European Journal of Agriculture and Food Sciences
Vol 6 | Issue 4 | July 2024
ISSN 2684-1827

RESEARCH ARTICLE

Optimization of Hardness as a Textural Property of a Fruit Enriched Honey Sweetened Snack Bar for Children Aged 5 to 13 Years

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

ABSTRACT

Optimization for hardness of the snack bar formulated from selected fruits and grain amaranths bound with honey was conducted using Response Surface Methodology (RSM). To achieve a desired degree of hardness, honey content and compression force were varied. The effects of this variation was investigated to determine the best Honey: Compression force combination that results into the desired hardness. Thirteen combinations were considered. The force-honey combination varied between 9.82 to 41.87 kN and 30 to 80 g, respectively. Results revealed that both honey and compression force had a significant effect ($p < 0.05$) on hardness of the snack bar. The optimal hardness of the snack bar was found at honey: compression force of 41.18 g (22.7%), 41.87 kN. At this optimal point, hardness was found to be 48.2 N/mm which is acceptable for children aged 5 to 13 years.

Submitted: August 28, 2023
Published: July 16, 2024

10.24018/ejfood.2024.6.4.733

[1] Department of Agricultural and Bio Systems Engineering, Makerere University, Uganda.
[2] Department of Food Technology and Nutrition, Makerere University, Uganda.

Corresponding Author:
e-mail: jbulyakigozi@yahoo.com

Keywords: Compression force, Hardness, Honey, Optimization.

1. Introduction

More than ever before, there is an increased community sensitization on proper feeding. This has since been recommended as a sure way to prevent or correct health problem such as obesity, diabetes, malnutrition, and heart disease, among other ailments that largely originate from dietary errors and are growing rapidly worldwide [1]. Secondly, the dynamic and fast developing world has changed individual lifestyles resulting from increased busy schedules workplaces. The population enjoys convenient and highly nutritious safe foods. The available fast foods and drinks, however, are more carbohydrate and fat-based and are low in fibre, protein, and vitamins [2].

This new trend for consumption of healthy, innovative and convenient food in more developed countries has resulted in gradual growth in the market of snack bars globally [1], [3]. Different scientists in the food processing industry have developed various types of snacks bars to meet the specific demands of consumers [1], [4], and more are seeking methodologies to not only improve organoleptic characteristics, and shelf life of products, but also ways of producing healthier and more nutritious products such as adding some or more natural and healthier ingredients.

Honey being a sweet, flavorful liquid substance of high nutritional value and immense therapeutic benefit [5] also contains many natural bioactive substances [6], [7]. Several researchers have highlighted the therapeutic and health benefits of the use of honey in enhancing health and improving body systems [8]. Natural honey has more than 300 constituents with sugar as the main component, primarily fructose and glucose, with small amounts of fructo-oligosaccharides [6], [8], [9]. It is this specification that makes honey suitable as a binder compared to sugar [10]. Regardless of the fructo-oligosaccharides in honey, it cannot independently generate a structurally stable bar thus the need to apply an appropriate compression force. An increase in honey increases the binding of particles together up to a certain limit beyond which the bar weakens whereas an increase in compression force strengthens the snack bar up to a maximum limit beyond which the bar deforms. The usage of honey as a binder with an ample compression force has not been reported.

The objective of this study was therefore to optimize levels of honey and compression force required to generate a texturally and nutritionally acceptable snack bar from selected fruits, vegetables, and grain amaranth.

TABLE I: Composite Composition for the Snack Bars

Ingredient	Weight (g)
Popped amaranth grain	60
Mango	20
Pineapple	25
Carrots	15
Lemon flakes	5
Raisins	15

2. Materials and Methods

2.1. Materials

The snack bar was developed from Honey, Popped amaranth grain, Mangoes, Pineapples, Carrots, Lemon flakes, and Raisins. Honey was purchased from the Food Parlor at the School of Food Technology, Nutrition and Bio Engineering, Makerere University Kampala (U). Grain amaranth was obtained from Nutreal Limited, Wakiso (U). All the highlighted vegetables and fruits were purchased from Nakasero and Kalerwe Markets in Kampala, Uganda's capital city. Submit your manuscript electronically for review.

