International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 3 | Issue: 4 | Jul - Aug 2022 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v3i4.40

Optimization of Raw materials for production of a Nutritious Snack Bar for Children aged between 5 to 13 years

Cynthia Mutonyi Wandeka[1], Julia Kigozi[1*], Robert Mugabi[2] and Paddy Ainebyona[1]

[1]Department of Agricultural and Bio-systems Engineering, Makerere University
P.O. Box 7062, Kampala Uganda

[2]Department of Food Technology and Nutrition, Makerere University
P.O. Box 7062, Kampala Uganda

*Corresponding author details: Julia Kigozi; jbulyakigozi@yahoo.com

ABSTRACT

There has been significant increase in consumption of fast foods including snack bars in the recent past. This increase is due to changes in the lifestyles of the population as consumers throughout the world are busy at work creating a demand for fast foods. The children find such products easy to consume as long as they are available. This study targeted developing nutritious snack bars from locally available raw materials to meet the nutritional demands of children aged between 5 to 13 years. The snack bars were developed from amaranth grains, mangoes, pineapples and carrots. Raisins and lemon were added as a colorant and flavorant respectively at a constant level of 7% and 10% respectively. Honey was used as a binder at 22%. The raw materials were varied using design expert (Version 11.1.0.1, Stat Ease, Minneapolis) to obtain 30 formulations in a factorial experiment. The formulations were tested for proximate composition, beta-carotene, vitamin C, energy composition, texture as well as sensory attributes and the optimum was obtained using design expert. The optimal formulation contained grain amaranths, mango, pineapples and carrots at 42.9, 14.3, 17.9 and 10.7% respectively. The composite had proteins, carbohydrates, beta carotene, vitamin C, Iron, Zinc, Fat, Fibre, Ash and moisture composition at 12.17%, 54.38%, 15.82mg/100g, 10.62mg/100g, 5.44mg/100g, 4.35mg/100g, 3.28%, 5.56%, 5.43%, and 19.18% respectively. The composite snack bar had desirable nutritional qualities with an overall acceptability of 7.6. The study therefore produced a snack bar that has capacity to meet the nutritional demands of children between 5 to 13 years of age.

Keywords: factorial experiment; nutritional composition; optimal formulation; snack bars

INTRODUCTION

Snack bars are convenient and highly nutritious ready-to-eat foods with a balanced source of nutrition with ability to abate hunger (King, 2006; Ryland et al., 2010; Wyatt, 2011). In the recent past, there has been a significant increase in consumption of fast foods (Bower & Whitten, 2000). This increase is attributed to the change in lifestyle of the population as consumers all over the world are becoming busier at work. As a result, there is high demand for easy and fast prepared foods for their children. In addition, Uganda continues to struggle with high post-harvest losses estimated at 20 to 60% in the fruit and vegetable industry. The good news is that these local fruits and vegetables can be used to make nutritious snack bars to contribute to availability of healthy, affordable and convenient. The reported growing consumer demand for natural, convenient, and nutritious food products, has led to emergence of various bar types, such as sim-sim bars in Uganda (Mackay et al., 2017), and other more modified versions like the granola bars elsewhere (Ryland et al., 2010). Chocolate coating or incorporation of different fruits and nuts targeting to modify, and improve the nutritional composition of snack bars for health benefits is also on the rise (Williams et al., 2006; Sun-Waterhouse et al., 2010).

To achieve this many companies have used too many ingredients and resultantly created very expensive products. This study targeted creation of an affordable snack bar while optimizing locally available ingredients but offering the same nutrients as other more expensive mostly imported snack bars on the market.

MATERIALS AND METHODS

Raw Material Selection

The raw materials used were amaranth grain, mangoes, pineapples and carrots. Lemon, raisins and honey were used as a flavorant, colorant and binder respectively. Nutri-survey (SEMEO-TROPMED RCCN, University of Indonesia) was used to determine the ranges of ingredients that would provide the Recommended Daily Intakes (RDIs) for children aged 5 to 13 years. Response surface methodology was employed using Design Expert (Version 11.1.0.1, Stat-Ease Inc., Minneapolis) for optimization and model construction. Central Composite Design (CCD) was used because of its suitability for mixture designs. The formulations obtained are given in Table 1.

Preparation of Snack Bar Mixtures and The Making of The Nutritious Snack Bar

Fresh and fully ripened mangoes (Keitt Variety), pineapple, carrots, and lemons were purchased from Kashasha, Mbarara district. The fruits were then sorted for uniformity by species, colour, and brix and transported to Jakana Foods, Kampala for drying. The popped amaranth grain, raisins, and honey were obtained from suppliers in Kampala. Majority were obtained from Nutreal Limited, and were transported to the Chemistry Laboratory at the Department of Food Technology and Nutrition, Makerere University Kampala Uganda. Snack Bars were prepared according to the method by Berglund et al. (1992). The fruits were washed carefully with clean potable water to removed dirt, debris and any other contaminants on the surfaces. The mango, pineapple, and carrots were sliced to 3 mm thickness and the lemon peels were grated into small particles (Abano et al., 2011, Kendall and Sofos, 2007) and dried to 10% moisture content at 65oC (Kendall and Sofos, 2007). A Harvest Saver R-5 Commercial Dehydrator was used instead of a solar dryer to maintain the natural fruit colour. The snack bar base was developed using amaranth grain, raisins, lemon, and honey and these were blended with the dry fruits according to formulations shown in Table 1.

Honey was melted on a gas stove in a wide pan for approximately 1 minute. The dried ingredients were then added to the binder and mixed together to form the snack bar matrix. The snack bar matrix was heated for 5 to 10 minutes at temperatures ranging from 80 to 200°C (Coleman et al., 2006) with constant stirring until all dry ingredients were well covered in honey. The hot snack bar mixture was thereafter poured and spread evenly onto a molding tray and was compressed manually using a rolling pin to produce snack bars with dimensions of 4 by 7 by 10 cm. The amount of lemon, raisins and honey were kept constant at 5, 15 and 40 g respectively to allow for assessment of the individual contribution of the major ingredients in the snack bar i.e. mango, pineapple, carrots, and popped amaranth grain, and to control their strong flavors. The total weight of mixture per formulation was 170g. Considering the average weight, each formulation was used to make an average of 5 snack bars of 30 g each. After shaping the snack bars were cooled and then packed and labeled in airtight polythene bags awaiting laboratory analysis.

TABLE 1: Formulations used for making a snack bar

Runs	Amaranth Grain(g)	Mango(g)	Pineapple(g)	Carrots(g)	Lemon Flakes(g)	Raisins (g)	Honey (g)
1	50	27.5	30	12.5	5	15	40
2	40	35.0	15	15.0	5	15	40
3	40	35.0	25	15.0	5	15	40
4	40	35.0	15	10.0	5	15	40
5	60	20.0	15	10.0	5	15	40
6	50	27.5	20	12.5	5	15	40
7	60	20.0	25	15.0	5	15	40
8	50	27.5	20	12.5	5	15	40
9	60	35.0	15	15.0	5	15	40
10	60	20.0	15	15.0	5	15	40
11	50	27.5	20	12.5	5	15	40
12	60	35.0	25	15.0	5	15	40
13	60	35.0	15	10.0	5	15	40
14	60	20.0	25	10.0	5	15	40
15	40	20.0	25	15.0	5	15	40
16	50	27.5	20	12.5	5	15	40
17	50	27.5	20	17.5	5	15	40
18	60	35.0	25	10.0	5	15	40
19	50	12.5	20	12.5	5	15	40
20	40	20.0	15	15.0	5	15	40
21	40	35.0	25	10.0	5	15	40
22	50	27.5	20	12.5	5	15	40
23	50	27.5	20	7.5	5	15	40
24	50	42.5	20	12.5	5	15	40
25	40	20.0	25	10.0	5	15	40
26	30	27.5	20	12.5	5	15	40
27	70	27.5	20	12.5	5	15	40
28	40	20.0	15	10.0	5	15	40
29	50	27.5	10	12.5	5	15	40
30	50	27.5	20	12.5	5	15	40

Determination of Effect of Ingredients on The Textural Properties of The Snack Bar

The texture properties of the snack bar were measured using mechanical methods. Texture profile analysis (TPA) to measure hardness and chewiness Zisu et al. (2007) using TA Plus texture analyzer (AMETEK, UK) connected to a computer programmed with Nexygen 3 software. The hardness test was carried out using a 3-point bend test. The bending probe was attached to a 2 kg compression load, while the target was set at 60 mm with pretest speed of 2 mm/s, testing speed at 1 mm/s and post-test speed of 10 mm/s.

