



Research article

Physicochemical properties and sensory evaluation of high energy cereal bar and its consumer acceptability

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ABSTRACT

This research aims to study the physicochemical and sensory evaluation of high energy cereal bars (HCB) and their consumer acceptability using logistic regression. The HCB was prepared and formulated under using a mixture design (d-optimal) experiment with three centerpoints, namely, cereals (60–66%) fruits (14–20%), and sweeteners (20–26%). The regression analysis indicated that the three main ingredients affected physicochemical properties (color value, hardness, and stickiness), chemical properties (a_w , total carbohydrate, gross energy, reducing sugar, non-reducing sugar, and total carotenoid), and sensory properties. The optimum content of cereals, fruits, and sweeteners for HCB was found to be 60.45%, 19.55%, and 20%. This indicates that puffed rice, roasted nuts, cereal seed, mixed fruits, corn syrup, and honey can provide high consumer product acceptance and purchase intention for a cereal bar and can be used to develop a high-energy cereal bar product desirable for the consumer market.

1. Introduction

Cereal bars are considered a healthy type of food because they are rich in fiber, and poor in fat content (Palazzolo, 2003). They contain a wide range of nutrients; are available in small packets or pouches; are light in weight and convenient to carry; and can be eaten at any point in time (Yadav and Bhatnagar, 2015). Every type of cereal bar possesses different characteristics and purposes which fit the trend for consumption of healthy, innovative, and practical food, which led the market of cereal bars to a gradual growth (Sharma, 2011).

New product development is essential to optimize product properties and attributes such as shape, color, appearance, flavor, and texture. Interaction of components must also be optimized to accomplish a full balance that results in exceptional quality and good acceptability (Barboza et al., 2003). There are many developments in ready to eat (RTE) cereal bars which combine different ingredients to create alternative cereal bar choices. The optimization of different cereal bar ingredients was studied in Ahmad et al. (2017); and Appelt et al. (2015); whose findings suggest that cereals, nuts, and seeds can be used to develop a high energy cereal bar which can provide energy and basic nutrients to the consumer. Additionally, Iuliano et al. (2019), and Torres et al. (2011), indicated that quinoa, amaranth, chia, genipap, and jackfruit

seed can deliver textural properties which correlate to regular cereal bar made with only cereal ingredients. Moreover, Yadav & Bhatnagar (2015) optimized corn syrup and honey to develop a cereal bar, and their results suggest that the highest overall acceptability was found with a 30% composition of corn syrup and honey. However, there are inconclusive results from the mixture of cereals, fruits, and sweeteners to achieve consumer acceptance with regards to suitable adhesion and good texture properties. The Response Surface Methodology (RSM) was then employed to explore the effect of different amounts of ingredients in the development of a cereal bar. The RSM suggested that a suitable amount of ingredients can be used and still provide a cereal bar with acceptable texture and sensory score (Srebernich et al., 2016). In closing, this research aimed to develop a high-energy cereal bar using local ingredients from the southern part of Thailand which has satisfactory texture and high product acceptance.

2. Materials and methods

2.1. Raw materials

All food ingredients in this research were purchased in Thailand. Saba chips, which were a waste product from Saba crispy snack production,

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Table 1. Experimental design of three main ingredients and Physical properties of HCB.