2.2. Methods

Snack bars were developed using a method described by [11], with slight modifications where amaranth grains were popped using an LPG gas stove, fruits were dried using a commercial dryer (HARVEST SAVER TRAY DRIER, Model: R-5A, Eugene, USA) and blended into smaller pieces using a commercial blender. Prepared ingredients were then weighed and mixed using proportions (Table I). The mixture was heated for 5–10 minutes to reduce the water activity of the external portion thereof while maintaining an internal portion of the cereal matrix at a higher water activity [12]. The method provided snack bars at less compressive force as a cohesive self-supporting structure with an improved shelf life is produced.

The mixture was thereafter poured into the mould (Fig. 1) fabricated by Tonnet Agro-Engineering Company, Kampala (U) to hold and shape the snack bar mix during compression. The compression force was applied by a Testometric, Universal Materials Testing Machine (SGS, Model F0300-02032, Songzhuang Industrial Park, Jinan City, China) at the College of Engineering Design Art and Technology, Makerere University Kampala (U) connected to a computer display and programmed with win test software (version 10, Rochdale, UK). The Compression Test was done at a Speed of 40.0 mm/min and a sample height of 43.0 mm to a thickness of 1 cm following methods described by [12].

Treatment limits highlighted in Table II were used to generate the optimal values. Ranges for honey and force were selected based on limits recommended by [13] in the development of sorghum based snack bar with honey. These limits were fed into design experts (Version 11, Stat-Ease, Inc. Minneapolis, USA).

Each factor was set to 5 levels: axial points, factorial points and the center points generating 5 center points, 8 axial and factorial points, totaling to 13 treatments as indicated in Table III.

Fig. 1. (L-R) Fabricated mould for snack bar shaping. Testometric materials testing machine.

TABLE II: Ranges for Processing Variables for Snack Bar Hardness Optimization Using the Central Composite Design

Factor	Description	Minimum	Maximum
A	Force (kN)	9.82	41.87
B	Honey (g)	30	80

TABLE III: Treatments Used for Analysis of the Effect of Force and Honey on Hardness of the Snack Bar Developed with Central Composite Design Using Design Expert

	Force (kN)	Honey (g)
1	9.82	80
2	48.51	55
3	25.84	55
4	25.84	55
5	25.84	55
6	25.84	55
7	9.82	30
8	25.84	19.64
9	41.87	30
10	25.84	55
11	3.18	55
12	25.84	90.35
13	41.87	80

Compression tests were based on equipment calibration (the peak force estimated during the first compression cycle, the deflection and Young's modulus). These values were used to give a record of forces applied to be matched with textural properties. The tests were carried out as shown in Fig. 2.

2.3. Determination of the Effect of Honey and Compression Force on Hardness of the Snack Bar

The texture profile analysis (TPA) was used to measure hardness using TA Plus texture analyzer (AMETEK, UK) fitted with a 3 point bend test and programmed with Nexygen 3 software. The bending probe was attached to a 2 kg compression load, while the target was set at 60 mm with a pretest speed of 2 mm/s, testing speed of 1 mm/s, and post-test speed of 10 mm/s. The samples of 30 g were placed on the two-points at a distance of 60 mm apart. The probe was set to penetrate the sample at a depth of 10 mm. The effect of the variation of force and honey on hardness of the snack bars was investigated using a design expert.

Fig. 2. Hardness analysis of snack bar samples.

TABLE IV: Central Composite Design Showing Results for Hardness of the Optimum Snack Bar

Run	Force (kN)	Honey (g)	Hardness (kN)
1	9.82	80.00	37.812
2	48.51	55.00	49.050
3	25.84	55.00	45.125
4	25.84	55.00	42.601
5	25.84	55.00	44.724
6	25.84	55.00	44.161
7	9.82	30.00	36.172
8	25.84	19.64	39.195
9	41.87	30.00	46.571
10	25.84	55.00	44.670
11	3.18	55.00	40.155
12	25.84	90.35	33.994
13	41.87	80.00	37.476

Note: Two-sided Confidence = 95%.

