x_2z_5 + 1.62x_2z_6 \\ &- 3.50x_3x_4 + 0.0750x_3z_1 + 0.331x_3z_2 + 0.446x_3z_3 - 0.149x_3z_4 \\ &+ 0.264x_3z_5 + 0.877x_3z_6 - 3.56x_4z_1 + 1.54x_4z_2 - 0.189x_4z_3 + 2.38x_4z_4 \\ &- 0.182x_4z_5 - 1.03x_4z_6 - 0.313x_2x_3z_1 + 1.90x_2x_3z_2 + 0.382x_2x_3z_3 \\ &- 1.13x_2x_3z_4 + 1.92x_2x_3z_5 + 3.22x_2x_3z_6 + 11.4x_2x_4z_1 - 3.94x_2x_4z_2 \\ &+ 2.\quad x_2x_4z_3 - \quad 1x_2x_4z_4 + \quad 36x_2x_4z_5 + 0.316x_2x_4z_6 + 5.86x_3x_4z_1 \\ &- 3.51x_3x_4z_2 - 2.47x_3x_4z_3 - 0.0595x_3x_4z_4 - 0.380x_3x_4z_5 + 0.441x_3x_4z_6 \end{aligned}\right\} \tag{3}$$

$$\left.\begin{aligned} y_{pH} &= 3.37x_2 + 3.33x_3 + 5.04x_4 + 1.07x_{23} - 3.90x_{24} + 0.0413x_2z_1 - 0.00867x_2z_2 \\ &+ 0.0682x_2z_3 + 0.0789x_2z_4 + 0.00386x_2z_5 + 0.497x_2z_6 - 2.49x_{34} - 0.159x_3z_1 \\ &- 0.202x_3z_2 + 0.286x_3z_3 - 0.324x_3z_4 + 0.131x_3z_5 + 0.258x_3z_6 + 0.0602x_4z_1 \\ &- 0.00252x_4z_2 - 0.470x_4z_3 - 2.13x_4z_4 + 2.71x_4z_5 + 0.00853x_4z_6 + 9.15x_{234} \\ &+ 1.33x_{23}z_1 + 1.42x_{23}z_2 - 0.427x_{23}z_3 - 0.967x_{23}z_4 - 1.49x_{23}z_5 - 0.947x_{23}z_6 \\ &- 0.446x_{24}z_1 - 0.576x_{24}z_2 + 0.732x_{24}z_3 + 6.72x_{24}z_4 - 7.10x_{24}z_5 + 0.456x_{24}z_6 \\ &+ 0.448x_{34}z_1 - 0.511x_{34}z_2 - 0.295x_{34}z_3 + 5.13x_{34}z_4 - 5.58x_{34}z_5 - 0.543x_{34}z_6 \\ &- 11.5x_{234}z_1 + 6.05x_{234}z_2 - 10.4x_{234}z_3 - 0.944x_{234}z_4 + 19.9x_{234}z_5 - 2.67x_{234}z_6 \end{aligned}\right\} \tag{4}$$

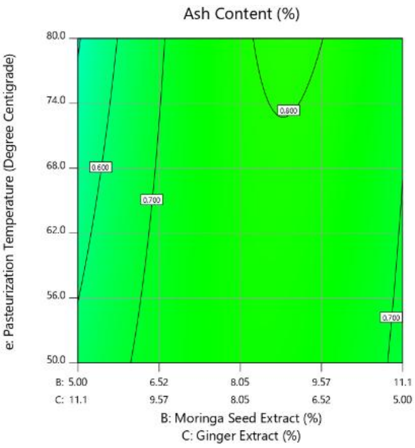
$$\left. y_{pc} = 7.68 - 0.254z_1 + 0.676z_2 + 0.394z_3 + 0.855z_4 + 0.270z_5 + 0.462z_6 \right\} \tag{5}$$

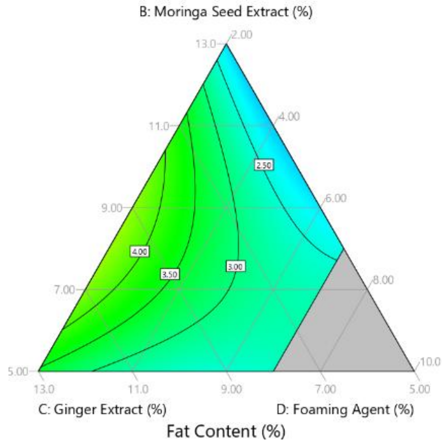
$$y_{cho} = 38.1 + 6.04z_1 - 1.45z_2 + 0.209z_3 + 0.437z_4 + 7.04z_5 + 8.02z_6 \tag{6}$$

