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ORIGINAL ARTICLE

Sensory Analysis and Consumer Acceptability of a Newly Developed Sago Pellet Based Nutrition Bar

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ABSTRACT - This study aimed to develop a nutrition bar incorporating locally available ingredients: sago pellets, jackfruit flesh and seed, and stingless bee honey. Sago pellets, a distinctive ingredient found exclusively in the central region of Sarawak, particularly in Sibu and Mukah, were utilized as an alternative to conventional cereal- or rice-based components commonly used in commercial nutrition bars. A total of fourteen formulations were developed using a mixture design approach, varying the proportions of sago pellets, jackfruit flesh, and jackfruit seed, while maintaining a constant 30% (w/v) stingless bee honey as a binder. Sensory evaluation, conducted using a nine-point hedonic scale, assessed panelists' acceptance of the different formulations. The formulation containing 60% sago pellets, 5% jackfruit flesh, and 5% jackfruit seed achieved the highest overall acceptance, with an average score of 7.3. This formulation also received high mean scores for aroma (7.00), color (7.70), sweetness (7.83), sourness (7.37), hardness (7.10), and texture (7.33). Contour plots generated by the mixture design software illustrated the influence of ingredient composition on sensory attributes. Model validation demonstrated that the formulation with 60% sago pellets, 5% jackfruit flesh, and 5% jackfruit seed yielded an experimental overall acceptability score of 6.10, closely aligning with the predicted value of 6.59, with a low percentage error (7.44%). These findings highlight the potential of sago pellets as a novel base ingredient for nutrition bar development, leveraging indigenous resources for innovative food product formulations.

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INTRODUCTION

Nutrition bars were initially developed by NASA in the 1960s specifically for astronauts. In the 1980s, there was an increase in the scope of the product to include the sports market due to a growing demand [1]. In today's society, nutrition bars are no longer limited to astronauts and athletes; they are now consumed by individuals for many reasons such as providing energy, replacing meals, serving as a healthy snack option, aiding in weight control, or offering convenience in our fast-paced lifestyles. The demand for energy and nutrition bars has been experiencing a significant increase in recent years, driven by the growing trend of health consciousness urging for diverse and innovative product options. Existing product varieties are no longer sufficient to meet the expectation of consumers who seek uniqueness, improved quality, and personalization. As a result, this research was done to provide consumer with new improved varieties of nutrition bar. Grand View Search [2] reported that the worldwide snack bar market was valued at USD 20.15 billion in 2018 and is projected to experience a growth rate of 6.64% from 2019 to 2025. Nutrition bars are a convenient, portable, nutritious, and tasty snack that is ideal for health-conscious individuals who struggle to fit well-balanced meals into their busy schedules [3-5]. The nutrition bars offer a fast and handy food option that necessitates no prior preparation, has an extended

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period of storage, and does not require refrigeration. In Malaysia, the nutrition bar sector is experiencing significant growth, with companies like Nestle, Kellogg's, and Kraft actively involved [3; 5].

Nutrition bars typically consist of a mixture of cereal or grains, nuts, dried fruits, and sweeteners such as sugars or honey [6]. Whole grains enable food developers to utilise transparent and easily identifiable components, enhance visual attractiveness, make claims about including several grains, and enhance the nutritional profiles of fibre and plant-based protein. It was seen as a real component for consumers that provides energy, carbohydrates, and a crunchy texture. The cereals or grains commonly utilised include rice, bran, oats, wheat, soy, and cornflake [6]. Carbohydrates are crucial in nutrition bars as they serve as a primary source of energy and help optimise energy reserves. It can be utilised to optimise energy levels, whether it is before, during, or after engaging in activities such as sports and exercise [3].

In the present study, the sources of carbohydrate for the newly developed nutrition bar were sago pellets, jackfruit and stingless bee honey. Sago pellets were produced using dehydrated sago flesh, desiccated coconut, powdered paddy husk, coconut milk, and salt [7]. The brown sago pellets are prepared for consumption and can be enjoyed with tea, coffee, or as an accompaniment to savoury foods, particularly in the Sibu and Mukah districts. Before being replaced by rice in the 1990s, it served as a main food for them. Metaragakusuma et al. [8] found that sago contains a larger amount of carbohydrates (84.7 g per 100 g) compared to rice (80.0 g per 100 g) and wheat flour (77.3 g per 100 g). Another advantage of utilising sago pellet is their low glycaemic index (GI), as well as their low fat and calorie content [8-10]. In their study, Wahjuningsih et al. [11] discovered that sago starch has a glycaemic index (GI) of 40.7, indicating a low GI value. Additionally, they revealed that sago starch contains 12.5% resistant starch.