| Formulae | Cereals (%) ¹ | Fruits (%) ¹ | Sweetener (%) ¹ | Color value | | | Texture value (g.force) | |
|----------|--------------------------|-------------------------|----------------------------|---------------------------|---------------------------|---------------------------|-----------------------------|-----------------------------|
| | | | | L* | a* | b* | Hardness | Stickiness |
| 1 | 60.00 | 14.00 | 26.00 | 48.31 ± 0.02 ^a | 4.88 ± 0.10 ^c | 15.41 ± 0.06 ^c | 2642.79 ± 0.08 ^d | 1168.51 ± 0.36 ^d |
| 2 | 63.00 | 17.00 | 20.00 | 30.06 ± 0.10 ^f | 8.41 ± 0.04 ^b | 22.52 ± 0.22 ^b | 2663.70 ± 0.23 ^c | 1349.48 ± 1.39 ^c |
| 3 | 60.00 | 17.00 | 23.00 | 45.36 ± 0.01 ^c | 8.35 ± 0.08 ^b | 22.41 ± 0.50 ^b | 2001.02 ± 0.15 ⁱ | 1044.01 ± 0.66 ^f |
| 4 | 63.00 | 14.00 | 23.00 | 37.53 ± 0.41 ^d | 4.75 ± 0.18 ^e | 14.59 ± 0.06 ^f | 2687.73 ± 0.59 ^b | 1462.59 ± 0.27 ^b |
| 5 | 66.00 | 14.00 | 20.00 | 28.68 ± 0.49 ^g | 4.86 ± 0.07 ^e | 13.12 ± 0.12 ^g | 3560.59 ± 0.38 ^a | 1847.40 ± 0.35 ^a |
| 6 | 60.00 | 20.00 | 20.00 | 45.92 ± 0.05 ^b | 10.01 ± 0.11 ^a | 26.77 ± 0.18 ^a | 2004.10 ± 0.05 ^h | 838.46 ± 1.71 ^g |
| 7 | 62.00 | 16.00 | 22.00 | 36.56 ± 0.40 ^e | 6.62 ± 0.04 ^c | 20.90 ± 0.05 ^c | 2253.98 ± 0.11 ^e | 1053.66 ± 0.77 ^e |
| 8 | 62.00 | 16.00 | 22.00 | 36.19 ± 0.30 ^e | 6.43 ± 0.08 ^d | 20.69 ± 0.02 ^c | 2252.31 ± 0.04 ^f | 1050.47 ± 6.04 ^c |
| 9 | 62.00 | 16.00 | 22.00 | 36.58 ± 0.07 ^e | 6.68 ± 0.04 ^c | 20.10 ± 0.05 ^d | 2241.44 ± 0.51 ^g | 1055.01 ± 4.59 ^e |
| p-value | | | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

Note¹: Cereals = puffed Sung Yod rice, puffed Mur Lor rice, roasted Bambara nut, white sesame seeds, and black sesame seeds. Fruits = saba chips and chopped date. Sweetener = corn syrup and honey.

Note²: The different letter in the same column stated the statistical different at 95% confidence level ($p < 0.05$).

and Mue Lor rice were collected from Yala, Thailand. Sungyod rice, Bambara groundnut, and honey were purchased from a local market in Phatthalung, Thailand. The date palm was purchased from a local market in Hat Yai District, Songkhla, Thailand. Black and white sesame were purchased from a supermarket (Tesco Lotus, Thailand), along with the corn syrup and palm oil (Morakot, Sime Darby Oil Morakot Public CO. LTD., Thailand).

2.2. Chemicals

The carotenoid standards were obtained from Sigma–Aldrich Chemie GmbH (Steinheim, Germany). 35.4% HCl (PubChem CID 313) was acquired from LOBA CHEMIE PVT. LTD., India. Anthrone (PubChem CID 7018) was purchased from HiMedia Laboratories Pvt. Ltd., India. Acetone (PubChem CID 180) was procured from RCI Labscan, Thailand. All chemicals were analytical grade.

2.3. Preparation of HCB

The HCB was prepared from cereals, fruits, corn syrup, and honey (modified from Pallavi et al., 2015). The cereals were in a total of 66.5% (puffed Sungyod rice 19.95%, puffed Mue Lor rice 19.95%, Bambara nut 13.3%, white sesame seed 6.65%, and black sesame seed 6.65%). The fruits were in a total of 13.4% (Saba chips 6.7% and dates 6.7%). The cereals were mixed with the fruits in a stainless-steel bowl. The corn syrup (10.05%) and honey (10.05%) were heated at 70 °C for 3 min, and then added into the dry ingredients and thoroughly mixed at 70 °C with a stirring stick for 3 min. The contents were spread on a stainless-steel tray. The cereal mixture was removed from a stainless-steel tray to silicone tray and cooled to 28 °C, then cut into pieces (10 cm × 3.3 cm × 3.1 cm) of approximately 25 g. The bars were packed in polystyrene trays (24 cm × 318 cm × 34 cm) using PVC film, and stored in a cool and ventilated place until the time of analysis. The physicochemical and sensory properties were analyzed and evaluated to achieve optimal level of cereals, fruits, and sweeteners for HCB.