The samples of 30 g were placed on two-points and put at a distance of 60 mm apart. The probe was set to penetrate the sample at a depth of 10 mm. Texture profile analysis (TPA) was based on the calculation of instrumental hardness (the peak force estimated during the first compression cycle) and this was observed from the monitor screen as the probe applied breaking force to the snack bar. The effect of variation of ingredients on the hardness of the snack bar was analyzed statistically using design expert.

Determination of Effect of Ingredients on Nutritional Composition of The Snack Bar

The nutritional composition (moisture, crude protein, crude fat, ash and crude fibre) of the product were determined using methods described in AOAC (1995). Oven drying method (AOAC method 977.11) was used to examine moisture content, Kjeldahl's method (AOAC method 955.04) for crude protein determination, Soxhlet method (AOAC method 960.39) for crude fat determination, dry ashing method (AOAC method 923.03) was performed to determine ash content, and gravimetric method (AOAC method 991.43) was used to determine crude fibre. The chemicals used in this study were of analytical grade. Sample carbohydrates were obtained using Phenol Sulphuric acid method (AOAC 1995).

Determination of Effect of Ingredients on The Sensory Properties of The Snack Bar

Sensory evaluation was performed by 40 untrained panelists consisting of male and female non-smoker, age from 7 to 30 years old. The sensory analysis of the snack bars was carried out in the sensory laboratory at the School of Food Technology, Nutrition, and Bioengineering, Makerere University. Panellists tasted the products in separate booths illuminated with normal daylight. The items evaluated included the different snack bars from the different formulations being tested to get the one with the best sensory properties. Availability and willingness of the panellists to participate in the session were put into consideration when choosing panellists. Each panellist scored the products for the different prescribed attributes using the 9-point hedonic scale (Meilgaard, Carr, & Civille, 2006). The details of the scale were provided on the score sheets as follows: 9 = "like extremely"; 8 = "like very much"; 7 = "like moderately"; 6 = "like slightly"; 5 = "neither like nor dislike"; 4 = "dislike slightly"; 3 = "dislike moderately"; 2 = "dislike very much"; 1 = "dislike extremely". The panelists were presented with 5g of each of the samples on a white disposable plastic plate (identified with randomly assigned three-digit codes) alongside the questionnaires. Bottled water was provided to clean and rinse the mouth palate between tasting and retesting of the samples. The evaluation attributes included appearance, colour, flavour, taste, texture, mouthfeel, and overall acceptability. The effect of the variation of ingredients on the sensory properties was analyzed statistically using design expert.

DATA ANALYSIS

All statistical analyses were performed using Design Expert software. To evaluate the effect of individual ingredients on nutritional, sensory and textural properties of the bar, RSM was applied for all formulations. A Multiple Linear Regressions Analysis (MLRA) technique embedded within RSM was performed to determine all the regression coefficients of constant, linear, quadratic and interaction terms for the mathematical model of the collected data. The statistical significance of the terms in the regression equations and adequacy of the model was examined using ANOVA for each response at $p<0.05$. The lack of fit test was used to evaluate the fitness of the model using coefficient of determination. Numerical optimization technique using the desirability function approach (Derringer& Suich, 1980) was employed to establish the optimum formulation that gives the best results for nutritional, sensory and textural needs for children 5 to 13. The optimized proportions of the independent variables (A, B, C, and D) were further applied to developed models for validation.

RESULTS AND DISCUSSIONS

TABLE 2: Nutritional composition and textural properties of snack bars obtained from 30 formulations

FC	MH (N/mm^2)	Protein (g/100g)	Carb (%)	BC*10e-2 (μg/100g)	Vit C (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	Fat (%)	Fibre (g/100g)	Ash (%)	MC (%)
1	23.35	10.73	55.10	10.40	7.19	3.45	2.16	1.14	3.90	4.42	21.34
2	24.94	10.52	50.78	15.53	10.38	3.49	2.49	1.44	3.17	4.23	21.12
3	36.29	11.79	68.33	12.68	10.33	5.00	3.79	2.70	4.10	5.26	20.90
4	47.59	12.91	74.55	10.54	10.28	5.89	4.51	3.43	5.44	5.37	19.22
5	33.38	11.93	63.24	17.85	11.41	4.75	3.65	2.68	4.53	4.39	20.25
6	47.37	12.02	75.04	15.92	10.38	5.10	4.38	3.31	5.69	5.48	19.37
7	28.49	10.22	55.06	15.78	8.77	3.50	2.27	1.25	3.40	3.35	21.64
8	24.42	10.94	54.32	10.84	9.50	3.43	2.79	1.80	3.59	3.47	21.80
9	52.67	13.71	86.50	12.76	10.88	6.14	5.88	4.85	6.53	6.70	18.75
10	45.19	12.72	77.95	15.87	8.53	5.63	4.09	3.03	5.67	5.57	19.05
11	31.70	11.27	61.67	12.69	12.34	4.34	3.22	2.25	4.81	4.82	20.16
12	37.32	11.94	68.37	12.48	8.32	4.30	3.03	2.38	4.48	4.46	20.50
13	34.04	11.67	63.07	12.34	13.68	4.88	3.97	2.99	4.64	4.59	20.54
14	35.87	11.99	64.99	12.48	10.83	4.99	3.75	2.31	4.46	4.46	20.84
15	29.63	10.40	56.70	15.64	11.71	3.59	2.13	1.13	3.54	3.33	21.75
16	35.23	11.56	67.90	12.55	10.63	4.34	3.23	2.27	4.70	4.39	20.69
17	42.06	12.87	76.03	15.80	11.46	5.17	4.62	3.69	5.73	5.71	19.95
18	46.50	12.13	70.07	15.28	13.67	5.82	4.26	3.26	5.07	5.30	20.85
19	31.51	11.66	68.94	12.23	10.73	4.05	3.27	2.25	4.34	4.59	20.92
20	37.57	11.81	61.67	12.99	7.97	4.90	3.18	2.18	4.08	4.56	20.20
21	34.29	11.30	69.59	7.36	9.75	4.10	3.09	2.05	4.40	4.61	20.56
22	26.12	10.59	52.62	10.50	10.83	3.80	2.62	1.70	3.18	3.14	21.22
23	47.84	12.45	75.81	10.15	7.95	5.74	4.81	3.87	5.11	5.38	19.57
24	29.45	10.39	57.39	10.34	12.37	3.43	2.57	1.52	3.20	3.79	21.61
25	44.78	12.96	77.66	10.02	12.19	5.26	4.85	3.96	5.10	5.74	19.31
26	49.69	12.39	70.50	10.95	9.96	5.43	4.59	3.58	5.56	5.12	19.77
27	16.40	9.93	48.94	12.37	10.28	2.62	1.03	0.25	1.43	2.40	22.71
28	34.09	11.43	60.70	12.44	10.53	4.98	3.11	2.11	4.95	4.40	20.99
29	31.66	11.90	64.32	12.97	10.53	4.46	3.67	2.63	4.23	4.20	20.91
30	21.02	10.49	52.18	15.69	13.72	3.42	2.82	1.86	3.31	3.41	21.45