According to Pinto et al. [12] and Ranasinghe et al. [13], raw ripe jackfruit is rich in carbohydrates, proteins, fibre, vitamins, and minerals. The levels of carbohydrate and fibre in jackfruit flesh rise as it matures. Jackfruit is rich in many amino acids, including arginine, cystine, histidine, leucine, lysine, methionine, threonine, and tryptophan [13-14]. Ocloo et al. [10] found that jackfruit seed flour has a high carbohydrate content ranging from 74% to 81.6%, which contributes to its high energy value. The protein content of jackfruit seed flour varies between 6.34% and 31.9%. The fibre content in seed flour ranges from 2.36 to 3.19%.

The objective of incorporating sago pellets into the nutrition bar in this study is to offer customers a source of energy. Furthermore, the dry jackfruit meat and seed were utilised as substitutes for the dry fruit and nuts often included in traditional nutrition bars, thereby enhancing both the flavour and nutritional content of the bar. Meanwhile, stingless bee honey is used as a substitute for processed sugar in the nutrition bar, serving as both a sweetener and binder. Several documented researches have indicated that stingless bee honey possesses favourable chemical and physicochemical characteristics, suggesting its potential for promoting health benefits. Stingless bee honey exhibits favourable antibacterial, antioxidant, and anti-inflammatory properties, as demonstrated in studies conducted by [11; 14-15].

MATERIALS AND METHODOLOGY

Collection of Sample

Sago pellets with the Sago Medong brand were the main raw material used to make nutrition bars. Sago pellets were bought from Mukah, which is located at the central region of Sarawak. Sago pellets mainly produced using dehydrated sago flesh, desiccated coconut, and coconut milk [7]. Stingless bee honey, jackfruit flesh, and jackfruit seed are other components that can be found locally in Sibu, Sarawak.

Sample Preparation

The jackfruit pulp was sliced and the seed was taken out from it. Next, the jackfruit flesh was diced and dehydrated in the conventional oven for 4 hours at a temperature of 100°C. The seeds were boiled until soft and subsequently shaped into discs before being dried at a temperature of 100°C for a duration of 45 minutes. Figure 1 illustrates the preparation stages of the nutrition bar.

Experimental Design

This study employed a simplex lattice mixture design using Design-Expert® software (Version 10, Stat-Ease, Inc., Minneapolis, USA) to optimize the formulation of nutrition bars. The formulation consisted of four key ingredients: sago pellets, jackfruit flesh, jackfruit seed, and stingless bee honey, with the proportion of stingless bee honey fixed at 30% (w/v). The constraints of the sago pellet, jackfruit flesh and seed are listed in Table 1. A total of fourteen (14) formulations were generated by the software, as shown in Table 2. Figure 1 depicts the flow chart outlining the process of preparing a nutrition bar.

Table 1. Constraints of nutrition bar components

Components	Minimum (%)	Maximum (%)
Sago pellets	40	60
Jackfruit flesh	5	25
Jackfruit seed	5	25

The sensory evaluation by the panelists for each run was the response of the design. The sensory attributes of nutrition bar samples, including aroma, colour, sweetness, sourness, crispiness, texture, and overall acceptability, were assessed using a 9-point hedonic scale (1 extreme dislike, 2 very dislike, 3 moderately dislike, 4 slightly dislike, 5 neither like or dislike, 6 slightly like, 7 moderately like, very much like, 9 extremely like) by a panel of 30 untrained individuals. This panel consisted of undergraduate students and academic staff from the University of Technology Sarawak, Sibu. Before the test was done, the panelist was given simple briefing on the serving order in the sensory evaluation booth.