2.4. Just-About-Right (JAR) analysis and optimization of HCB

The basic formulation of HCB was evaluated for intensities of HCB key attributes (stickiness, color, sweetness, overall aroma, overall flavor, first bite texture, chewing texture, brittleness, and tackiness) using 5-point Just-About-Right (JAR) scales (1 = much too little, 2 = too little, 3 = just about right, 4 = too much, 5 = much too much) (Rothman, 2007). Maximum and minimum levels of independent variables (mixed cereals, mixed fruits, and sweeteners) were found through JAR analysis. The mixture design (D-optimal) was used to optimize the levels of mixed

cereals (60–66%), mixed fruits (14–20%), and sweetener (20–26%) and their effect on dependent variables. Nine HCB formulations were produced and runs 7, 8, and 9 corresponded to center point replicates (Table 1).

2.5. Water activity determination

The water activity (a_w) was determined using a hygrometer (Aqualab, Decagon 3TE, USA) at 25 °C. The HCB was crushed, ground, and weighed (0.5 g) before determination. The analysis was done in triplicate.

2.6. Color values (L^* , a^* , b^*) measurement

Color values, the L^* (lightness), a^* (red intensity), and b^* (yellow intensity) of the cereal bars were measured using a Colorimeter (Color Global, Color Quest XE, USA), according to CIEL*a*b* system, using spectral reflectance included as a calibration mode, illuminant D65, and an observation angle of 108.

2.7. Texture profile analysis on HCB

The cereal bars were subjected to texture analysis using a TA-TX2 Texture Analyzer (Stable Micro Systems Ltd., Surrey, England) with a load cell of 25 kg. The compression force and hardness of the product were measured with a flat ended 6 mm cylindrical aluminum probe (P/6). The force (N) applied was set to 6 mm compressive force corresponding to a deformation of 50%. The configuration parameters were distance: 6.00 mm, pre-test speed: 2.00 mm/s, test speed: 1.00 mm/s, post-test speed: 10.0 mm/s. Each sample was analyzed separately in 10 replications.

2.8. Total carbohydrate

The Saba cereal bar was analyzed for the total starch content following the method from Arora et al. (2008). The cereal bar sample (ground and sieved; 1.0 ± 0.05 g) was hydrolyzed by boiling it with 10 mL of 1 N HCl for 30 min in a glycerine bath at 112–115 °C. The extract was filled out to a final volume of 100 ml with double distilled water (DDW). Starch estimation was carried out on the extract using the anthrone method, and the absorbance at 620 nm was measured using a spectrophotometer.

2.9. Total sugar, reducing sugar, non-reducing sugar

Total sugar, reducing sugar, and non-reducing sugar (NRS) contents were also determined by a Lane & Eynon titration using Fehling's solution as described in AOAC (2019) method no. 925.35.

2.10. Total carotenoid content

The sample from each cereal bar (1.0 g) was ground with a mortar and pestle, then filled with 5 mL of 80% acetone, and filtered using Whatman paper No. 1. The sample was then washed with 80% acetone and filtered four times. The filtrate was collated and adjusted to the final volume of 25 ml with 80% acetone. The collected solution was taken to measure the absorbance at three different wavelengths (480, 663, and 645 nm) using a spectrophotometer by keeping 80% acetone as blank. The carotenoid content was calculated from the following equation (Eq.1).

$$\text{Total carotenoid} = [A_{480} + (0.114 \times A_{663}) - (0.638 \times A_{645})] \times \frac{V}{1000 \times W} \quad (\text{Eq.1})$$

where A = absorbance at given wavelength; V = final volume of 80% acetone in mL, and W = weight of sample in grams.

2.11. Gross energy determination

The gross energy (GE) of the HCB samples was determined by using a ballistic bomb calorimeter (Yoshida Seisakusho Co. Ltd, Tokyo, Japan). The sample (1.0 g) was ground in a micro-mill to pass a 1.5 mm diameter mesh screen and dried at 50 °C overnight. The weighed sample was placed into a nickel crucible and ignited in the bomb filled with oxygen. After firing the bomb, the galvanometer was stabilized for at least 3 min before taking the reading.

2.12. Sensory evaluation of the optimized HCB

Consumers were recruited from the students and staff of Prince of Songkla University, Hat Yai, Thailand. Written informed consent was obtained from all participants before the experiment was conducted. All participants signed and returned their consent form to the research team to ensure the consent of the participant before participating in the study. This study was conducted according to the guidelines presented in the Declaration of Helsinki. All sensory evaluations were performed under the same protocol, which was approved by the Office of Human Research Ethics Committee, Health Sciences, Prince of Songkla University (Approval No: HSc-HREC-61-10-04-1).

