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Physical properties and consumer acceptance of maize-baobab snacks

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Abstract

In this study, an instant maize meal (IMM) was composited with baobab fruit powder (BFP) and commercial starch (CS) which was used as a binding agent. The formulation for the snack was optimised with response surface methodology using design expert software. Thirteen experimental runs were generated by the software and prepared into composite snacks. The snacks were baked using a pilot scale baking oven and microwave oven. The maize-baobab snacks were analysed for colour and texture using different probes (compression force, guillotine, v-shaped and puncture probe). The optimised snacks were evaluated for consumer acceptability and textural properties (instrumental). The results showed an increase in the hardness, fracturability, crunchiness and thickness as the instant maize meal and baobab concentrations increased in the formulation. The colour of the snacks was significantly affected as the concentration of baobab fruit powder and commercial starch increased in the formulation. However, significant correlations existed between sensory attributes and textural parameters in both baking methods except for puncture and aroma of oven-baked snacks.

Keywords: Food technology, Food science

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1. Introduction

Snacks play a vital role in curbing hunger of both young and adult consumers in between meals. The most consumed and popular dry snacks are made from cereal grain (flour) [1], they are crunchy and predominantly made from white maize [2]. White maize lacks pro-vitamin A carotenoids, has poor quality storage proteins (lack tryptophan and lysine) and other essential nutrients such as minerals [3, 4]. Such essential nutrients could be obtained from other cheap locally-available sources such as baobab fruit (*Adansonia digitata*).

Baobab fruit is known to be a substantially high source of carotenoids, vitamin C (almost ten folds that of an orange) [5] and an outstanding source of calcium [6, 7]. In addition to high content of these essential nutrients and carotenoids, baobab fruit is rich in other compounds such as polyphenols, vitamin C and dietary fibre [5, 8, 9]. Therefore, the incorporation of baobab powders in snacks formulation could not only improve nutritional content, but could also impart health-promoting properties of snacks. The major component of interest in maize kernel used in the production of snacks is the endosperm, which contains high content of starch packed in protein matrix in the form of granule [10].

Each starch granule comprises amylose (25%) and amylopectin (75%) [11]. These starch molecules (amylose and amylopectin) play a significant role in microstructural formation of crunchy snacks. When starch is heated at high temperatures it undergoes structural arrangement of chains within amorphous and crystalline domain and becomes modified [12]. Amylose is responsible for hard and less expanded texture whilst amylopectin is responsible for light, elastic and homogenous expanded textures [13].

Physical quality of snacks such as expansion, texture and density are significant parameters that influence functional quality and acceptability of the final snack product [14]. However, the dilution of maize starch with non-endosperm materials (baobab fruit powder) may have an effect on the microstructure of the snacks. Crunchy snacks are mainly manufactured using highly sophisticated and expensive equipment. As a result, they are unaffordable to most households in low-income populations of developing countries.

Thus, the aim of this study was to (i) optimise the formulation and processing of crunchy snacks made with instant maize meal, and baking using household kitchen microwave oven and pilot plant-scale baking oven (ii) to determine the influence of baobab fruit powder on textural properties and consumer acceptability of maize-baobab composite snacks.

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2. Materials and methods

2.1. Source of materials

White maize meal and minor ingredients were purchased at Shoprite supermarket, Thohoyandou, South Africa. Dry baobab fruit samples were obtained from *Thengwe* village, Thohoyandou, South Africa. Maize (*Zea mays* L) commercial starch (stygel® W) was generously supplied by Tongaat Hullet (Germiston, South Africa).

2.2. Experimental design

Experiments were conducted using a central composite rotatable design comprising of three independent variables (commercial starch and baobab compositions). Table 1 shows the independent variables used to generate the experimental runs using Design-Expert software version 8.0.1.0. The quality parameters of the products were taken as response variables. Instant maize meal was used as the main ingredient in the snacks formulations.

2.3. Processing of instant maize meal and snacks

2.3.1. Instant maize meal

Maize meal was added in boiling water and it was stirred until it a porridge was formed. The porridge was then spread on trays which were subsequently transferred into hot air drying oven and allowed to dry overnight at 50 °C. The dry porridge samples were milled into powder using an ultracentrifugal miller (Retsch ZM 200, Haan Germany). The powder was sieved through a 0.8 mm screen using a vibratory sieve shaker (Fritsch Analysette 3 SPARTAN, Idar-Oberstein Germany).