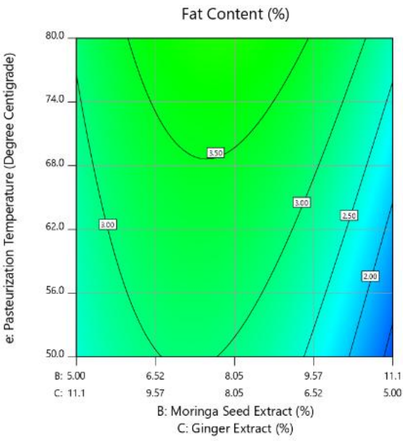
$$\left. y_{tta} = 1.88 - 0.0795z_1 + 0.0991z_2 - 0.0740z_3 + 0.0113z_4 + 0.306z_5 + 0.441z_6 \right\} \tag{7}$$

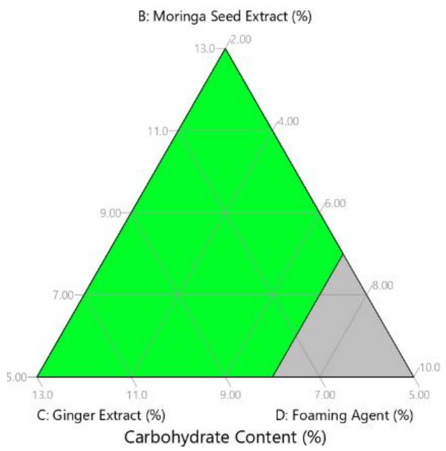
$$\left.\begin{aligned} Logit\ y_{total\ lactic\ acid} &= -6.69x_2 - 7.42x_3 - 7.88x_4 + 0.447x_2z_1 + 0.607x_2z_2 + 1.08x_2z_3 + 0.855x_2z_4 \\ &- 0.240x_2z_6 + 1.17x_3z_1 - 0.209x_3z_2 + 1.39x_3z_3 + 0.480x_3z_4 - 1.06x_3z_5 + 0.507x_3z_6 \\ &- 0.960x_2z_5 - 1.70x_4 + 0.00705x_4z_2 - 0.0734x_4z_3 + 0.756x_4z_4 + 2.14x_4z_5 + 0.297x_4z_6 \end{aligned}\right\} \tag{8}$$

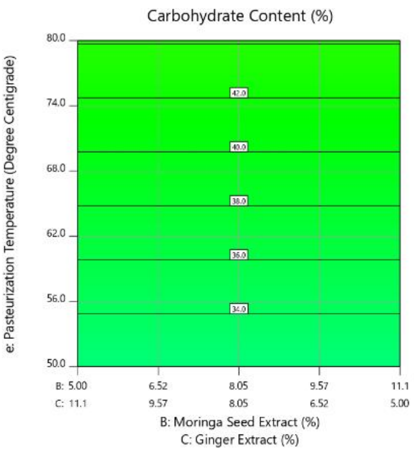
$$\left.\begin{aligned} Logit\ y_{fungi\ count} &= -6.26x_2 - 5.64x_3 - 12.1x_4 + 1.43x_2x_3 \\ &+ 17.4x_2x_2 + 3.67x_3x_4 - 13.2x_2x_3x_4 \end{aligned}\right\} \tag{9}$$

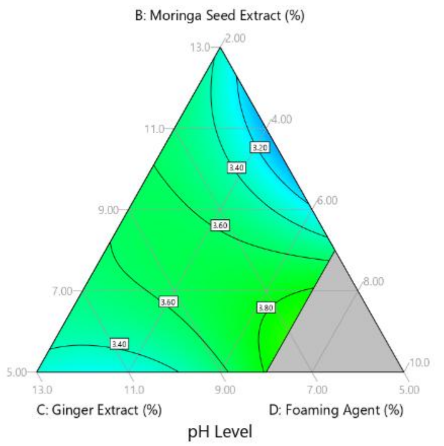

Ash Content (%)
e: Pasteurization Temperature (Degree Centigrade)
B: Moringa Seed Extract (%)
C: Ginger Extract (%)