Table 2. Composition of the component's in nutrition bar formulation

Formulation	Sago pellets (%)	Jackfruit flesh (%)	Jackfruit seed (%)	Stingless bee honey (%)
1	53.33	8.33	8.33	30.00
2	40.00	25.00	5.00	30.00
3	50.00	15.00	5.00	30.00
4	60.00	5.00	5.00	30.00
5	50.00	15.00	5.00	30.00
6	46.67	11.67	11.67	30.00
7	40.00	15.00	15.00	30.00
8	40.00	25.00	5.00	30.00
9	50.00	5.00	15.00	30.00
10	40.00	5.00	25.00	30.00
11	60.00	5.00	15.00	30.00
12	40.00	5.00	5.00	30.00
13	43.33	18.33	8.33	30.00
14	43.33	8.33	18.33	30.00

The sensory evaluation data were evaluated using Design-Expert® Software (V10, Stat-Ease, Inc., Minneapolis, USA). The experimental findings were analysed using one-way analysis of variance (ANOVA) to see if there were significant differences among the means. The significance level was set at 95% confidence limits ($p < 0.05$). Ultimately, the validation experiment was conducted to confirm the effectiveness of the optimal formulation, using overall acceptability as the optimised response. The goal or objectives of this study are to measure consumer acceptance, so overall acceptability was chosen to be optimised as a single critical criterion as per previous study [16]. The validity of the optimal formulation was assessed by computing the percent error between the predicted value and the experimental value of the overall acceptability, as shown in Equation 1.

$$Percent\ error = \frac{Predicted\ value - Experimental\ value}{Predicted\ value} \times 100\% \quad \text{(Equation 1)}$$

RESULTS AND DISCUSSION

A total of 14 formulations were produced through the analysis of the Simple Lattice of Mixture Design, as presented in Table 2. The entire attributes also significant with p-value ($P<0.05$). As per Everitt [18] and Meilgaard et al. [17], a mean liking score of 7 or higher on a 9-point hedonic scale indicate highly acceptable sensory quality and represent the consumer acceptance that contribute to product market potential. Market potential refers to assessment of the possibility for a product to succeed in the market after a positive sensory acceptance, where it showed the consumer readiness to accept or consume the product, which also promises commercial potential. The high mean value above 7.00 indicates good panelist acceptance and has market potential for sago-based bars. The score (7.00) is for "like moderately", and (8) is for "like very much", showing that majority of panelists had a positive perception of the product. The outcome implies that the newly developed sago-based bar is well accepted in terms of sensory attributes like taste (sweetness and sourness), aroma and appearance (colour). Meanwhile, a contour plot of the mean score visually represents the relationship between the ingredient ratio and its impact on the attributes. The red colour indicates that the ingredients are more accepted, while the blue colour indicates the opposite.

Table 3 showed the sensory evaluation results in mean and standard deviation for the entire attributes. The most acceptable formulation is Formula 4 with the maximum mean value 7.3. Formulation 4 also has achieved the highest mean for the entire attributes. The panelist preferred more sago pellets but less jackfruit seed and flesh, as shown in Figure 2(f) for overall acceptability. Higher acceptability of its texture and taste (sourness and sweetness) based on the mean score contributes to this outcome.

Formulation 4 has a significant amount of 60% sago pellets, which directly resulted in a notably high aroma score of 7.00. The sago pellet mainly contains sago, coconut milk and desiccated coconut [7]. When it was heated during production process, it produced the aroma of sago and roasted desiccated coconut [7]. Saittagaroon et al. [19] found that the roasted coconut emitted a distinct sweet and nutty aroma when analysed using gas chromatography (GC). This is caused by the increasing amount of pyrazine compounds after the Maillard reaction in the roasted coconut [19-21]. The contour plot 2(a) also reveals that higher sago pellets are more accepted compared to jackfruit seeds (towards the blue colour).

Considering the colour attributes, the panelists were more drawn to the bar with a smaller amount of jackfruit flesh and seed, as it had a mean score of 7.70, compared to the bar with an excessive amount of jackfruit flesh and seed. This is the result of a high quantity of sago pellets giving a brighter (yellow-brownish) colour compared to jackfruit flesh (darker) and seed (white). Based on Hutchings [22], nutrition bars are generally expected to have a moderately light, uniform colour. Any deviation, such as a very dark or uneven appearance may be perceived as a quality defect, even if the flavour remains acceptable. In Figure 2(b), the white colour of the seed is not desirable compared to sago pellets.