2.3.2. Maize-baobab snacks

The resultant instant maize meal was then mixed with baobab fruit powder and other minor ingredient (depending on optimized formulations of baobab powder and starch) until a homogeneous composite was obtained. The composite was added in the 175 ml of boiling water and 15 ml of sunflower oil, and then stirred for 6−10 min to avoid formation of lamps. The cooked mixture was removed, allowed to cool and kneaded for 4−6 min. The mixture was moulded into a flat sheet and cut

Table 1. Range of independent factors used to design the experimental runs.

Variables	Low range	Centre range	High range
Starch	5.00	5.7	10.00
Baobab	5.00	11.5	20
Instant Maize-meal	65.6	82.8	94.15

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into uniform triangular shaped dough pieces. The triangular shaped dough pieces were divided into set of samples. One set was baked in microwave oven at 300 W for 2 min while the second set was baked in the pilot-scale baking oven at 200 °C for 6 min. The snacks were removed and cooled to room temperature (25 °C), packaged in high-density polyethylene bags and stored in a cool dry place.

2.4. Physical and sensory quality

2.4.1. Colour measurement

The snacks were fried, cooled and the colour was measured using a Hunter Lab colorflex spectrophotometer (Hunter Associates Laboratory, Inc., Reston, VA) following a method described by Mohamed et al. [15]. Snack samples were placed in a glass sample jar, the jar was placed into the sample port and three replicate readings were recorded in L, a, b colour system. The *L* denotes lightness from black (0) to white (100), *a* redness (+) to greenness (-), *b* yellowness (+) to blueness (-).

2.4.2. Instrumental analyses of texture

The textural profile of snacks was analysed using texture analyser TA.XTplus (Stable Microsystems, Surey, UK) attached with a 50 kg load cell with different probes and settings as described by Paula and Conti-Silva [16].

2.4.3. Consumer acceptability

The optimised formulation obtained was used to produce snacks for consumer acceptance test. Ethical approval was granted by the University of Venda Ethics Committee. A panel of fifty judges was recruited from the University students. The composite snacks from the optimised formulation were presented to each panellist in a central location. The panellists were seated far from each other to avoid them from influencing each other. About five pieces of baobab composite snacks were served to each panellist in a randomized order, which was determined from a table of random permutations of nine. The consumer panel rated the sensory acceptability of snack samples in terms of appearance, aroma, texture, taste and overall acceptability on a 5-point hedonic scale, whereby 5 represented the highest score (like extremely) and 1 the lowest score (dislike extremely). Panellists were also provided with tap water to rinse their palates before and between testing.

2.5. Statistical analysis

The data for colour and texture profile of snacks were analysed with the aid of a commercial statistical package, Design-Expert Version 8.0.1.0 (Statease Inc. Minneapolis USA, version). Analysis of variance (ANOVA), mathematical modeling,

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regression analysis, response surface plot and optimization were obtained using the software. The optimised snack was subjected to consumer acceptability and instrumental texture analysis. The resultant data was analysed using Statistical Package for the Social Sciences (SPSS) version 22.0 for Windows (SPSS IBM, New York, USA). Comparison of multiple means was performed using Duncan's multiple range test at 5% levels of significance. Pearson's correlation was used to determine the relationship between consumer acceptability attributes and instrumental textural parameters of optimised snacks.

3. Results and discussion

3.1. Physical appearance of maize-baobab composite snacks

3.1.1. Colour

Fig. 1 shows representative sample of maize-baobab composite snacks before and after seasoning. The snacks were pale and dull before frying and seasoning but became yellowish in colour after frying.

The instrumental results for colour of both the microwave oven-baked and oven-baked seasoned snacks are presented in Table 2. The mean colour values of both snacks varied widely across experimental runs with no clear trend. This variation was mainly due to un-proportionally composited experimental runs. Generally, the decrease or increase of either the concentration of IMM or BFP or CS had a significant effect on the colour of snacks. The lightness (high L-values) and yellowness (high b-values) of oven-baked snacks tended to increase with high concentration of IMM and CS. It was also observed that in the case where the concentration of IMM was reduced with an increase in BFP and CS, the snacks became light yellow as shown by high L*-values and b*-values (experimental run 7, Table 2). Increasing the concentration of IMM and CS resulted in a significant decrease in lightness and yellowness while increasing the redness (high a* values) of oven-baked snacks. This implies that varying the concentrations of independent factors had a significant influence on the colour of snacks.