3. Results and Discussion

3.1. Effect of Compression Force and Honey on the Textural Properties of the Snack Bar

Generally, there were significant differences ($p < 0.05$) in hardness of the snack bars developed using different combinations of compression force and honey. The hardness of the snack bar increased with an increase in compression force and an increase in honey levels. The highest value for hardness recorded was 49.05 kN Table IV. This was observed at 48.51 kN compression force and 55 g of honey.

The addition of different levels of honey and force applied to the snack bar had a positive linear effect on the reading for the hardness of the fruit-based snack bars Fig. 3. The effect of the variables on hardness is expressed in (1).

$$\text{Hardness} = 14.122 + 0.565\text{A} + 0.821\text{B} - 0.007\text{AB} - 0.007\text{B}^2 \quad (1)$$

ANOVA in Table V indicates a p-value less than 0.05 indicating significance. "Lack of Fit F-value" of 1.09 implied that the Lack of Fit was not significant relative to the pure error. R^2 value of 0.9713 was observed proving that the model fits our observations up to a level of 97% accurately, and the Predicted R^2 of 0.9507 was in reasonable agreement with the Adjusted R^2 of 0.8835 indicating adequacy of the proposed model.

TABLE V: Anova for Quadratic Models for Hardness

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	238.81	5	47.76	47.32	<0.0001
A-force	64.09	1	64.09	63.49	<0.0001
B-honey	27.42	1	27.42	27.17	0.0012
AB	28.81	1	28.81	28.55	0.0011
A^2	0.0690	1	0.0690	0.0683	0.8013
B^2	117.14	1	117.14	116.05	<0.0001
Residual	7.07	7	1.01		
Lack of fit	3.17	3	1.06	1.09	0.4507
Pure error	3.89	4	0.97		
Corrected Total Sum of Squares	245.87	12			

TABLE VI: Prediction Values and Actual Values Obtained for the Different Responses for Hardness of the Snack Bars

Response	Predicted mean	Observed mean ± Std Dev	P-value
Hardness	48.2403	47.87 ± 1.00469	0.0015

Note: Two-sided Confidence = 95% Population = 99%.

3.2. Optimal Solutions for Selection of Ingredients for Snack Bar

The numerical optimization technique performed to optimize the hardness of snack bars was used assuming weight and importance values for all of the responses were equal [14]. The formulation upon 41.87 kN compression force and 41.18 g of honey was found as the optimal formulation Fig. 4. At the optimum level of force and honey, hardness value was measured at 48.24 which is acceptable hardness for a snack bar for children 5 to 13 years. The desirability of the model was 0.94. This was attributed to the use of honey instead of sugar as similar observations were made by [15], [16] who noticed softer hardness in snack bars made without sugar.

3.3. Validation of Models

According to the used design, 13 experiments were performed in triplicate and the obtained results are shown in Table VI. The regression models for all responses were all significant ($p < 0.05$), with a high coefficient of determination ($R^2 > 0.97$) and none of the models showed a significant lack of fit ($p > 0.05$), which shows a high suitability of the models to predict the dependent variables. The predicted mean values 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 values for compression force and honey.

The models were also tested with known values as shown in Table VII. There were slight differences between the calculated values (model) and actual tested values. The models can therefore be used to make predictions about the responses for given levels of each factor.