The average sweetness score for Formulation No. 4 is 7.83, suggesting that the panelists found it preferable. This is likely because the sago pellets absorbed the sweetness of the honey, resulting in a sweet taste in the bar [21]. However, the panelists found the sourness of the stingless bee honey attractive, with an average score of 7.37. Both contour plots for sweetness and sourness have a similar disfavouring of the quantity of jackfruit (blue colour). The final attributes for this sago-based nutrition bar are texture. Formulation 4 has a 7.33 mean value. The sago pellets absorbed the stingless bee honey, resulting in a softer texture. The panel's dislike for the hard jackfruit seed is evident in contour plot 2 (e). During drying, jackfruit seeds undergo moisture loss and structural hardening, which results in a noticeably harder texture [10].

On the other hand, Formulation No.10 exhibited the lowest scores for all the attributes. The average scores for each attribute were as follows: 3.47 for aroma, 3.57 for colour, 3.77 for sweetness, 3.81 for sourness, 3.73 for hardness, and 3.00 for texture. The overall acceptability score was 3.20. Formulation No.10 contained a small quantity of sago pellets (40%), resulting in a weak aroma of roasted coconut. The low amount of sago pellet will decrease the amount of stingless bee honey absorption, make it available on the surface of the nutrition bar as binder and caramelized during the nutrition bar production. This sourness smell after the heating process is strong which was disliked by panels [15; 23]. In addition, the 25% seed content did not add to any significant smell or taste, except for a nutty flavour. The texture was extremely stiff and deemed unacceptable for the panels [10]. This resulted in formulation No. 10 being rejected.

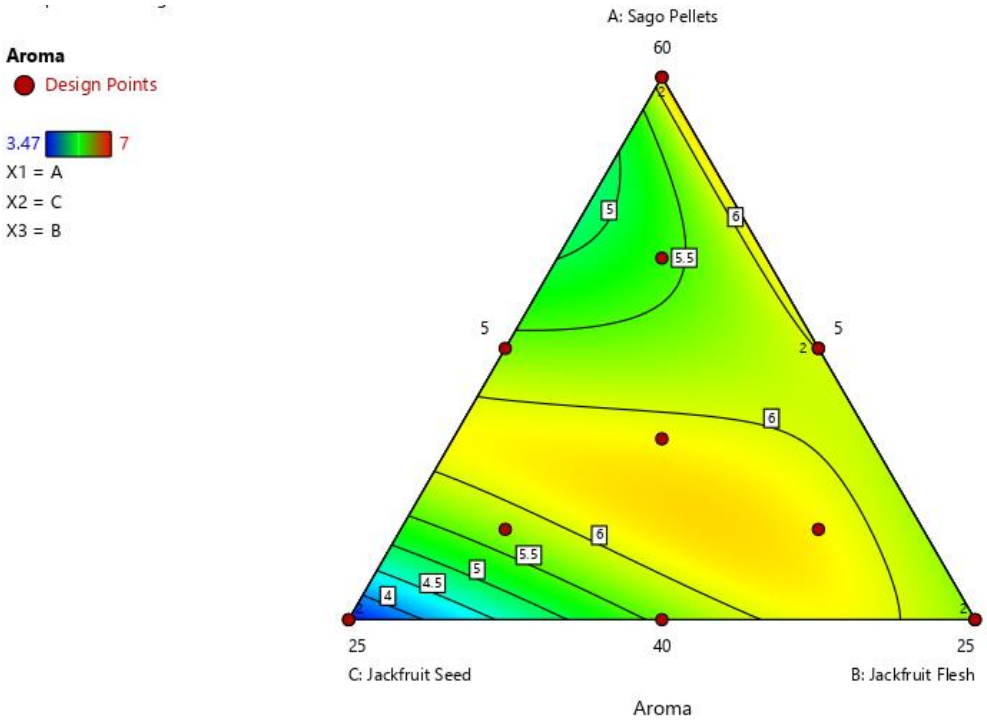
The validation and optimisation of the mixture model were carried out for a numerical optimisation with overall acceptability as a response to fulfil the product acceptance objective of this research. Table 4 gives the combination ingredients and targeted response, which is the overall acceptability that was taken into consideration for validation of the most accepted solution or formulation.

Meanwhile, Table 5 reported the numerical optimisation of 2 solutions generated by Design Expert (V10) software. The desirability of Solution 1 is 0.98 with the combination ingredients of sago pellet (46.23%), jackfruit flesh (5.00%), and jackfruit seed (18.77%). The second solution has 0.92 desirability with its component composition of sago pellet (60.00%), jackfruit flesh (5.00%), and jackfruit seed (5.00%).