Fig. 1. Representative samples of maize-baobab fruit composite snacks.

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Table 2. Experimental values of colour parameters for seasoned microwave and oven baked snacks.

SN	Independent factors			Response variables					
	IMM[∞]	BFP[α]	CS[α]	Microwave baked snacks			Oven baked snacks		
				L*	a*	b*	L*	a*	b*
1	80	7.50	12.50	32.5	10.6	17.7	46.1	7.0	21.9
2	80	7.50	12.50	29.9	10.3	15.4	40.5	7.9	21.8
3	75	5.0	20.00	38.9	9.7	20.8	44.6	9.1	22.8
4	85	10.00	5.00	41.8	7.7	20.0	37.3	6.1	14.9
5	90.61	7.50	1.89	40.4	11.7	22.2	38.1	9.0	20.8
6	80	7.50	12.50	36.9	11.7	19.1	38.4	8.4	19.6
7	70	10.00	20.00	47.9	10.9	26.2	42.7	7.2	21.7
8	76.46	11.04	12.50	40.7	6.2	17.7	37.2	10.3	20.4
9	83.54	3.96	12.50	39.9	10.2	21.5	34.9	10.7	19.8
10	69.39	7.50	23.11	33.7	8.8	18.0	33.0	8.5	16.3
11	80	7.50	12.50	37.6	6.5	17.3	39.6	7.7	19.0
12	90	5.00	5.00	41.3	9.6	22.5	38.2	8.1	19.0
13	80	7.50	12.50	39.0	6.1	13.5	37.2	10.5	20.1

Hunter values: L = black (0) to white (100); a = red (+) to green (-); b = yellow (-) to blue (+). IMM = Instant maize meal (g), BFP = Baobab fruit powder (g), CS = Commercial starch (g), [α]were generated using the design expert, [∞]were generated using the formula: 100 g instant maize meal − (starch + baobab) powder.

Maize contains reducing sugars and amino acids. Therefore, the colour changes were probably due to Maillard reactions and caramelization [17]. Moreover, colour changes of the seasoned snacks maybe closely related to degradation of pigments and formation of brown pigments by non-enzymatic and enzymatic reaction [18]. Chevalier et al. [19] reported that Maillard reaction play an important role in the colour formation in food products during processing. Maillard reaction and caramelization of sugar are considered to produce brown pigments during baking as reported by Laguna et al. [20].

The analysis of variance (ANOVA) results for colour attributes (L*, a* and b*) is shown in Table 3. ANOVA of the effect of model parameters on colour characteristics of both snacks showed that linear effect of starch, quadratic effect of baobab and interaction effects of starch and baobab had significant ($P \leq 0.05$) effect on a*-values (redness) of microwave baked snacks whereas all the model parameters had no significant effect on L* and b*-values of microwave baked snacks. In the case of oven baked snacks, linear effect of baobab, quadratic effect of baobab and interaction effect of starch and baobab had significant effect ($P \leq 0.05$) on yellowness of the snacks while all the model parameters had no significant effect on lightness and redness of the snacks.

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Table 3. ANOVA results of regression models obtained for colour parameters for microwave and oven baked snacks.

Factors	Response variables p − values					
	Microwave baked snacks			oven baked snacks		
	L*	a*	b*	L*	a*	b*
A-Starch	0.6938	0.0379[A]	0.4369	0.9159	0.6048	0.8976
B-Baobab	0.5775	0.0867	0.3414	0.2597	0.2566	0.0168[A]
A^2	0.5707	0.6201	0.8601	0.4733	0.2373	0.6915
B^2	0.4846	0.0004[A]	0.5147	0.3676	0.7279	0.0400[A]
AB	0.9722	0.0003[A]	0.1135	0.1202	0.8192	0.0481[A]

[A]Significant at $P \leq 0.05$; *A*- linear effect of starch; *B*- linear effect of baobab; *AB* − interaction effect of starch and baobab; A^2 − quadratic effect of starch; B^2 − quadratic effect of baobab; L* (lightness/darkness); a* (redness/greenness) and b* (yellowness/blueness).