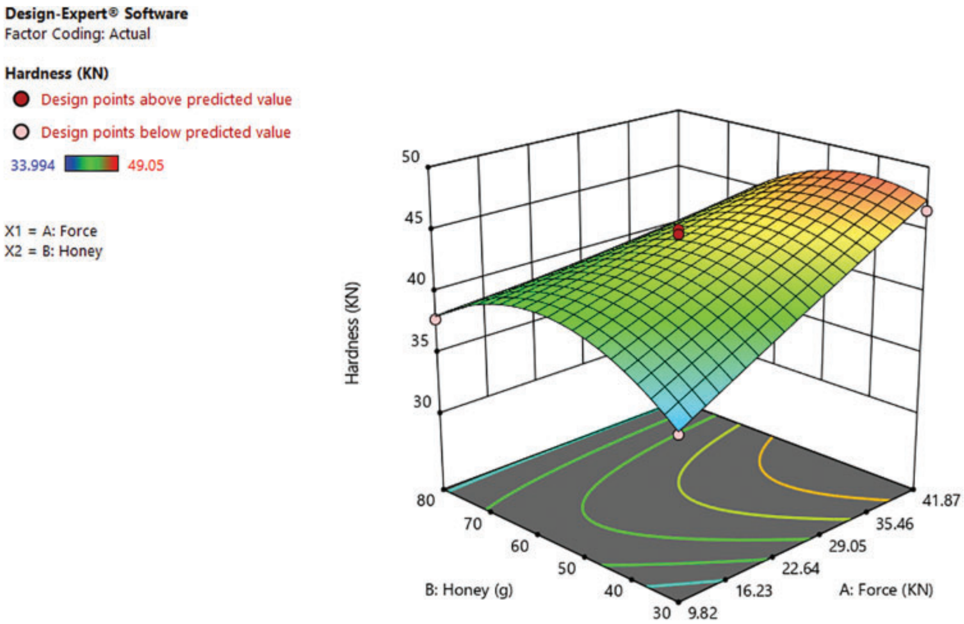

Fig. 3. Response surface plot showing variation of Honey and Force with hardness.

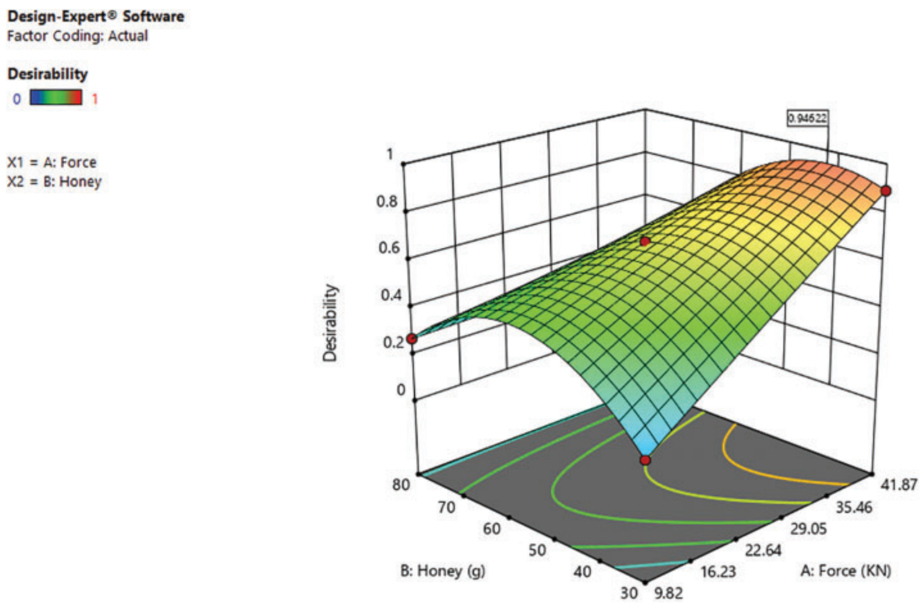

Fig. 4. Response surface plot showing interaction of honey and compression force with desirability of models.

TABLE VII: Validation of Models

Formulation Code		Force	Honey	Hardness
H opt	Calculated	41.87	41.18	48.240
	Actual			46.946 ± 1.776
H1	Calculated	32.477	80	34.742
	Actual			36.433 ± 2.506
H2	Calculated	22.5666	50	42.320
	Actual			40.745 ± 2.431
H3	Calculated	41.87	60	43.552
	Actual			41.921 ± 1.763

4. Conclusions

The results of this study revealed that the quadratic model was more adequate than other models for the hardness values of snack bar samples. A formulation at 41.87 kN compression force and 41.18 g natural honey was found as the optimal formulation for best hardness of the snack bar. At the optimal formulation, the hardness of the snack bar was predicted to be 48.24. Snack bars' hardness was lower than the commercial snack bar. Snack bar with low hardness however value indicates that this snack bar was acceptable for the children.