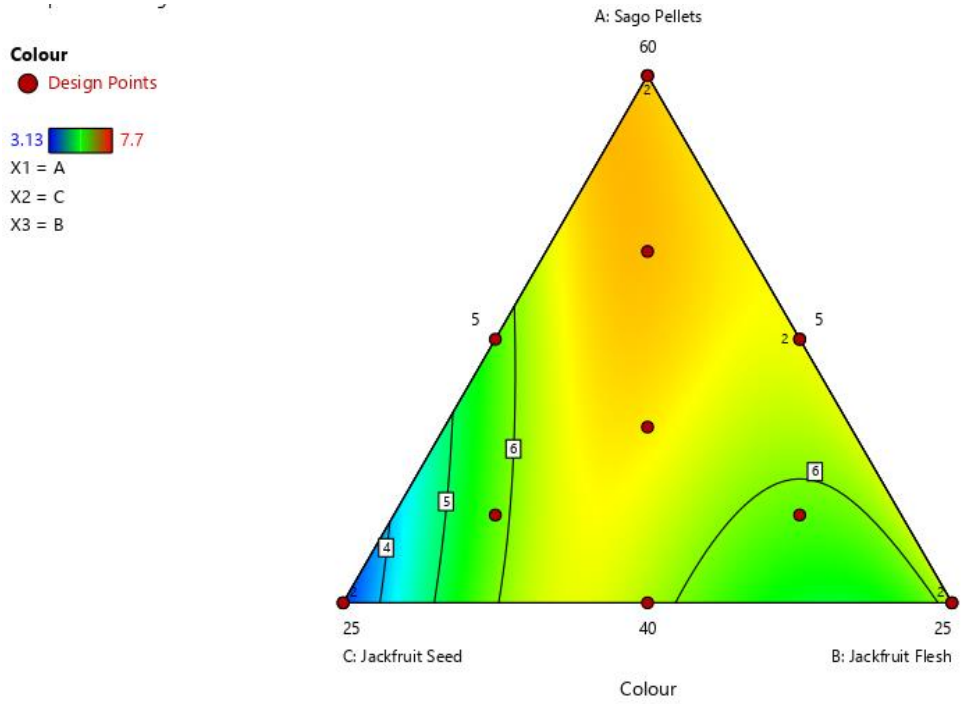
Table 3. Input factors and target for model optimisation

Formulations	Aroma	Colour	Sweetness	Sourness	Texture	Overall Acceptability
1	5.63 ± 1.87	6.57 ± 1.28	5.93 ± 1.57	5.53 ± 1.68	5.27 ± 1.48	5.27 ± 1.80
2	5.90 ± 1.12	6.23 ± 1.28	5.83 ± 1.76	5.73 ± 1.74	5.57 ± 1.72	5.73 ± 1.72
3	5.97 ± 1.50	6.17 ± 1.51	6.23 ± 2.06	5.60 ± 2.14	6.00 ± 1.64	6.33 ± 1.73
4	7.00 ± 1.51	7.70 ± 1.26	7.83 ± 1.39	7.37 ± 1.52	7.33 ± 1.78	7.30 ± 1.64
5	5.90 ± 1.37	6.43 ± 1.74	6.13 ± 1.78	6.23 ± 1.74	5.93 ± 1.48	6.27 ± 1.68
6	5.60 ± 1.52	5.97 ± 1.43	5.73 ± 1.51	5.63 ± 1.87	5.73 ± 1.72	5.43 ± 1.77
7	5.60 ± 1.48	6.13 ± 1.33	5.90 ± 1.63	3.73 ± 1.74	5.33 ± 1.54	5.50 ± 1.59
8	5.57 ± 1.59	6.33 ± 1.60	6.00 ± 1.74	6.13 ± 1.83	5.57 ± 1.59	6.10 ± 1.84
9	5.57 ± 1.74	5.80 ± 1.45	6.07 ± 1.64	6.20 ± 1.52	5.90 ± 1.67	5.93 ± 1.80
10	3.47 ± 1.76	3.57 ± 1.83	3.77 ± 1.76	3.81 ± 1.83	3.00 ± 1.76	3.20 ± 1.87
11	5.70 ± 1.74	6.23 ± 1.74	5.70 ± 1.62	5.60 ± 1.65	5.83 ± 1.76	5.93 ± 1.31
12	3.53 ± 1.83	3.13 ± 1.53	3.13 ± 1.61	3.53 ± 1.63	5.53 ± 2.00	3.19 ± 1.71
13	6.13 ± 2.11	6.07 ± 1.64	6.13 ± 1.72	5.97 ± 1.83	5.43 ± 1.85	6.37 ± 1.79
14	6.07 ± 1.84	6.07 ± 1.44	6.07 ± 1.62	5.73 ± 1.62	6.00 ± 1.51	6.43 ± 1.68