MC=Moisture content, MH=Mechanical Hardness

Effect of Ingredients on Protein Composition

The protein composition of the snack bar increased with increase in amaranth grain. The study showed the optimal snack bar had higher crude protein (12.17 g/100g) than other fruit-based functional snack bars and fruit bars made from date paste (1.07-2.74 and 2.22 - 4.06%, respectively) (Sun-Waterhouse et al., 2010; Parn et al., 2015). However, lower crude protein than the "energy" bar reported by other researchers for traditional energy bars (13.5%) (Reader et al., 2002). Williams et al. (2006) reported that snack bars with a high ratio of protein/carbohydrate may improve post meal and diurnal glucose profiles in patients with type-2 diabetes and insulin resistance. This proves that the fewer ingredients selected can be used to make snack bar with similar protein composition as those made with more ingredients and also contribute to reduction of protein deficiency amongst children 5 to 13 years.

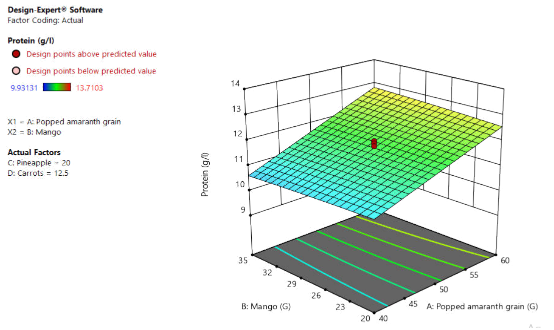


FIGURE 1: 3D plot highlighting the interaction of ingredients with protein composition

Popped grain Amaranth, A had the significant model term for the protein in the model equation indicating that popped amaranth grain had the most significant effect on protein content of the snack bar. The "Lack of Fit F-value" of 2.31 implied that the Lack of Fit is not significant relative to the pure error and that there is an 18.38% chance that a "Lack of Fit F- value" this large could occur due to noise. R2 value of 0.95 was observed proving that the model fits our observations and the Predicted R^2 (0.75) was in reasonable agreement with the Adjusted R^2 (0.90) all indicating adequacy of the proposed model (Equation 1).

$$PROTEIN = 0.103A + 2.897 \quad (1)$$

Effect of Ingredients on Ash Composition

The value of ash (5.43%) was higher than those reported for snack bars containing apple dietary fibre with apple polyphenol extract (1.03%) and inulin with apple polyphenol extract (1.33%) (Sun-Waterhouse et al., 2010). This value also indicated similarities between the snack bar macro- and micro- minerals and those of bananas (banana puree) which was reported to be a rich source of essential minerals especially potassium (Kanazawa and Sakakibara, 2000; Nieman et al., 2012). Increase in mango and amaranth showed significant increase in the ash content of the snack bar. Figure 2 and the predictive model (Equation 2) also showed significant effects of the ingredients on the ash content of the snack bar.

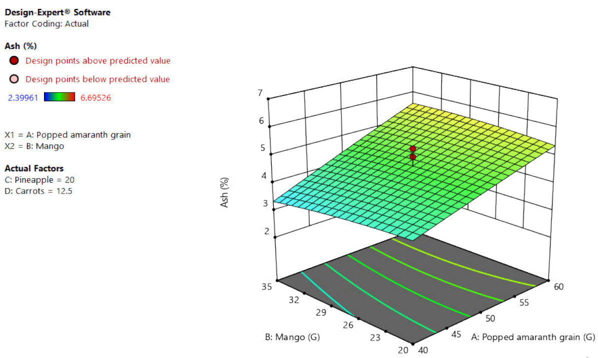


FIGURE 2: 3D plot highlighting the interaction of ingredients with Ash composition

A was the significant model term (p < 0.05). Lack of fit was also not significant with F-value of 0.88 showing that there is a 59.66% chance that a Lack of Fit F-value this large could occur due to noise. R^2, predicted R^2 and adjusted R^2 were 0.92, 0.65 and 0.84 respectively

$$Ash = 3.915 + 0.041A \quad (2)$$

Effect of Ingredients on Zinc and Iron

The snack bar had a greater score for minerals zinc and iron than the recommended for children 5 to 13 years which stand at 2.0 mg and 10 mg respectively. The snack bar had values at 4.35 mg/100g and 5.44 mg/100g respectively. Thus, it would be equally good for older children who require higher values for zinc and iron. Increase in amaranth showed greater increase in the values for zinc and iron so that the highest level of the minerals was recorded in formulations with over 60% of amaranth grain (Figure 3A and Figure 3B). Generally, there were significant differences in values for iron and zinc proving that variation in ingredients had an effect on the responses. ANOVA results also showed that the models were significant with P-value less than 0.05 for both responses and A was the significant model term for both zinc and iron showing dependence on popped amaranth grain over other ingredients. Lack of fit was also not significant both iron and zinc with R^2 values for both responses greater than 0.9, predicted R^2 and adjusted R^2 in agreement (difference between Pred R^2 and Adj R^2 less than 0.2). All showing the suitability of models (Equation 3 and 4).

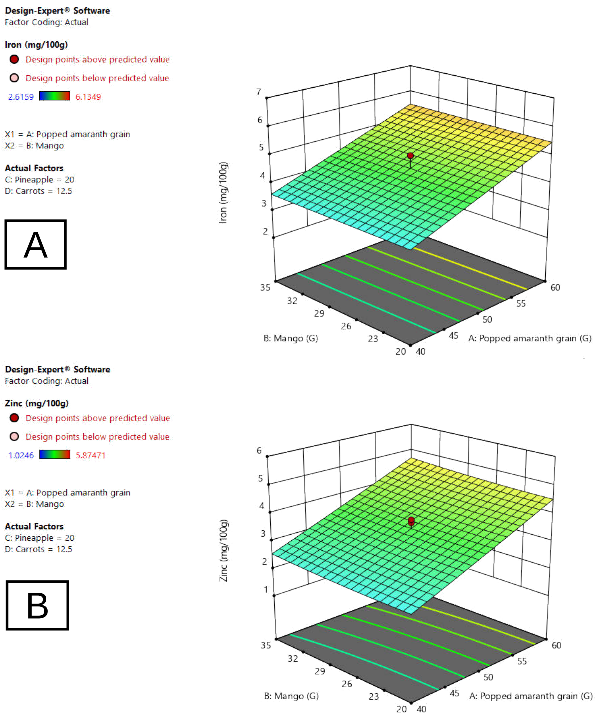


FIGURE 3: 3D plot highlighting the interaction of ingredients with Iron (A) and Zinc (B) composition

$$Iron = 0.096A - 0.249 \quad (3)$$
$$Zinc = 0.161A - 5.723 \quad (4)$$

Effect of Ingredients on Carbohydrates, Crude Fat and Fibre

Generally, there were significant differences (p< 0.05) in the levels of crude fat, fibre and carbohydrates in the snack bars produced using different formulations (Table 1).