B: Moringa Seed Extract (%)
C: Ginger Extract (%)
D: Foaming Agent (%)
Fat Content (%)


Fat Content (%)
e: Pasteurization Temperature (Degree Centigrade)
B: Moringa Seed Extract (%)
C: Ginger Extract (%)


B: Moringa Seed Extract (%)
C: Ginger Extract (%)
D: Foaming Agent (%)
Carbohydrate Content (%)


Carbohydrate Content (%)
e: Pasteurization Temperature (Degree Centigrade)
B: Moringa Seed Extract (%)
C: Ginger Extract (%)


B: Moringa Seed Extract (%)
C: Ginger Extract (%)
D: Foaming Agent (%)
pH Level

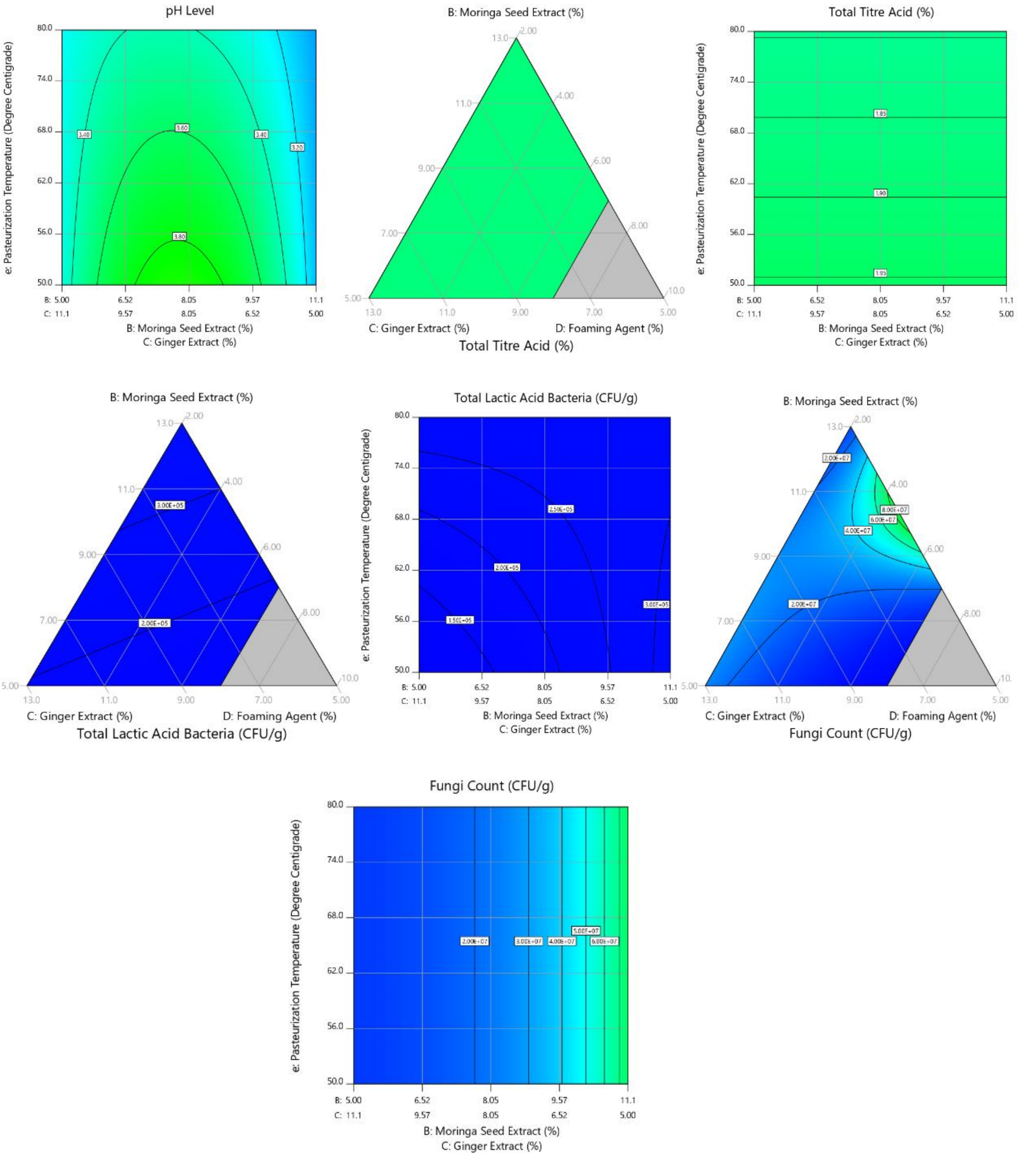


Figure 1: The contour and mix-process plots for the proximate and microbiological characteristics of yoghurt.