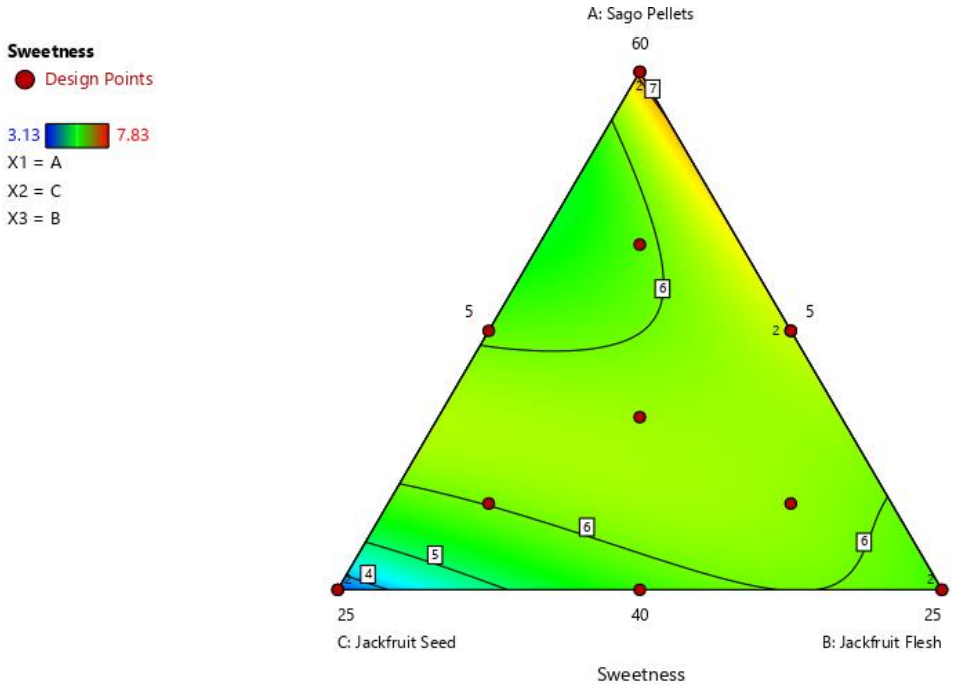
Note: Number after "+" refers to standard deviation of 30 panelists' responses


Aroma
Design Points
3.47
7
X1 = A
X2 = C
X3 = B
A: Sago Pellets
60
5
6
5.5
5
5
2
6
6
5.5
5
4.5
4
25
40
25
C: Jackfruit Seed
B: Jackfruit Flesh
Aroma