Figure 4A, Figure 4B and Figure 4C show increase in values of total carbohydrates, fat and crude fibre and with increase in amaranth grain with optimum levels at 71.562%, 3.275% and 5.56g/100g respectively.

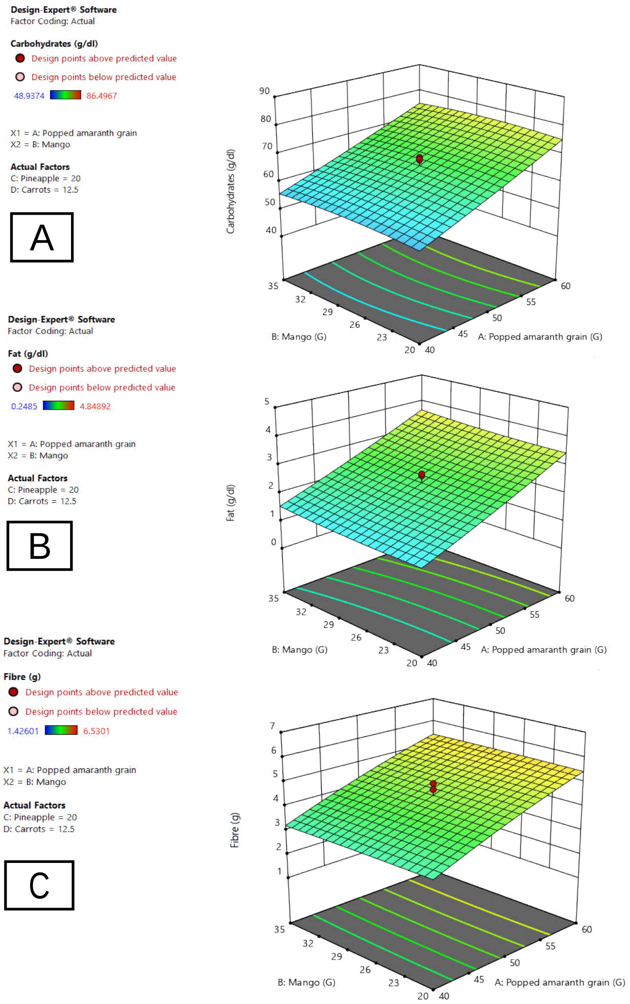


FIGURE 4: 3D plot highlighting the interaction of ingredients with Carbohydrates (A) Fat (B) and Crude fibre (C) composition

The low energy value (362.33 kcal/100g) was attributed to the low level of crude fat content of the present innovated product's ingredients in comparison to snack bars made using coconut milk, roasted peanuts, and milk chocolate among others. The snack bar however had high values for fibre which is an added benefit. The ingestion of snack bars high in fibres is associated with greater ratings of fullness for up to 3 hours as compared to snack bars with low fibre content (Chow et al., 2007). Therefore, it is expected that the presently developed snack bar has longer fullness than the traditional bars on the market. ANOVA results also showed that the models were significant with P-value less than 0.05 for the responses and lack of fit was not significant for all. R2 values for both responses were also greater than 0.9 with predicted R2 and adjusted R2 in agreement (difference between Pred R2 and Adj R2 less than 0.2). All showing the suitability of models (Equation 5, 6 and 7).

$$\text{Carbohydrates} = 0.777A + 1.450C - 19.490 \quad (5)$$
$$\text{Fat} = 0.123A - 4.015 \quad (6)$$
$$\text{Fibre} = 0.169A - 1.442 \quad (7)$$

Effect of Ingredients on Beta-Carotene and Vitamin C Levels in The Snack Bar

The snack bar also contained high levels of Beta-carotene and Vitamin C with optimum at 1580 µg (15.8E2 µg/100g) and 12.2 mg/100g respectively. The beta-carotene content was almost equal to the findings of Sarojini et al., 2009 whose fruit bar made of carrots and guava had Beta carotene content of 1622 µg/100g at 10% incorporation of carrots. The Beta-carotene content just like in this study were seen to increase with increase carrots so that the highest level was observed at 17.5g and 20% of carrot respectively. There was no significant change in values for Beta-carotene with amaranth mango or pineapple as can be seen in Figure 5A. This means that the B-carotene content in the snack bar was mainly affected by amounts of carrot added. Sharma et al., 2012 and Leja et al., 2013 reported the same findings for incorporation of carrot in various food mixtures. Vitamin C on the other hand increased more with increase in fruits and vegetables total and the highest level of vitamin C was observed when fruits and vegetables were at highest total of 75g. Values for amaranth were lower meaning amaranth grain contributed little to the vitamin C composition of the snack bar (Figure 5B).

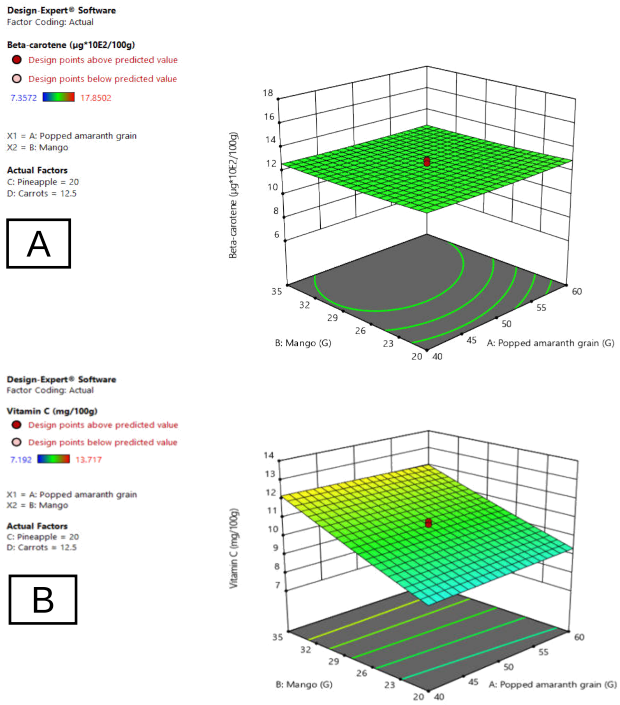


FIGURE 5: 3D plot highlighting the interaction of ingredients with Beta Carotene (A) and Vitamin C (B)

ANOVA results showed that the models were significant with P-value less than 0.05 for the responses and lack of fit was not significant for both responses. R2 values for both responses were also greater than 0.9 with predicted R2 and adjusted R2 in agreement showing the suitability of models (Equation 8 and 9).

$$\text{Beta-carotene} = 0.701D + 3.287 \quad (8)$$
$$\text{Vitamin C} = 0.170B + 0.288C + 0.234D - 4.004 \quad (9)$$

Effect of ingredients on the textural properties of the Snack Bar

Results were taken for 30 different formulations (Table 1) measured using TA Plus texture analyzer (AMETEK, UK). Generally, there were significant differences ($p < 0.05$) in the values for mechanical hardness of the snack bars produced using different formulations. The hardness of the snack bar increased with increase in amaranth grain (Figure 6). While snack bars are typically hard texture foods, the hardness of the developed bars was lower than those of commercial snack bars. This could be attributed to the use of honey instead of sugar as similar observations were made by Saputro et al. (2017) who noticed softer textures in chocolate bars made without sugar than those with sugar. Similar findings were reported by Yadav & Bhatnagar (2015) in development of a RTE cereal bar.