The sensory evaluation of HCB was prepared for product preference (n = 60) and consumer acceptance (n = 400) using untrained consumers (Yamane, 1967). It was carried out using a 9-point hedonic scale (Meilgaard et al., 2007) on appearance, color, aroma, flavor, texture, stickiness, aftertaste, and overall liking. To unify the conditions of the evaluation, all samples were prepared in disposable closed lid plastic cups coded with a three-digit number, evaluated by each panelist in a monadic order, following a balanced-incomplete box design (Stone et al., 2020). The samples were served in three sessions consisting of 3–4 samples for each round, and served in random order to each panelist. During the test, the panelists were asked to pause between the sample and cleanse their palate with prepared tap water at room temperature. The evaluation was performed in individual air-conditioned booths (25 °C) under white light at the Sensory Evaluation and Consumer Testing Unit (Department of Food Technology, Faculty of Agro-Industry, Prince of Songkla University, Songkhla, Thailand).

2.13. Statistical analysis

All data were analyzed in triplicate and reported as mean ± standard deviation. The statistical analysis was conducted using SPSS 11.0 (SPSS Inc., IBM Corp., IL, USA) using Duncan's multiple range test (DMRT) with a significant level determined at a 95% confidence limit. The regression analysis on RSM to indicate the optimal content of mixed cereal, mixed

fruit, and sweetener was employed using Design Expert 6.0 (Stat Ease Inc., MN, USA).

3. Results and discussion

3.1. JAR analysis of HCB

The HCB was analyzed to identify potential directions for product development. All of the untrained panel (n = 60) were familiar with cereal bar products. The panel evaluated HCB attributes (appearance, color, overall aroma, overall flavor, texture while chewing, crispiness, brittleness, and tackiness) using 5-point Just-About-Right (JAR) scales. Generally, at least 70% of responses should be at the JAR level to conclude that a specific attribute is at its optimal level (Xiong and Meullenet, 2006). The color, and texture while chewing, were found to be at the just-right level (75.0 and 81.67). The other attributes were carried through the net effect calculation to indicate the specific attribute that should be improved. Generally, at least 20% of responses should be excluded from the selection to be improved (Lawless and Heymann, 2010). Three attributes had a net effect higher than 20%, namely, sweetness (50.0%), overall aroma (21.7%), and overall flavor (38.3%). The magnitude percentage of sweetness and overall aroma was shifted toward *much to increase* whereas the magnitude percentage of overall flavor was shifted toward *much to decrease*. The factors that affected those attributes were cereals, fruits, and sweeteners as suggested in the research from Pallavi et al. (2015). As a result, the JAR and net effect results were coherent with the sensory evaluation for HCB. The preference rating score was found to be lower than 7.0. Typically, a mean preference rating score of 7 or higher on the 9-point hedonic scale is indicative of highly acceptable sensory quality. To increase the preference rating score, three factors (cereals, fruits, and sweeteners) were considered as the main factors for the optimization of HCB.

3.2. Optimization of cereals, fruits, and sweeteners in HCB using response surface methodology (RSM)

3.2.1. Color measurement

All the color values were observed and showed significant differences among treatments (Table 1). The L* value was changed significantly by decreasing the cereal and increasing the fruit amount, due to the pigment in colored rice and fruits causing the lightness to be altered (Cömet et al., 2019). Similar behavior was observed for the a* value representing the red (positive values) and green (negative values) colors, and b* value which defines the yellow (positive values) and blue (negative values) colors. The a* and b* value from HCB exhibited significant differences as a result of all treatments. Increasing the amount of fruit ingredients increased both the a* and b* value, because of the variables related to the quantities of components in the product (Lins et al., 2014).