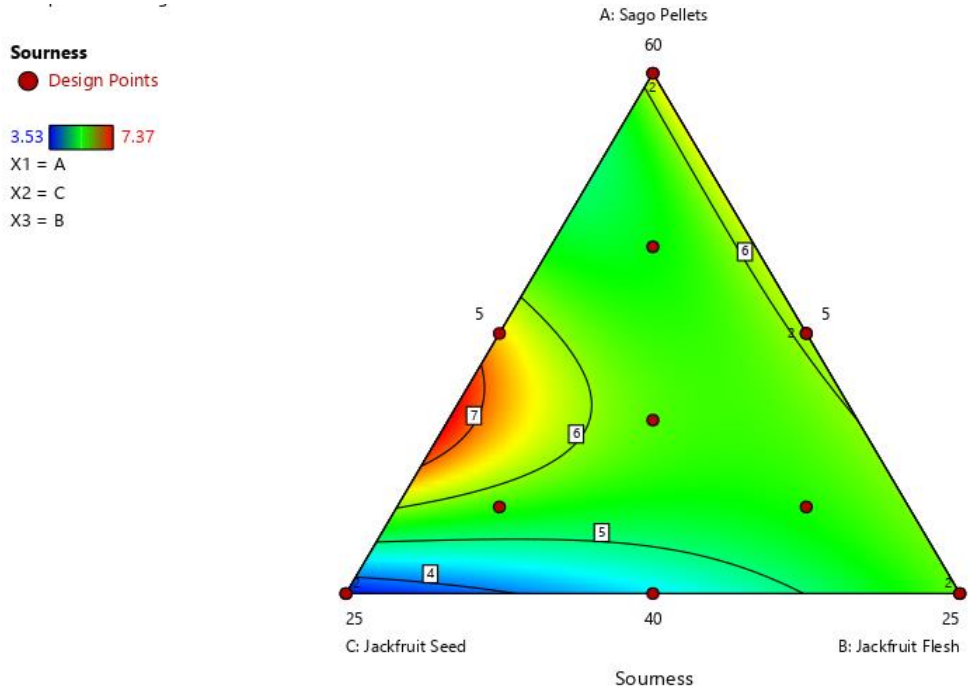
(a)


Colour
Design Points
3.13
7.7
X1 = A
X2 = C
X3 = B
A: Sago Pellets
60
2
5
5
2
6
6
5
4
25
40
25
C: Jackfruit Seed
B: Jackfruit Flesh
Colour

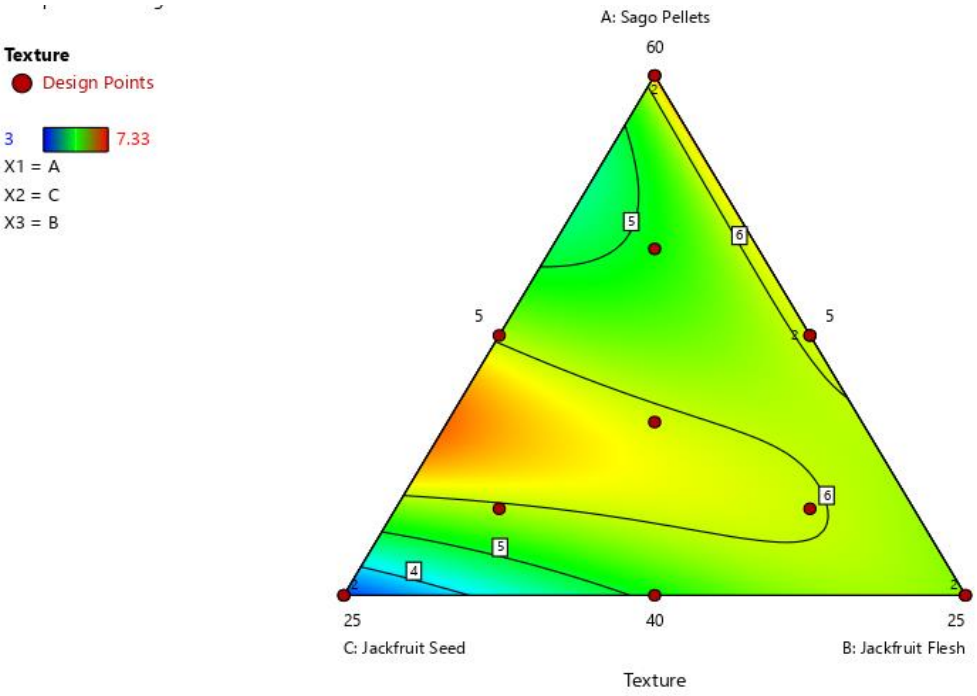
(b)


Sweetness
Design Points
3.13
7.83
X1 = A
X2 = C
X3 = B
A: Sago Pellets
60
5
5
25
40
25
C: Jackfruit Seed
B: Jackfruit Flesh
Sweetness