Snack bar with low hardness value i.e. softer snack bars however indicate that this snack bar was acceptable for the children (Aramouni et al., 2011).

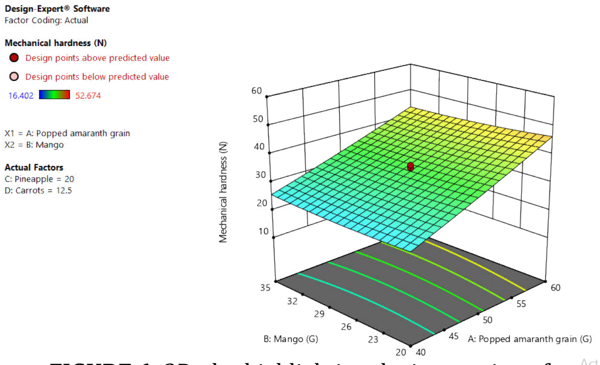


FIGURE 6: 3D plot highlighting the interaction of ingredients with Mechanical Hardness

The effect of ingredients on the textural properties of the snack bar was also calculated using predictive models retrieved for the dependent variables in the fruit-based snack bars (Equation 10).

$$\text{Mechanical hardness} = 0.917A - 22.374 \quad (10)$$

Where A- Popped Amaranth Grain

The study indicated that the popped amaranth grain, A had the significant model term ($p < 0.05$) meaning that popped amaranth grain had the most significant effect on the mechanical hardness of the snack bar. The "Lack of Fit F-value" of 2 also implied that the Lack of Fit is not significant relative to the pure error. R2 value of 0.96 was observed proving that the model fits our observations and the Predicted R^2 of 0.79 was in reasonable agreement with the Adjusted R^2 of 0.92 all indicating adequacy of the proposed model.

Effect of Ingredients on Sensory Properties of The Snack Bar

The addition of fruits and vegetables to popped amaranth grain significantly ($p<0.05$) affected the sensory properties of the snack bar (Table 3). The snack bar was acceptable as the products received rating greater than 5 for all attributes.

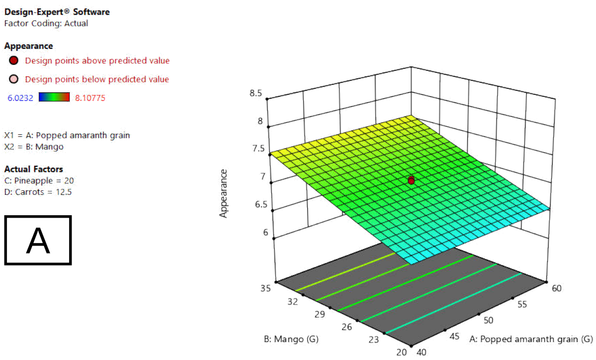
TABLE 3: Sensory evaluation results

Code	App	Color	Flavor	Aroma	Taste	MF	OA
1	6.02	7.14	7.08	6.88	7.08	7.03	7.23
2	7.06	7.44	7.55	7.23	7.38	7.03	7.26
3	7.01	7.41	7.39	7.08	7.31	6.97	7.42
4	7.03	7.45	7.02	6.87	7.36	6.81	7.69
5	7.35	7.50	7.32	7.02	7.46	6.97	7.38
6	7.05	7.44	7.50	7.22	7.27	6.89	7.69
7	6.30	7.23	7.08	6.85	7.12	7.03	7.19
8	6.72	7.35	7.53	7.26	7.27	7.03	7.24
9	7.02	7.41	7.32	7.08	7.32	6.74	7.82
10	6.31	7.30	7.10	6.88	7.11	6.85	7.64
11	7.71	7.64	7.78	7.40	7.50	6.99	7.49
12	6.30	7.21	7.11	6.80	7.17	6.97	7.43
13	8.11	7.75	7.27	7.08	7.64	6.94	7.48
14	7.06	7.41	7.21	7.00	7.39	6.92	7.50
15	7.30	7.58	7.03	6.86	7.41	7.11	7.03
16	7.05	7.46	7.35	7.04	7.31	6.99	7.49
17	7.36	7.60	7.07	6.88	7.41	6.83	7.69
18	8.11	7.79	7.61	7.30	7.70	6.82	7.60
19	7.00	7.43	7.39	7.09	7.32	6.99	7.26
20	6.10	7.10	7.31	7.06	7.06	6.91	7.29
21	6.72	7.36	7.35	7.01	7.21	6.99	7.28
22	7.04	7.50	7.11	6.85	7.35	7.04	7.10
23	6.07	7.14	7.08	6.80	7.05	6.84	7.62
24	7.76	7.67	7.49	7.20	7.54	7.03	7.19
25	7.75	7.66	7.52	7.29	7.57	6.85	7.63
26	6.76	7.32	7.45	7.21	7.21	6.83	7.53
27	7.06	7.44	7.26	7.03	7.37	7.27	6.82
28	7.10	7.45	7.39	7.00	7.32	6.93	7.27
29	7.05	7.49	7.39	7.04	7.31	6.96	7.25
30	8.10	7.64	7.53	7.20	7.51	7.09	7.06

App-Appearance, MF- Mouthfeel, OA-Overall Acceptability

Effect of Ingredients on Color and Appearance Properties of the Snack Bar

Based on the statistical results, panelists rated the developed snack bar appearance and color as "like very much" with the score value of 7.06 and 7.45 respectively. This indicates that consumers preferred the mix fruit color of the product. It was predicted that the fruity color of the outer layer was due to the natural color of the dried fruits and brown raisins. Figure 7A and Figure 7B show that general appearance and color of the snack bar increased with increase in the level of fruits and vegetables added.



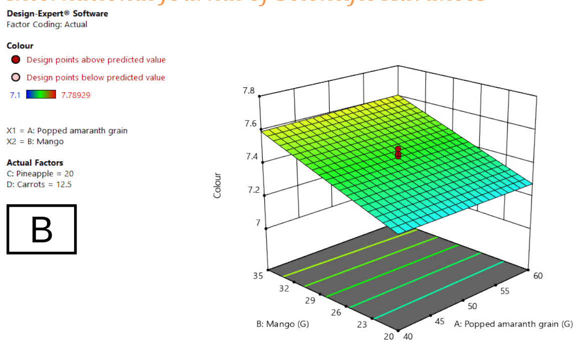


FIGURE 7: 3D plot highlighting the interaction of ingredients with Appearance (A) and Color (B)

Equations 11 and 12 are predictive models for effect of snack bar ingredients on the appearance and color of the snack bar respectively.

$$App=3.262+0.046B+0.073C+0.038D+0.0003B^2 \quad (11)$$
$$Color = 0.026B + 0.030C + 0.001D + 6.49 \quad (12)$$

Effect of Ingredients on Flavor and Aroma of the Snack Bar

The snack bar received score 7.2 and 7.5 for the parameters of aroma and flavor, respectively. The desired aroma and flavor were derived from the natural sweet smell of the dried fruits. The variation is indicated in Figure 8A and Figure 8B for aroma and Flavor respectively. There was however a clearer trend observed with increase in aroma and flavor with increase in pineapple where highest values for both were seen at 30g of pineapple (Table 1). This was linked to high preference or likeability of the sweet strong scent of pineapples by people, which increased further with drying (Zhu et al., 2020; Braga et al., 2009). Therefore, the sensory attribute (color) was positively correlated with aroma and flavor and also confirms the correlation between increased fruits with improved aroma and flavor.