Regression equations relating the colour parameters L*, a*, and b* of microwave and oven-baked snacks to the model parameters are shown in Table 4. The Table shows that the predictive models had insignificant ($P > 0.05$) lack of fit values. An insignificant lack of fit value implies a good fitness of the models when applied. This is in agreement and consistent with the observation of Myers and Montgomery [21]. The 3D plots showing the effects of baobab fruit powder and commercial starch on the colour of microwave-baked and oven baked snacks are shown in Figs. 2 and 3, respectively. In the case of microwave baked snacks, lightness (L*-values) reduced with an increase in baobab powder and commercial starch while redness (a*-values) increased with increase in both baobab powder and commercial starch. Consequently, yellowness (b*-values) of the microwave baked snacks increased with increase in baobab powder and commercial starch contents. This trend was equally evident for oven baked snacks.

Table 4. Regression models obtained of colour parameters for microwave and oven baked snacks.

Baking methods	Response variables	Models	Lack of fit p value
Microwave	L*	$57.12-3.38A-0.88B+0.19A^2+0.028B^2+5.33E\text{-}003AB$	0.9893*
	a*	$-5.62+1.44A+1.58B+0.02A^2-0.03B^2-0.12AB$	0.8314*
	b*	$9.50+1.04A+1.40B+0.04A^2-0.02B^2-0.015AB$	0.9736*
Oven	L*	$9.17+4.57A+2.03B-0.16A^2-0.02B^2-0.17AB$	0.8474*
	a*	$14.77-1.96A+0.11B+0.12A^2-3.60B^2+9.33AB$	0.4870*
	b*	$3.49+1.72A+1.51B+0.04A^2-0.02B^2-0.09AB$	0.3782*

*Not significant at $P > 0.05$; *A*- linear effect of starch; *B*- linear effect of baobab; *AB* − interaction effect of starch and baobab; A^2 − quadratic effect of starch; B^2 − quadratic effect of baobab; L* (lightness/darkness); a* (redness/greenness) and b* (yellowness/blueness).

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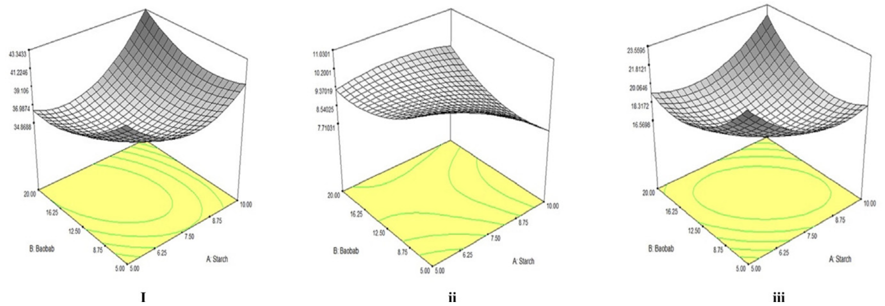

Fig. 2. Response surface plot for the effects of baobab powder and commercial starch on L (i), a (ii) and b (iii) values of microwave baked composite snacks.

3.1.2. Textural profile of oven and microwave baked snacks

The textural properties of both oven-baked and microwave-baked snacks as measured using different probes are shown presented in Table 5. The compression force (hardness) ranged from 16.1 to 58.9 N for oven-baked snacks while that of microwave baked snacks ranged from 5.9 to 58.6 N. The maximum hardness of both oven and microwave baked snacks were obtained at 7.50 g of commercial starch and 12.50 g of baobab powder. This implies that the snacks were getting harder with increased concentration of baobab powder and commercial starch [3D plot in Figs. 4(i) and 5(i)]. The maximum force (crispness) for oven-baked snacks as measured using a v-shaped probe ranged from 8.6 to 46.4 N. The maximum force (46.4 N) was recorded for snacks composited with 11.04 g of baobab powder and 12.50 g of commercial starch. The crispness of microwave baked snacks ranged from 8.9 to 56.8 N.

The maximum crispness was obtained in snacks composited with 5.00 g of baobab powder and 20.00 g of commercial starch. As the concentrations of baobab powder and commercial starch increased in the formulation, there was an increase in the maximum force required to cut the snacks [3D plots in Figs. 4 (ii) and 5 (ii)]. Firmness as measured with a puncture probe [16] ranged from 4.4 to 54.6 N for oven