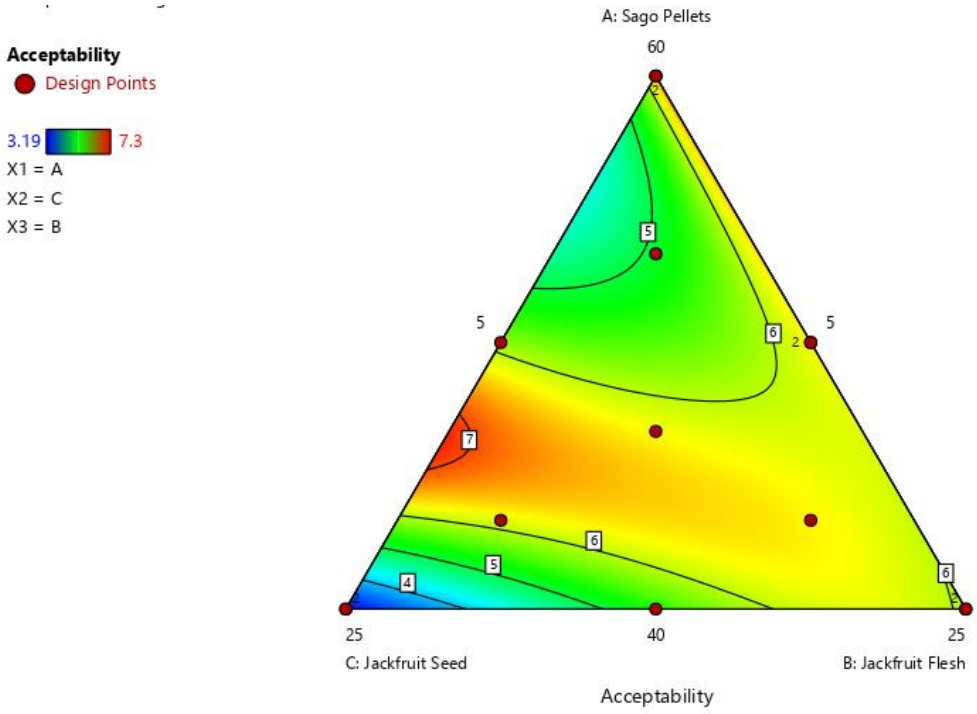
(c)


Sourness
Design Points
3.53
7.37
X1 = A
X2 = C
X3 = B
A: Sago Pellets
60
5
5
25
40
25
C: Jackfruit Seed
B: Jackfruit Flesh
Sourness

(d)



(e)



(f)

Figure 2. The contour plot of attributes of Sago-based bars.

Table 4. Input factors and target for model optimisation

Combination	Values
A: Sago pellets	Is in range (40-60%)
B: Jackfruit flesh	Is in range (5-25%)
C: Jackfruit seed	Is in range (5-25%)
Overall acceptability	Target (3.19-7.30)

Table 5. Solutions of optimised model for validation

Solutions	Combination (%)			Response	Desirability
	Sago	Jackfruit flesh	Jackfruit seed	Overall acceptability	
1	46.23	5.00	18.77	7.11	0.98
2	60.00	5.00	5.00	6.59	0.92

An additional sensory evaluation was conducted to validate the optimal mixture model. The percentage error was determined by comparing the predicted and experimental values. As shown in Table 6, Solution 2 exhibited a percentage error below 10%, which is considered acceptable, whereas Solution 1 had a higher error of 22.64%. Among the tested formulations, Solution 2 demonstrated the lowest percentage error (7.44%) and the highest mean score for overall acceptability. Thus, the validation model supports Solution 2 (equivalent to Formulation 4) as the optimal formulation, comprising 60.00% sago pellets, 5.00% jackfruit flesh, and 5.00% jackfruit seed, based on its superior sensory acceptability.

Table 6. Predicted value, experimental value, and percentage error of overall acceptability

Solution	Predicted value	Experimental value	Percentage Error (%)
1	7.11	5.50	22.64
2	6.59	6.10	7.44

CONCLUSION

The statistical analysis results demonstrate that the nutrition bar formulated with sago pellets, jackfruit, and stingless bee honey was well accepted by panelists, indicating positive consumer perception and market potential. Formulation 4 achieved high mean sensory attribute scores for aroma (7.00), color (7.70), sweetness (7.83), sourness (7.37), hardness (7.10), and texture (7.33), reflecting high acceptability. Across both rounds of sensory evaluation, Formulation 4, comprising 60% sago pellets, 5% jackfruit flesh, and 5% jackfruit seed, consistently received the highest mean of overall acceptability score (7.3). Additionally, the validation of the optimized model showed a low percentage error, further supporting the reliability and robustness of the formulation 4.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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