Table 12 presents the summary of the optimization constraints employed in the optimization module. The eleven desirability solutions that were found are presented in Table 13.

The numerical solution desirability contour, mix-process plots, and bar graph for the optimal formulated foam-mat dried yoghurt were presented in Figure 2. The graphical optimization overlay contour and mix-process plots, showing the optimized formulation compositions with the respective quality parameters, were presented in Figure 4. The box in the overlay plots indicates the properties of the optimal formulated foam-mat dried yoghurt and the component proportions to obtain it. The formulated foam-mat dried yoghurt numerical optimization gave optimized foam-mat dried yoghurt with an overall desirability index of 0.514, based on the set optimization goals and individual quality desirability indices. The optimal foam-mat dried yoghurt was obtained from 80 % raw yoghurt, 13 % moringa seed extract, 5 % ginger extract, and 2 % foaming agent. The optimized processing conditions are: pasteurization temperature, 30 minutes pasteurization duration, 10 hours fermentation duration, 10 minutes mixing duration, drying temperature, and 5 hours drying duration. The quality properties of this optimal formulated foam-mat dried yoghurt are: 27.1 % moisture content, 10.1 % crude protein, 0.673 % ash content, 1.43 fat content, 58.4 % carbohydrate, 4.05 pH, 2.58 % total titre acid, 2.23E+05 CFU/g total lactic acid bacteria, and 3.81E+06 CFU/g fungi count. The sensory evaluation based on a 9-point hedonic scale gave high overall acceptability. The results are comparable to a study by Charles et al. (2015) [11] in which yoghurt was produced from eight formulations of cow milk and milk extract from soybean and tiger nut and evaluated. In their findings, the fat, protein, ash, and carbohydrate contents of yoghourt ranged from 1.15 – 3.26%, 2. 14 – 3.56%, 0.22 – 0.68%, and 3.77 – 9.27%, respectively. Total bacterial plate count of the yoghurt formulations ranged from 1.3 E+05 - 10.5 E+05CFU/ml and mould plate count from 2.4 E+05 - 8.7 E+05CFU/ml. The pH of yoghurt formulations ranged from 3.97 to 4.75, whereas titratable acidity ranged from 0.09 to 1.13%." In another study [12], commercial plain yoghurt was blended with 20% maltodextrin and foam-mat dried. The moisture, protein, fat, ash contents were 10.3%, 31.2%, 36.2%, 6.7%, respectively. The pH was 6.6 and the total Lactic Acid Bacteria (LAB) was 12 E+06 CFU/g.

Table 12: Optimization constraints for formulated foam-mat dried yoghurt

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Moringa Seed Extract	maximize	5	13	1	1	3
Ginger Extract	in range	5	13	1	1	3
Foaming Agent	in range	2	7	1	1	3
Pasteurization Temperature	in range	50	80	1	1	3
Pasteurization Duration	in range	5	30	1	1	3
Fermentation Duration	in range	5	10	1	1	3
Mixing Duration	in range	2	10	1	1	3
Drying Temperature	in range	50	80	1	1	3
Drying Duration	in range	2	5	1	1	3
Moisture Content	target = 12	11.5	50	1	1	5
Crude Protein	target = 17	3.28	17.5	1	10	3
Ash Content	in range	0.02	1.5	1	1	3
Fat Content	in range	0.94	3	1	1	3
Carbohydrate Content	minimize	2.37	80	1	1	3
pH Level	target = 4.5	2.66	4.99	1	1	3
Total Titre Acid	in range	0.7	4.05	1	1	3
Fungi Count	target = 190000	190000	1.9E+08	10	1	3