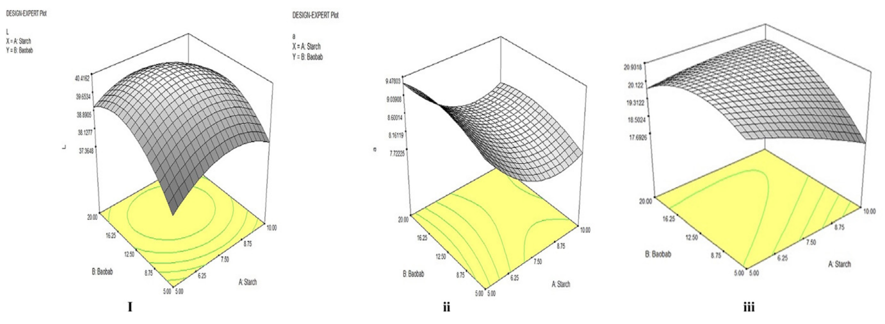

Fig. 3. Response surface plot for the effects of baobab powder and commercial starch on L* (i), a* (ii) and b* (iii) values of oven baked composite snacks.

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Table 5. Experimental values of textural properties for microwave and oven baked snacks.

SN	Independent variables			Response variables							
	IMM∞	BFP∝	CS∝	Microwave baked snacks				Baking oven snacks			
				CF	GT	VR	P	CF	GT	VR	P
1	80	7.50	12.50	58.6	26.2	28.8	4.6	55.3	8.2	10.4	5.6
2	80	7.50	12.50	57.6	36.4	31.8	16.6	58.9	9.9	14.9	19.5
3	75	5.0	20.00	53.5	20.6	56.8	35.3	52.7	6.5	20.0	10.1
4	85	10.00	5.00	59.0	15.5	15.0	16.0	26.7	15.7	8.6	2.5
5	90.61	7.50	1.89	16.6	16.3	12.9	19.4	16.1	13.1	16.9	4.4
6	80	7.50	12.50	22.1	48.4	56.4	7.8	55.2	19.6	26.4	54.6
7	70	10.00	20.00	18.1	15.9	16.2	18.1	50.3	14.4	37.3	23.4
8	76.46	11.04	12.50	45.9	26.5	27.6	4.79	50.7	15.7	46.4	11.6
9	83.54	3.96	12.50	41.3	19.8	26.1	14.3	55.7	19.3	38.5	7.8
10	69.39	7.50	23.11	27.1	21.0	20.9	6.2	54.8	14.4	17.8	7.8
11	80	7.50	12.50	45.7	4.9	8.9	5.4	52.9	44.4	23.6	12.7
12	90	5.00	5.00	54.7	51.4	37.1	23.9	25.7	32.7	24.8	14.0
13	80	7.50	12.50	52.2	40.1	55.6	49.3	56.4	26.8	24.5	7.8

IMM = Instant maize meal, BFP − Baobab fruit powder, CS = Commercial starch. CF = compression force, GT = guillotine, P = puncture, VR = v-shaped rig, ∝were generated using design expert package, ∞were generated using the formula: 100 g instant maize meal − (starch + baobab) powder.

baked snacks and 4.6−49.3 N for microwave baked snacks, however the maximum thickness of both oven and microwave baked snacks was obtained in snacks composited with 7.50 g of starch and 12.50 g of baobab.

The 3D plot in Fig. 4 (iii) shows that firmness of oven baked snacks increased with increase in baobab powder and starch contents whereas Fig. 5 (iii) reveal that firmness of microwave baked snacks increased with increase in baobab powder of the snacks but decreased with increase in starch content. Low starch-maize formulation resulted in reduction of texture since starch is responsible for structural stability food products [22]. In oven baked snacks, the fracturability force which was measured using a guillotine probe ranged from 8.2 to 44.4 N. The maximum fracturability was obtained in snacks composited with 7.50 g of starch and 12.50 g of baobab whereas the fracturability of microwave baked snacks ranged from 4.9 to 51.4 N. In microwave baked snacks, the maximum fracturability was obtained in snacks composited with 5 g starch and 5 g baobab powder. The interaction of baobab powder and commercial starch as shown in Figs. 4(iv) and 5(iv) reveal that fracturability of oven and microwave baked snacks increased as the concentration of baobab powder and commercial starch increased in the formulation.