3.2.2. Hardness and stickiness

The textural properties (hardness and stickiness) of HCB in this study increased when cereals and sweeteners were increased. Higher amounts of cereals and sweeteners caused the HCB to be harder, stickier, and more intact, unlike HCB with a lower amount of cereals and sweeteners (p ≤ 0.05) (Table 1). Divergent ingredients (cereals and mixed fruits) particles, moisture content, and variation of sweeteners can all cause the hardness to be diversified. Additionally, high amounts of honey, corn syrup, and date palm fruit can increase the hardness and stickiness of HCB due to the elevated moisture absorption of liquid sugar and sucrose from date fruit, which exhibits high hygroscopic properties in HCB. The addition of these sweeteners can affect the solid cohesion of HCB ingredients due to the strong formation of sugar networks which requires higher penetration forces. Related results can be found in the development of cereal and granola bars prepared using sucrose alternatives (Sethupathy et al. 2020; Torres et al., 2011; Yadav and Bhatnagar, 2015). In this study, increasing sweeteners caused the cereal bar to have a soft

and sticky texture because of the hygroscopic nature of polysaccharides that results in absorption of moisture (Shourideh et al., 2012). However, high values of hardness and stickiness are undesirable characteristics of cereal bars. Therefore, a suitable amount of cereals and sweetener must be used to provide appropriate hardness and stickiness, to make the product more desirable.

3.2.3. Water activity

Water activity was found to be in the range of 0.37–0.50 and significantly different between treatments. Water activity determination was done to estimate available water in foods. Water activity will predict the growth of undesirable microbes, give indication of potential food hazards, regulate packaging requirements, and influence food packaging standards (Agbaje et al., 2016). The highest water activity (0.50) was observed in formulation 2, which contained the highest quantity of sweetener (26%). The lowest water activity (0.37) was in formulation 1 which had the lowest amount of sweetener (20%). Generally, cereal bars prepared with sugar showed lower water activity (0.1–0.6), whereas cereal bars prepared without added sugar showed water activity above 0.7. The sorption isotherms of low-sugar bars with both lower and higher water activity than 0.5 were practically identical. Clear differentiation in the isotherms can be observed when compared to cereal bars without sugar. A sudden increase of the water activity (>0.6) was also observed in cereal bars prepared with alternative sweeteners, compared to a gradual increase in bars with sugar (Pallavi et al., 2015).

3.2.4. Total carbohydrate

The carbohydrate content of the samples ranged from 39.64–64.26 g/100g sample (Table 2). The results in this study were comparable with the high carbohydrate content generally found in cereal bars formulated with cereals and fruits; cereal bars with cream nuts (*Lecythis prinos* Camb.) (63.9%), cereal bar with Sterculia seeds (*Sterculia striata*) (70.7%), cereal bar with tonka beans (*Dipteryx lacunifera* Ducke) (69.3%) (Carvalho, 2008), and gluten-free cereal bar with pseudo-cereal cultivars (68.33–71.57%) (Souza et al., 2014). There are many studies on cereal bars made with puffed rice, cereals, and fruits that contain a high carbohydrate content (Freitas and Moretti, 2006). In addition, the incorporation of honey and sugar syrup in cereal bars as binding agents can contribute to the high content of carbohydrates (Agbaje et al., 2016).

3.2.5. Total sugar, reducing sugar, and non-reducing sugar

The total, reducing, and non-reducing sugar in the HCB was in the range of 10.13–38.19%, 4.08–15.44%, and 6.12–22.95% respectively (Table 2). The differences in sugar content can be explained by the different amounts of sweeteners and fruits in HCB as explained in Megala and Hymavathi (2011). Moreover, there was a higher amount of reducing sugar and a lower amount of non-reducing sugar which is inconsistent with Megala and Hymavathi (2011). This incident happened because the HCB in this study contained puffed rice and date fruits which can provide high reducing sugar content and low non-reducing sugar content. The results also suggested that the increase in sugar content can be observed after the addition of cereals, fruits, and sweeteners in HCB.

3.2.6. Gross energy of HCB

The gross energy of the HCB in this research varied between 481.35–679.87 kcal/100g (Table 2). The gross energy from this study was higher than other studies on cereal bars from cereals and fruits. HCB formulation 3 provided the highest gross energy (679.87 kcal/100g) whereas formulation 1 provided the lowest gross energy (481.35 kcal/100g). On the other hand, many studies reported lower gross energy from cereal bar made with Baru pulp and almond (337.37 kcal/100g), cereal bar made with Macauba nuts (348.66 kcal/100g), cereal bars with cream nut, Sterculia seed, Tonka bean, and pineapple peel

Table 2. Chemical properties of HCB.