Table 13: The 100 desirability solutions found

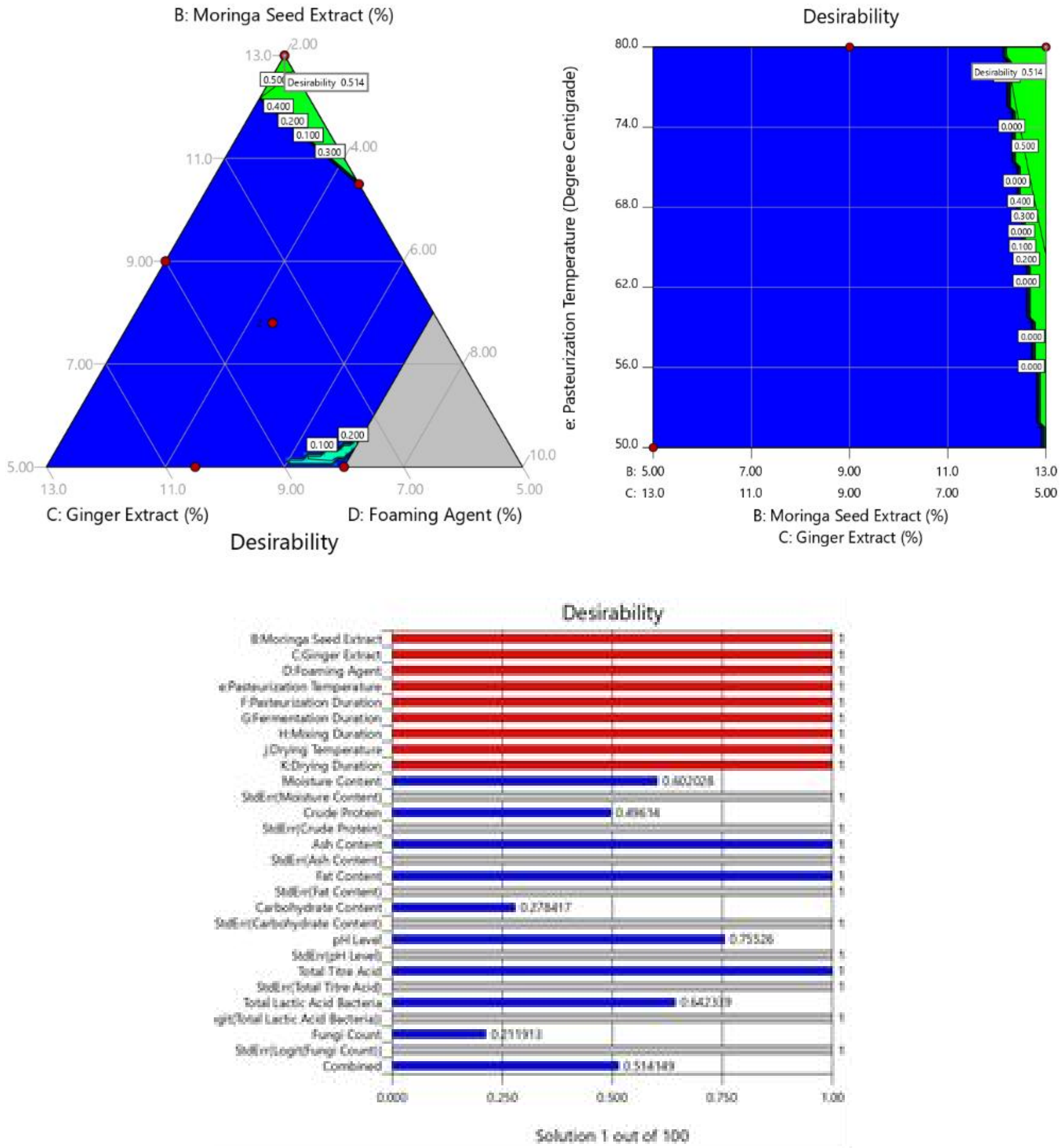
No	y_{mc}	y_{cp}	y_{ac}	y_{fat}	y_{cho}	y_{ph}	y_{tta}	y_{bac}	y_{fungi}	D_i	
1	**27.1**	**10.1**	**0.673**	**1.43**	**58.4**	**4.05**	**2.58**	**2.23E+05**	**3.81E+06**	**0.514**	**Selected**
2	27.7	9.97	0.703	1.77	57.7	4.02	2.61	1.54E+05	3.84E+06	0.512	
3	27.5	9.67	0.762	2.27	57.5	3.97	2.66	6.73E+04	3.81E+06	0.511	
4	26.9	9.49	0.824	2.51	57.9	3.95	2.68	4.71E+04	3.81E+06	0.510	
5	26.6	9.29	0.743	2.47	58.6	3.95	2.65	3.92E+04	3.81E+06	0.508	
……..	………	………	………	………	………..	………	………	…………….	…………….	……….	
99	37.0	8.35	0.020	3.00	51.5	4.10	1.98	1.62E+04	6.69E+06	0.401	