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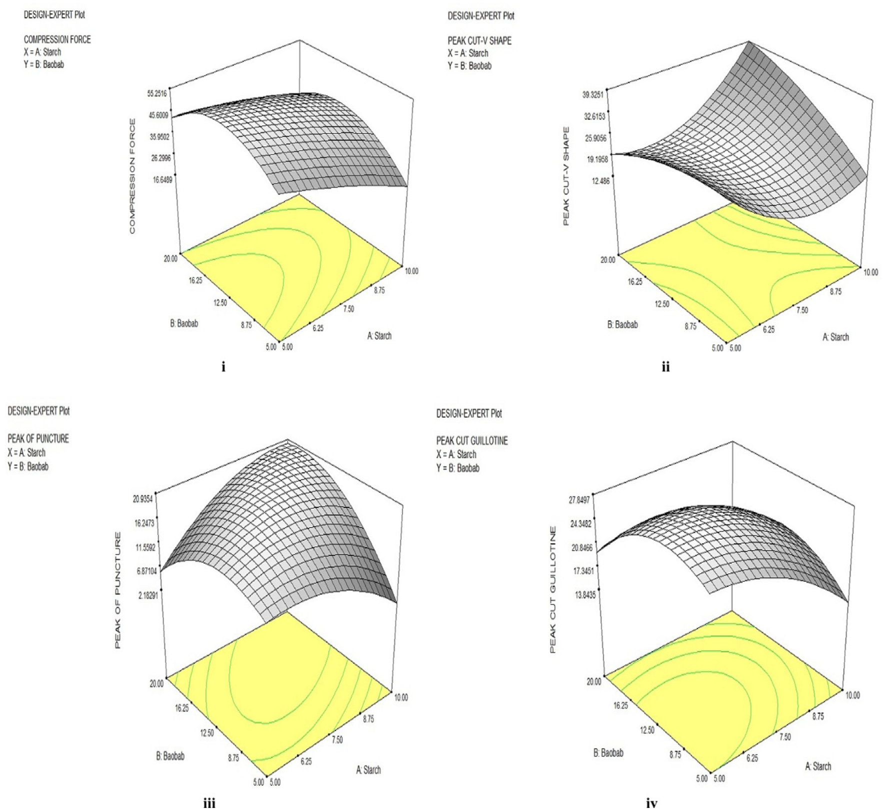

Fig. 4. Response surface plot for the effects of baobab powder on (i) compression force of composite snacks, (ii) peak cut of composite snacks, (iii) puncture force of composite snacks, (iv) peak cut force (guillotine probe) of oven baked composite snacks.

The analysis of variance (ANOVA) result for textural properties show that the model factors (A, B, $A^{2,}$ B^{2}, and AB) had no significant ($P > 0.05$) effect on the textural properties of microwave baked snacks (Table 6). Consequently it can be observed in Table 6 that linear effect of baobab and interaction effect of starch and baobab had significant ($P < 0.05$) effects on the hardness (CF) of oven baked snacks while quadratic effect of baobab had significant ($P < 0.05$) effect on crispness (VR) of oven baked snacks. The regression models relating the factors and textural properties for microwave and oven-baked snacks are shown in Table 7. The Table show that lack of fit p values for the models is not significant. This guarantees good fittness of the models when applied as stated by Omolola et al. [23].

3.2. Consumer acceptance of maize baobab snacks

The formulation with 84.75 g of IMM, 5.25 g BFP and 10 g CS was identified as the optimum formulation. The optimisation was based on maximising IMM, BFP, and CS using design expert software. The snacks from the formulation were subjected to consumer acceptance using untrained regular consumers of snacks. Generally,

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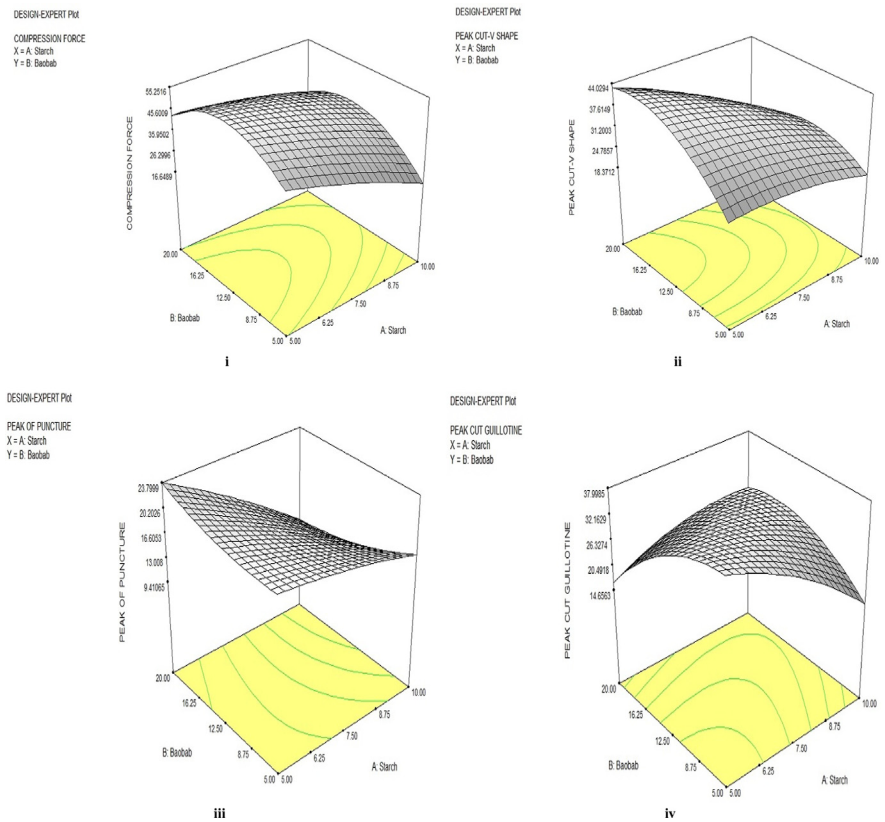