Conflicit of Interest

The authors declare that they do not have any conflict of interest.

References

[1] Clemente-Suárez VJ, Beltrán-Velasco AI, Redondo-Flórez L, Martín-Rodríguez A, Tornero-Aguilera JF. Global impacts of western diet and its effects on metabolism and health: a narrative review. *Nutrients*. 2023;15(12):2749. doi: 10.3390/nu15122749.

[2] Spatz M and Dallas R. Blood Glucose Log 4×/Day with Carbs, Snacks and Insulin-English. Diabetes Education Tools. 2017:30.

[3] Siro I, Kápolna E, Kápolna B, Lugasi A. Functional food. Product development, marketing, and consumer acceptance. A review. *Appetite*. 2008;51(3):456–67.

[4] Ryland D, Vaisey-Genser M, Arntfield SD, Malcolmson LJ. Development of a nutritious acceptable snack bar using micronized flaked lentils. *Food Res Intern*. 2010;43(2):642–9.

[5] Krishnasree V. *Exploring the health potential of honey and development of a value-added nutraceutical drink* (Doctoral dissertation, College of Agriculture, Vellayani). 2015.

[6] Alvarez-Suarez JM, Tulipani S, Diaz D, Estevez Y, Romandini S, Giampieri F, *et al.* Antioxidant and antimicrobial capacity of several monofloral Cuban honeys and their correlation with color, polyphenol content and other chemical compounds. *Food Chem Toxic*. 2010;48(8–9):2490–9. doi: 10.1016/j.fct.2010.06.021.

[7] Alvarez-Suarez J, Gasparrini M, Forbes-Hernández T, Mazzoni L, andGiampieri F. The composition and biological activity of honey: a focus on Manuka honey. *Foods*. 2014;3(3):420–32.

[8] Ajibola A, Chamunorwa JP, Erlwanger KH. Nutraceutical values of natural honey and its contribution to human health and wealth. *NutrMetab (Lond)*. 2012;9:61. doi: 10.1186/1743-7075-9-61.

[9] Eteraf-Oskouei T, Najafi M. Traditional and modern uses of natural honey in human diseases: a review. *Iran J Basic Med Sci*. 2013;16(6):731–42.

[10] Gunderson K, Coate K, Terry P. The effects of replacing granulated sugar with locally farmed honey on the physical, nutritional and sensory characteristics of sugar cookies. *J Acad Nutr Diet*. 2018;118(9):A94.

[11] Berglund PT, Fastnaught CE, Holm ET. Food uses of waxy hullless. *World*. 1992;37(707).

[12] Coleman J, Abaye AO, Barbeau W, Thomason W. The suitability of teff flour in bread, layer cakes, cookies and biscuits. *Int J Food Sci Nutr*. 2013;64(7):877–81. doi: 10.3109/09637486.2013.800845.

[13] Ribanar AA, Hemalatha S. Optimization of high protein and high energy sorghum flakes based snack bar. *Karnataka J Agric Sci*. 2015;28(3):394–7.

[14] Yolmeh M, Jafari SM. Applications of response surface methodology in the food industry processes. *Food Bioprocess Technol*. 2017;10:413–33.

[15] Saputro AD, Van de Walle D, Aidoo RP, Mensah MA, Delbaere C, De Clercq N *et al.* Quality attributes of dark chocolates formulated with palm sap-based sugar as nutritious and natural alternative sweetener. *Eur Food Res Technol*. 2017;243(2):177–91.

[16] Yadav L, Bhatnagar U. Optimization of ingredients in cereal bar. *Food Sci Res J*. 2015;6:273–8. doi: 10.15740/HAS/FSRJ/6.2/273-278.