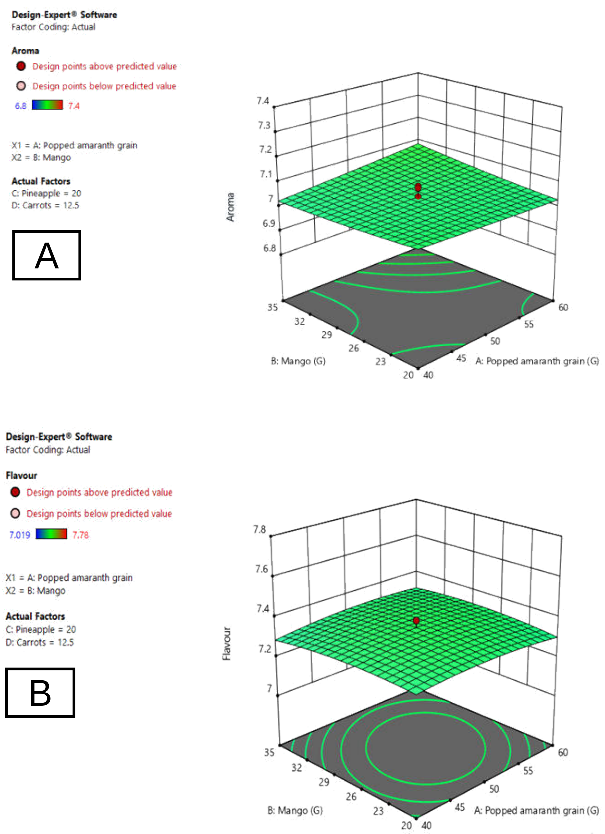


FIGURE 8: 3D plot highlighting the interaction of ingredients with Aroma (A) and Flavor (B)

Equations 13 and 14 are predictive models for changes in flavor and aroma of snack bars with snack bar ingredients respectively.

$$Flavor = 6.644 - 0.008C \quad (13)$$
$$Aroma= 0.011C + 0.0003AB + 7.055 \quad (14)$$

Effect of Ingredients on Taste and Mouth Feel of The Snack Bar

The sensory panel rated the snack bar taste as like very much with optimal value of 7.3. The mouth feel was however less liked with optimal value of 6.8. This could be attributed to the uneven bond between the amaranth pops and dried fruits since they were of different sizes, shapes and texture (Strokes et al., 2013). The value of 6.8 however still fell on the like side of the scale and thus it can be concluded that the snack bar mouthfeel was acceptable to the consumers. The taste of the snack bars was most preferred at higher level of fruits and vegetables (Table 3 and Figure 9A) while values for mouthfeel showed higher correlation and increase with reduction in popped amaranth grain (Table 3 and Figure 9B)

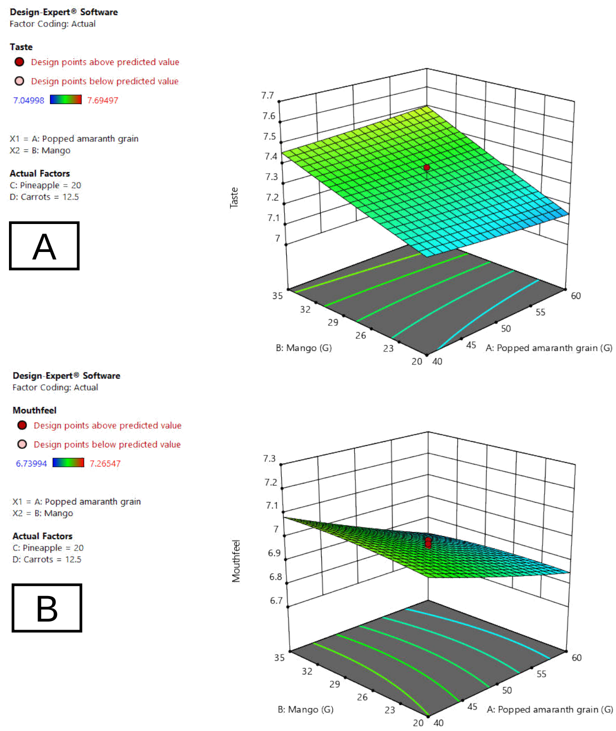


FIGURE 9: 3D plot highlighting the interaction of ingredients with Taste (A) and Mouth feel (B)

Equations 15 and 16 are predictive models for the interaction of snack bar ingredients with the taste and mouthfeel of the snack bars respectively.

$$Taste=7.244-0.001B+0.006C-0.004D+0.0004AB \quad (15)$$
$$Mouthfeel = 7.235 - 0.013A \quad (16)$$

Overall Acceptability of the Snack Bar

Overall acceptability is an attribute determined by a combination of sensory perception components (color, aroma, flavor, taste, and mouthfeel) of a product. The optimum score (Figure 10) for the overall acceptance was 7.63 ("like very much"). The results suggested that the new innovated convenient nutritious snack bar has very high earnings potential in both domestic and foreign markets.

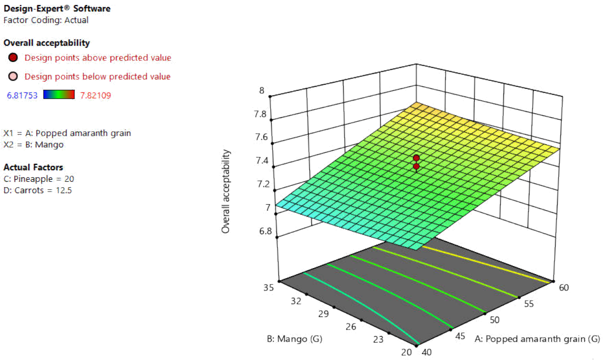


FIGURE 10: 3D plot highlighting the interaction of ingredients with overall acceptability

ANOVA results also showed that all the models were significant with P-value less than 0.05 for responses and lack of fit was not significant for all sensory responses. R2 values for all responses including the overall acceptability were greater than 0.9 with predicted R2 and adjusted R2 in agreement (difference between Pred R2 and Adj R2 less than 0.2). All showing the suitability of models. Equation 17 shows effect of snack bar ingredients on the overall acceptability.

$$\text{Overall acceptability} = 6.919 + 0.014A \quad (17)$$

The popped amaranth grain (A) had the most effect on the protein, carbohydrates, fat, fibre, iron, zinc and ash as well as the major textural properties of the snack bar samples i.e the overall acceptability. The amount of fruits added had more effect on the vitamin C content and Beta-carotene content which increased mainly with increase in carrots. Fruits added also had significant effect on the general physical/sensory properties of the snack bar. Pineapple had the most effect on the aroma and flavor of the snack bar and the whole ingredient matrix on the moisture content.

Optimal solutions for selection of ingredients for snack bar Data analysis revealed that while increase in individual ingredient levels may have a positive effect on some responses, other responses were negatively impacted. Thus, there was need for optimisation to get optimal formulation where all responses were at their best.

The numerical optimization technique was and important value for all of the responses were considered equal (Yolmeh et al., 2017). Selected formulations for the snack bar were those that resulted in highest desirability. The nutritional and textural responses as well as sensory attributes were considered for the optimal formulation of the snack bar. The formulation upon 60g amaranth grain, 20g mango, 25g pineapple and 15g carrot (Table 4) were found to be the optimal formulation for snack bars containing fruits and vegetables with highest desirability score of 0.86. Response values for all quality attributes at optimum were also seen to match recommended requirements for children aged 5 to 13 years proving that snack bar can be utilized to reduce some of the nutritional deficiencies among these children.