| Formulæ | Cereals (%) | Fruits (%) | Sweetener (%) | a_w | Total carbohydrate (g/100g) | Gross energy (Kcal/100g) | Total sugar (%) | Reducing sugar (%) | Non reducing sugar (%) | Total carotenoid ($\mu\text{g}/100\text{g}$) |
|---------|-------------|------------|---------------|---------------------------|-----------------------------|-----------------------------|---------------------------|----------------------------|---------------------------|--|
| 1 | 60.00 | 14.00 | 26.00 | 0.37 ± 0.01 ^e | 64.26 ± 0.03 ^a | 481.35 ± 0.22 ^a | 38.19 ± 0.20 ^a | 15.44 ± 0.04 ^a | 22.95 ± 0.11 ^h | 581.60 ± 0.07 ^h |
| 2 | 63.00 | 17.00 | 20.00 | 0.50 ± 0.01 ^a | 54.29 ± 0.11 ^g | 588.08 ± 0.07 ^c | 27.68 ± 0.06 ^e | 11.08 ± 0.12 ^d | 16.64 ± 0.13 ^c | 2696.41 ± 0.19 ^f |
| 3 | 60.00 | 17.00 | 23.00 | 0.44 ± 0.01 ^{bc} | 49.06 ± 0.09 ^c | 679.87 ± 0.04 ^{ef} | 37.44 ± 0.23 ^b | 15.00 ± 0.10 ^b | 22.46 ± 0.01 ^a | 2959.39 ± 0.07 ^b |
| 4 | 63.00 | 14.00 | 23.00 | 0.44 ± 0.02 ^{bc} | 48.57 ± 0.18 ⁱ | 504.84 ± 0.01 ^f | 27.17 ± 0.11 ^e | 10.87 ± 0.02 ^d | 16.33 ± 0.07 ^d | 630.30 ± 0.05 ^g |
| 5 | 66.00 | 14.00 | 20.00 | 0.43 ± 0.01 ^d | 57.31 ± 0.14 ^h | 489.58 ± 0.04 ^b | 10.13 ± 0.03 ^f | 4.08 ± 0.02 ^e | 6.12 ± 0.83 ^g | 741.56 ± 0.01 ^f |
| 6 | 60.00 | 20.00 | 20.00 | 0.44 ± 0.01 ^{bc} | 39.64 ± 0.06 ^b | 650.48 ± 0.37 ^e | 37.80 ± 0.05 ^b | 15.12 ± 0.12 ^{ab} | 22.65 ± 0.53 ^b | 4853.35 ± 1.71 ^a |
| 7 | 62.00 | 16.00 | 22.00 | 0.43 ± 0.03 ^c | 48.99 ± 0.10 ^f | 495.00 ± 0.68 ^{ef} | 27.98 ± 0.16 ^c | 11.03 ± 0.46 ^c | 17.33 ± 0.21 ^e | 1994.73 ± 1.12 ^d |
| 8 | 62.00 | 16.00 | 22.00 | 0.44 ± 0.01 ^{bc} | 49.13 ± 0.17 ^d | 492.85 ± 0.09 ^e | 28.81 ± 0.10 ^c | 11.63 ± 0.16 ^c | 17.38 ± 0.07 ^f | 1972.07 ± 18.72 ^e |
| 9 | 62.00 | 16.00 | 22.00 | 0.46 ± 0.01 ^b | 49.75 ± 0.04 ^e | 505.07 ± 0.28 ^d | 28.45 ± 0.11 ^d | 11.33 ± 0.26 ^c | 17.34 ± 0.10 ^d | 1976.69 ± 9.86 ^e |
| p-value | | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

Note: The different letter in the same column stated the statistical different at 95% confidence level ($p < 0.05$).