100	32.4	8.17	0.140	2.38	55.5	4.12	2.48	5.21E+04	1.17E+06	0.400	

$y_{mc} = Moisture\ content,\ y_{cp} = Crude\ protein,\ y_{ac} = Ash\ content,\ y_{fat} = Fat\ content,$

$y_{cho} = Carbohydrate,\ y_{tta} = Total\ titre\ acid,\ y_{bac} = Total\ lactic\ acid\ bacteria,$

$$y_{pH} = pH\ level,\ y_{fungi} = Fungi\ count.\ D_i = Desirability$$



Figures 2: The numerical solution desirability contour, mix-process plots, and bar graph for the optimal yoghurt

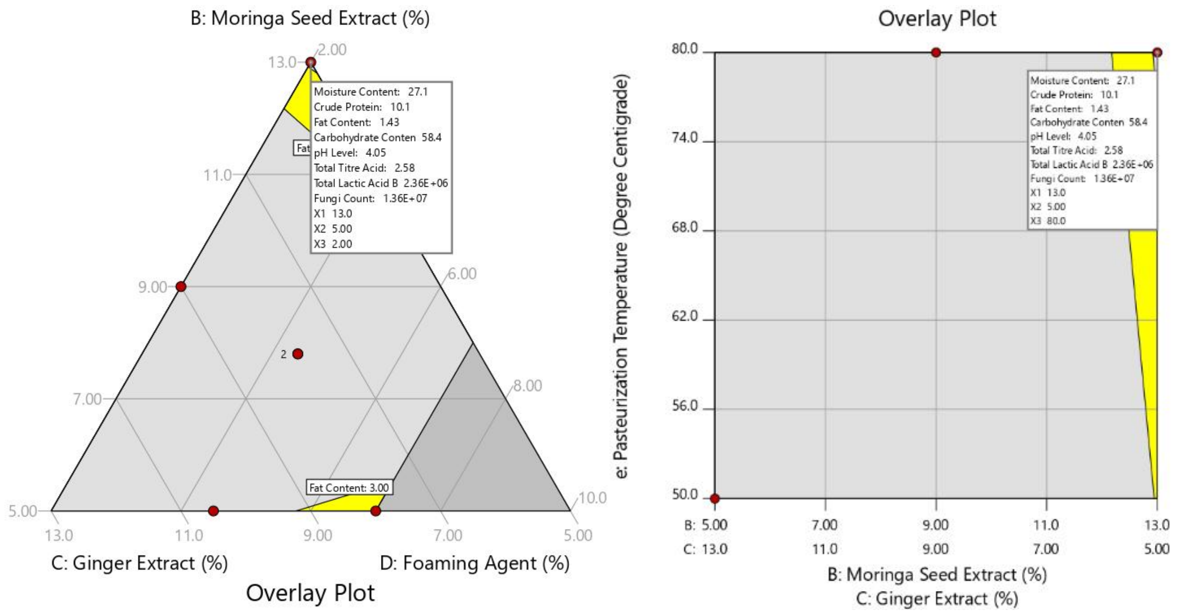


Figure 4: The graphical overlay contour and mix-process plots

4. Conclusion

This result of the study showed that the optimized formulated foam-mat dried yoghurt was found to be of high quality. Fortifying yogurt with moringa seed flour and ginger extract is of great interest to improve the functionality, complement its healthy characteristics and produced acceptable products with potential beneficial health effects. Improving the nutritional value and shelf-stability of yoghurt will also increase its market value.

Declaration of interest

The authors declare no conflicts of interest. The authors alone are responsible for the content and writing of the manuscript.

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