TABLE 4: Optimal snack bar formulation

PAG	Man	Pineapple	Carrots	Desirability
60	20	25	15	0.86

PAG=Popped amaranth grain and Man=mangoes

Validation of Models

According to the design, 30 experiments were performed in triplicate and the obtained results are shown in Table 5 and Table 6. Generally, there were significant differences ($p < 0.05$) in the values for all responses. Variations in the levels of ingredients were found to influence nutritional, sensory and textural properties of the snack bar and their relationships were represented by a number of predictive models. The regression models for all responses were all significant ($p<0.05$), with a high coefficient of determination ($R2>0.90$) and none of the models showed significant lack of fit ($P>0.05$), which shows a high suitability of the models to predict the dependent variables. For each term in the models, a small p- value and a large F- value showed a more significant effect on the response (Yolmeh et al., 2017). When model equations were tested using optimum values given in Table 4, values as predicted by the means and standard deviations in Table 5 were found proving validity of the models. The predicted mean values (Table 6) also showed no significant difference ($p>0.05$) with actual/observed mean values proving that the models can be used to predict actual values for responses when using selected ingredients.

TABLE 5: Prediction values (suggested by the software) and actual values obtained for the different responses of the composite snack bar

Responses	Predicted Mean	Observed Mean& Std Dev.	SE Mean	95% CI Low for Mean	95% CI High for Mean	95% TI Low For 99% Pop	95% TI High for 99% Pop	P-Value (T Test)
Mechanical hardness	46.48	35.35± 2.70	2.06	42.08	50.88	32.86	60.11	>0.05
Protein	12.17	11.62± 0.30	0.23	11.69	12.65	10.67	13.66	>0.05
Carbohydrates	54.38	65.00± 2.67	2.04	67.21	75.91	58.09	85.03	>0.05
Beta-carotene	15.82	12.85± 0.36	0.28	15.23	16.41	13.99	17.65	>0.05
Vitamin C	10.62	10.57± 0.23	0.18	10.24	11.00	9.45	11.80	>0.05
Iron	5.44	4.53± 0.30	0.14	5.16	5.715	4.18	6.69	>0.05
Zinc	4.34	3.46± 0.33	0.25	3.82	4.87	2.70	5.98	>0.05
Fat	3.28	2.46± 0.32	0.25	2.75	3.80	1.64	4.91	>0.05
Fibre	5.56	4.41± 0.34	0.26	5.00	6.12	3.82	7.30	>0.05
Ash	5.43	4.55± 0.36	0.28	4.84	6.03	3.59	7.28	>0.05
MC	19.18	20.56± 0.19	0.15	18.87	19.48	18.22	20.14	>0.05
Appearance	7.05	7.05± 0.03	0.02	7.01	7.10	6.91	7.20	>0.05
Colour	7.45	7.44± 0.04	0.03	7.38	7.51	7.26	7.64	>0.05
Flavour	7.54	7.32± 0.07	0.05	7.43	7.64	7.20	7.87	>0.05
Aroma	7.22	7.05± 0.04	0.03	7.17	7.28	7.04	7.40	>0.05
Taste	7.31	7.33± 0.04	0.03	7.24	7.38	7.10	7.52	>0.05
Mouthfeel	6.86	6.95± 0.03	0.03	6.80	6.92	6.69	7.03	>0.05
Overall acceptability	7.64	7.39± 0.09	0.07	7.49	7.78	7.19	8.08	>0.05

Two-sided Confidence = 95% Population = 99%

TABLE 6: Testing validity of models

	Ag (g)	Mg (g)	Pp (g)	Ct (g)	MH (N/mm²)	Pro (g/100g)	Carb (%)	Vitc (mg/100g)	Bc*10e2 (µg/100g)	Fat (%)	Fibre (g/100g)	Ash (%)	Iron (mg/100g)	Zinc (mg/100g)
Clt	60	20	25	15	47.88	13.49	73.76	10.24	16.54	2.31	6.01	5.69	5.43	3.77
Act					47.37	12.02	75.04	10.38	15.92	3.31	5.69	5.48	5.10	4.38
Clt	60	10	15	15	53.05	13.10	76.63	6.63	16.76	2.96	5.95	5.57	5.51	4.17
Act					50.40	12.90	74.46	6.03	16.04	1.83	4.82	4.85	5.21	4.64
Clt	50	30	20	15	34.26	12.88	67.20	11.14	15.80	1.60	4.76	4.59	4.56	2.94
Act					31.76	12.99	65.14	11.39	15.31	1.41	5.62	4.26	4.28	2.27

Ag=Amaranth Grains; Mg=Mangoes; Pp=Pineapples; Ct=Carrots and MH=Mechanical Hardness; Pro=Proteins; Carb=Carbohydrate

The results indicate that there are slight differences between the calculated values (model) and actual tested values (Table 6). The observed differences could be as a result of rounding off of co-efficient terms in the models but most are within the same range. The models can therefore be used to make predictions about the responses for given levels of each factor. The levels should be specified in the original units for each factor to be fed into the design expert program

CONCLUSION

A nutritious snack bar was successfully prepared by utilizing fruits, vegetables and popped grain amaranth. According to values observed from analysis it was concluded that the composite snack bars would contribute significantly to availability of convenient and healthier snack on the market. The sensory evaluation results also showed that the nutritious snack bar received a high acceptance by consumers. In addition, the snack bar produced from the study is comparable to the market available snack bars in proximate composition which proves that the few well selected ingredients were successfully used to make snack bars with similar nutrient level as those made with many ingredients which also solves the issue of expensive healthy snacks with a more affordable option. The study/experiments done on the composite snack bars from the different formulations shows that addition of fruits and vegetables to popped amaranth grain had significant effect on the nutritional, textural and sensory properties of the snack bar. It was also observed that when these ingredients were mixed in the right proportions, they produced a nutritionally whole snack bar with proper texture and acceptable sensory properties for children 5 to 13 years. Optimization of ingredients generated acceptable models which can be used to predict changes in snack bar properties with change in ingredients and also helped identify predicted formulation with best nutritional, textural and sensory properties for children 5 to 13 years. Based on the results, it can be concluded that the developed snack bar is suitable for small children.

ACKNOWLEDGMENT

This study was funded by the Federal Ministry of Education and Research (BMBF), Germany through the Reduction of Post-Harvest Losses and Value Addition in East African Food Value Chains (RELOAD). Authors also acknowledge Associate Professor Susan Balaba Tumwebaze of Makerere University, School of Forestry and Natural Resources Conservation for managing the funds of this project.

REFERENCES

[1] Abano, E. E., Ma, H., & Qu, W. (2011). Influence of air temperature on the drying kinetics and quality of tomato slices. Journal of Food Processing & Technology, 2(5), 2-9.

[2] AOAC 1995. Official Methods of Analysis. Washington

[3] Aramouni, F. M., & Abu-Ghoush, M. H. (2011). Physicochemical and sensory characteristics of no-bake wheat–soy snack bars. Journal of the Science of Food and Agriculture, 91(1), 44-51. Association of Analytical Chemists.

[4] BeMiller, J. N. and Low, N. H. 1998. Carbohydrate analysis. In Nielsen, S. S. (Ed). Food Analysis, p. 169. Gaithersburg: An Aspen Publication.

[5] Black, R. E., Allen, L. H., Bhutta, Z. A., Caulfield, L. E., De Onis, M., Ezzati, M., ... & Maternal and Child Undernutrition Study Group. (2008). Maternal and child undernutrition: global and regional exposures and health consequences. The Lancet, 371(9608), 243-260.