Fig. 5. Response surface plot for the effects of baobab powder on (i) compression force of composite snacks, (ii) peak cut of composite snacks, (iii) puncture force of composite snacks, (iv) peak cut force (guillotine probe) of microwave oven baked composite snacks.

consumer quality is a major important parameter for selecting a product and among the main characteristics related to quality are texture, taste, and surface colour of the snacks [24]. The mean acceptance scores of oven-baked snacks were slightly more than that of the microwave-baked snacks in terms of appearance, aroma, and overall

Table 6. ANOVA results of regression models obtained for textural properties of microwave and oven baked snacks.

Factors	Response variables p − values							
	Microwave baked snacks				Baking oven snacks			
	CF	GT	VR	P	CF	GT	VR	P
A-Starch	0.6091	0.4971	0.2776	0.4304	0.4187	0.6846	0.5712	0.8742
B-Baobab	0.5718	0.6017	0.5512	0.9139	<0.0001[A]	0.4688	0.2625	0.6329
A^2	0.2613	0.3438	0.6268	0.7836	0.6407	0.3282	0.0555	0.4484
B^2	0.8049	0.6469	0.7407	0.9304	0.0861	0.7139	0.0113[A]	0.5144
AB	0.1750	0.4159	0.3220	0.8676	<0.0001[A]	0.4504	0.2983	0.3533

[A]Significant at $P \leq 0.05$; *A*- linear effect of starch; *B*- linear effect of baobab; *AB* − interaction effect of starch and baobab; A^2 − quadratic effect of starch; B^2 − quadratic effect of baobab; CF-compression force; GT-guillotine; P-puncture; VR- v-shaped rig.

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Table 7. Regression models obtained of colour parameters for microwave and oven baked snacks.

Baking methods	Response variables	Models	Lack of fit p value
	CF	$47.24-3.07A-3.41B-9.92AB+1.58A^2-9.29B^2$	0.3611*
Microwave	GT	$31.20-3.89A-2.97B+7.80AB-2.79A^2-5.04B^2$	0.6299*
	VR	$36.30-7.57A+4.03B-4.62AB-2.37A^2-7.35B^2$	0.6518*
	P	$16.74-4.82-0.6460B-2.32AB-0.5594A^2+1.07B^2$	0.7515*
	CF	$55.74-1.06+13.17B-0.8500AB-2.64A^2-11.51B^2$	0.0860*
Oven	GT	$21.78-1.77A-3.21B+6.23AB-1.71A^2-3.59B^2$	0.9065*
	VR	$19.96+1.53A+3.15B+8.38AB+9.44A^2-3.11B^2$	0.4014*
	P	$20.04+0.8968A+2.73B+6.20AB-4.02A^2-5.82B^2$	0.9823*

*Not significant at $P > 0.05$; *A*- linear effect of starch; *B*- linear effect of baobab; *AB* − interaction effect of starch and baobab; A^2 − quadratic effect of starch; B^2 − quadratic effect of baobab; CF-compression force; GT-guillotine; P-puncture; VR- v-shaped rig.

acceptance (Fig. 6). However, both snacks were rated (3.2) the same in terms of taste. It is obvious from the figure that both oven and microwave baked snacks were not significantly different in terms of sensorial attributes and consumer acceptance.