[6] Bower, J. A., & Whitten, R. (2000). Sensory characteristics and consumer liking for cereal bar snack foods. Journal of Sensory Studies, 15(3), 327-345.

[7] Braga, A. M. P., Pedroso, M. P., Augusto, F., & Silva, M. A. (2009). Volatiles identification in pineapple submitted to drying in an ethanolic atmosphere. Drying Technology, 27(2), 248-257.

[8] Chow, J., Choe, Y. S., Noss, M. J., Robinson, K. J., Dugle, J. E., Acosta, S. H. and Garleb, K. A. 2007. Effect of viscous fibre-containing nutrition bar on satiety of patients with type 2 diabetes. Diabetes Research and Clinical Practice 76(3): 335–340.

[9] Christensen, C. M. 1983. Effects of color on aroma, flavor and texture judgments of foods. Journal of Food Science 48(3): 787–790.

[10] Chuah, T. G., HairulNisah, H., Thomas Choong, S. Y., Chin, N. L. and Nazimah Sheikh, A. H. 2007. Effects of temperature on viscosity of honey. Journal of Food Engineering 80: 423–430.

[11] Coelho, E., Vilanova, M., Geneva, Z., Oliveira, J. M., Teixeira, J. A. and Domingues, L. 2015. A systematic approach to the development of fruit wines from industrially processed fruit concentrates, including optimization of fermentation parameters, chemical characterization, and sensory evaluation. LWT–Food Science and Technology 62: 1043–10

[12] Derringer, G., & Suich, R. (1980). Simultaneous optimization of several response variables. Journal of quality technology, 12(4), 214-219.

[13] handevi, P. E. M., &Jeewon, R. (2015). Fruit and vegetable intake: Benefits and progress of nutrition education interventions-narrative review article. Iranian journal of public health, 44(10), 1309.

[14] Euromonitor International. 2015. Snack bars in Malaysia. Retrieved on July 10, 2015, from a website: http://www.euromonitor.com/snack-bars-in-malaysia/report.

[15] FAOSTAT (Food and Agriculture Organization of United Nations Statistics). 2015. Production crops: bananas. Retrieved on July 14, 2015, from FAOSTAT website: http://faostat3.fao.org/download/Q/QC/E.

[16] Ghorbannezhad, P., Bay, A., Yolmeh, M., Yadollahi, R., & Moghadam, J. Y. (2016). Optimization of coagulation–flocculation process for medium density fibreboard (MDF) wastewater through response surface methodology. Desalination and Water Treatment, 57(56), 26916-26931.

[17] Kanazawa, K. and Sakakibara, H. 2000. The high content of dopamine, a strong antioxidant in Cavendish banana. Journal of Agricultural Food Chemistry 48: 844–848.

[18] Kendall, P., &Sofos, J. (2007). Drying fruits. Food and nutrition series. Preparation; no. 9.309.

[19] Kemp, S., Hollowood, T. and Hort, J. 2011. Sensory evaluation: a practical handbook. United Kingdom: John Wiley and Sons.

[20] Kim, E. J., Corrigan, V. K., Hedderley, D. I., Motoi, L., Wilson, A. J., & Morgenstern, M. P. (2009). Predicting the sensory texture of cereal snack bars using instrumental measurements. Journal of texture studies, 40(4), 457-481.

[21] King, J. 2006. Nutrition bar update. Nutraceuticals World 9(1): 32–36.

[22] Kirk, S., & Sawyer, R. (1991). Pearson's composition and analysis of foods (No. Ed. 9). Longman Group Ltd.

[23] Malawat, S. and Hidayah, I. 2013. The effects of the concentration of brown sugar and the comparison of cassava (Dioscoreaalata) paste proportion to the making of "dodol" (Indonesian food). Journal of Agriculture and Veterinary Science 6(2): 9–15.

[24] Nielsen, S. S. 1998. Nutrition labeling. In Nielsen, S.S. (Ed). Food Analysis, p. 44. Gaithersburg: An Aspen Publication.

[25] Parn, O. J., Bhat, R., Yeoh, T. K. and Al-Hassan, A. A. 2015. Development of novel fruit bars by utilizing date paste. Food Bioscience 9: 20–27.

[26] Reader, D. M., O'Connell, B. S., Johnson, M. L. and Franz, M. 2002. Glycemic and insulinemic response of subjects with type 2 diabetes after consumption of three energy bars. Journal of the American Dietetic Association 102(8): 1139–1142.

[27] Ryland, D., Vaisey-Genser, M., Arntfield, S. D. and Malcolmson, L. J. 2010. Development of a nutritious acceptable snack bar using micronized flaked lentils. Food Research International 43: 642–649.

[28] Sarojini, G., Veena, V., & Rao, M. R. (2009, January). Studies on fortification of solar dried fruit bars. In International Solar Food Processing Conference (Vol. 12, No. 6, pp. 592-597).

[29] Srivastava, S. (2005). U.S. Patent Application No. 11/073,025.

[30] Statista. 2015. Retail sales of nutrition and energy bars in the U.S. from 2005 to 2015 (in million U.S. dollars). Retrieved on July 11, 2015, from a website: http://www. statista.com/statistics/235816/us-retail-sales-of-energy-bars/.

[31] Stone, H. Bleibaum, R., and Thomas, H. A. 2012. Measurement. In Stone, H. Bleibaum, R., and Thomas, H. A. (Eds). Sensory Evaluation Practices, p. 101-104. United States: Academic Press.

[32] Stokes, J. R., Boehm, M. W., & Baier, S. K. (2013). Oral processing, texture and mouthfeel: From rheology to tribology and beyond. Current Opinion in Colloid & Interface Science, 18(4), 349-359.

[33] Sun-Waterhouse, D., Teoh, A., Massarotto, C., Wibisono, R. and Wadhwa, S. 2010. Comparative analysis of fruit-based functional snack bars. Food Chemistry 119: 1369–1379.

[34] Tontisirin, K., & Bhattacharjee, L. (2001). Global burden of malnutrition and infection in childhood. In Nestle Nutrition Workshop Series (Vol. 45, pp. 1-22). Philadelphia; Lippincott-Raven; 1999.

[35] Williams, G., Noakes, M., Keogh, J., Foster, P., and Clifton, P. 2006. High protein high fibre snack bars reduce food intake and improve short-term glucose and insulin profiles compared with high fat snack bars. Asia Pacific Journal of Clinical Nutrition 15(4): 443–450.

[36] Wyatt, S. L. 2011. State of the snack industry 2010. SymphonyIRI Group. Retrieved on July 14, 2015, from a website: http://www.healthycornerstores.org/wp content/uploads/2011/11/SNAXPO-2011.pdf

[37] Yadav, L. A. T. I. K. A., & Bhatnagar, U. (2015). Optimization of ingredients in cereal bar. Food Science Research Journal, 6, 273-278.

[38] Yolmeh, M., Khomeiri, M., Ghorbani, M., Ghaemi, E., & Ramezanpour, S. S. (2017). High efficiency pigment production from Micrococcus roseus (PTCC 1411) under ultraviolet irradiation. Biocatalysis and Agricultural Biotechnology, 9, 156-161.

[39] ZHU, G., & YU, G. (2020). A pineapple flavor imitation by the note method. Food Science and Technology, (AHEAD).

[40] Zisu, B., & Shah, N. P. (2007). Texture characteristics and pizza bake properties of low-fat Mozzarella cheese as influenced by pre-acidification with citric acid and use of encapsulated and ropy exopolysaccharide producing cultures. International Dairy Journal, 17(8), 985-997