3.3. Correlation between consumer acceptability attributes and instrumental texture parameters of microwave and oven-baked optimised snacks

Correlation analysis was carried out to determine the correlation between instrumental and consumer acceptability of microwave and oven baked snacks as shown in Table 8. These results revealed a mixture of positive and negative correlations amongst the variables/properties. Generally, negative correlation is a relationship between two variables in which one variable increases as the other decreases, and *vice versa* whereas a positive correlation exists when one variable decreases as the other variable decreases, or one variable increases while the other increases.

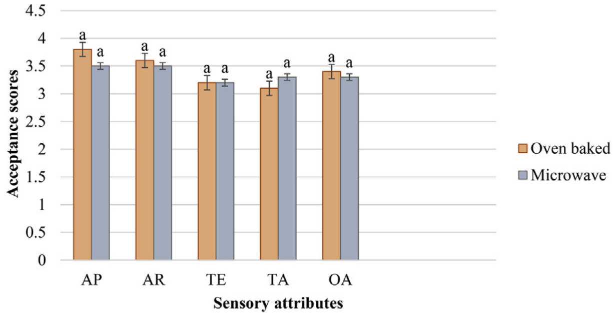

Fig. 6. Consumer acceptance of snacks made from the optimum formulation. AP-Appearance, AR-Aroma, TE-Texture, TA-Taste, OA-Overall acceptability.

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Table 8. Correlation matrix of textural parameters (instrumental) and consumer acceptability properties of microwave-baked and oven-baked snacks.

Sensory attribute	Microwave-baked snack				Oven-baked snack			
	Compression	Cut-guilotine	Cut-“V” shape	Puncture	Compression	Cut-guilotine	Cut- “V” shape	Puncture
Appearance	-0,181	0,095	−0,113	−0,127	0,094	0,007	−0,098	0,112
Aroma	0,049	0,158	0,007	−0,054	0,249	0,191	−0,112	−0,298[A]
Texture	−0,217	−0,036	0,101	−0,157	0,085	0,007	0,107	−0,073
Taste	−0,110	0,097	−0,111	−0,081	0,121	0,102	−0,223	−0,097
Overall acceptability	−0,067	0,044	−0,039	0,004	0,118	0,049	−0,083	−0,179

[A]Significant at $P \leq 0.05$ level (2-tailed).

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It is conspicuous from Table 8 that in microwave baked snack, there was no significant correlation between the instrumental textural properties (compression, cut-guilotine, cut-“V” shape, puncture) and sensory properties (appearance, aroma, texture, taste, overall acceptability). However, a significant ($P \leq 0.05$) negative correlation between aroma and puncture of oven-baked snack was observed. This correlation implies that as the snack required less biting force (using incisor teeth), the more the aroma of the snack became acceptable to the consumers. Probably, the cracking sound stimulated some form of relaxation and enjoyment of the snack while the consumers were experiencing the release of volatile compounds. A non-existence of correlation between some textural parameters of the snacks and sensory attributes was also observed.

4. Conclusion

The snacks from experimental runs exhibited high resistance to fracturability and compression. The maximum force required to fracture the oven-baked snacks was 44.4 N while microwave-baked snacks fractured at a maximum force of 51.4 N. These snacks were compressible at a maximum force of 58.9 N for oven-baked and 58.6 N for microwave baked snacks. This implies that the snacks from both baking methods were the same in terms of hardness. The hardness of these snacks was due to high concentrations of baobab powder and commercial starch. Baobab powder and commercial starch also had a significant effect on the colour of snacks as shown by Hunter Lab colour system. The optimised snacks were highly acceptable by consumers in terms of appearance and aroma as these sensory attributes were scored higher than texture, taste and overall acceptability. Both snacks (oven-baked and microwave-baked) were rated the same for texture. A significant decrease in mean values of textural parameters was observed for the optimised snacks. However, no correlation was found between textural parameters (instrumental) and sensory attributes for both snacks except for aroma and puncture of the oven-baked snacks. Though the force values of textural parameters of the optimised snacks decreased drastically, the snacks were still hard. Therefore, there is a need for use of tenderising ingredients. Furthermore, a detailed micro-structural profile and sensory profile could give a better understanding of the quality of these snacks.

Declarations

Author contribution statement

Miranda Netshishivhe, Daniso Beswa: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Adewale Olusegun Omolola: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mpho Edward Mashau: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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