Table 3. Sensory evaluation of HCB.

| Formulae | Cereals (%) | Fruits (%) | Sweetener (%) | Appearance | Color | Aroma | Flavor | Sweetness | Texture | Stickiness | Aftertaste | Overall liking |
|----------|-------------|------------|---------------|--------------------------|--------------------------|------------------------|--------------------------|-------------------------|------------------------|-------------------------|--------------------------|-------------------------|
| 1 | 60.00 | 14.00 | 26.00 | 7.4 ± 0.8 ^a | 7.4 ± 0.8 ^a | 7.3 ± 0.9 ^a | 6.9 ± 0.9 ^a | 7.0 ± 1.1 ^{ab} | 6.9 ± 0.9 ^a | 6.7 ± 1.2 ^a | 6.6 ± 1.1 ^a | 7.1 ± 1.1 ^a |
| 2 | 63.00 | 17.00 | 20.00 | 7.3 ± 0.9 ^{ab} | 7.2 ± 1.0 ^{ab} | 6.7 ± 1.1 ^b | 6.9 ± 1.1 ^{ab} | 7.2 ± 1.2 ^a | 4.7 ± 1.4 ^d | 5.6 ± 1.3 ^{cd} | 6.5 ± 1.2 ^{ab} | 7.1 ± 0.8 ^a |
| 3 | 60.00 | 17.00 | 23.00 | 7.2 ± 0.9 ^{abc} | 7.0 ± 1.0 ^{bc} | 6.7 ± 1.1 ^b | 6.7 ± 1.1 ^{abc} | 7.3 ± 1.2 ^a | 5.5 ± 1.3 ^c | 5.5 ± 1.3 ^d | 6.6 ± 1.2 ^a | 5.0 ± 1.4 ^e |
| 4 | 63.00 | 14.00 | 23.00 | 6.8 ± 0.9 ^d | 6.8 ± 1.0 ^{bc} | 6.5 ± 1.1 ^b | 6.5 ± 1.1 ^{abc} | 6.4 ± 1.2 ^c | 6.5 ± 1.3 ^a | 5.0 ± 1.4 ^e | 6.3 ± 1.2 ^{abc} | 5.4 ± 1.0 ^e |
| 5 | 66.00 | 14.00 | 20.00 | 6.9 ± 0.9 ^{bcd} | 6.8 ± 1.0 ^{bc} | 6.5 ± 1.1 ^b | 6.6 ± 1.1 ^{abc} | 6.6 ± 1.2 ^{bc} | 6.6 ± 1.3 ^a | 6.4 ± 1.3 ^{ab} | 6.4 ± 1.2 ^{abc} | 6.6 ± 0.9 ^b |
| 6 | 60.00 | 20.00 | 20.00 | 6.9 ± 0.9 ^{cd} | 6.8 ± 1.0 ^c | 6.5 ± 1.1 ^b | 6.6 ± 1.1 ^{abc} | 7.4 ± 1.2 ^a | 6.7 ± 1.3 ^a | 6.3 ± 1.3 ^{ab} | 6.0 ± 1.2 ^c | 6.7 ± 1.1 ^{bc} |
| 7 | 62.00 | 16.00 | 22.00 | 7.0 ± 0.9 ^{bcd} | 6.8 ± 0.9 ^{bc} | 6.6 ± 1.1 ^b | 6.5 ± 1.1 ^{bc} | 6.3 ± 1.2 ^c | 5.9 ± 1.3 ^c | 6.1 ± 1.2 ^b | 6.3 ± 1.2 ^{abc} | 6.1 ± 1.0 ^d |
| 8 | 62.00 | 16.00 | 22.00 | 6.9 ± 1.0 ^{cd} | 6.9 ± 0.9 ^{bc} | 6.6 ± 1.1 ^b | 6.3 ± 1.1 ^c | 6.2 ± 1.2 ^c | 5.9 ± 1.3 ^c | 6.0 ± 1.3 ^{bc} | 6.1 ± 1.2 ^{bc} | 6.2 ± 1.2 ^{cd} |
| 9 | 62.00 | 16.00 | 22.00 | 7.0 ± 0.9 ^{bcd} | 7.1 ± 1.0 ^{abc} | 6.7 ± 1.1 ^b | 6.7 ± 1.1 ^{abc} | 6.4 ± 1.1 ^c | 5.9 ± 1.4 ^c | 6.1 ± 1.2 ^{bc} | 6.6 ± 1.0 ^{bc} | 6.1 ± 1.1 ^d |
| p-value | | | | 0.002 | 0.001 | 0.002 | 0.035 | <0.001 | <0.001 | <0.001 | 0.009 | <0.001 |

Note: The different letter in the same column stated the statistical different at 95% confidence level ($p < 0.05$).

Table 4. Regression equation for the responses of HCB from response surface methodology.

| Responses | Regression equation | R-square | p-value |
|-----------------------------|--|----------|----------|
| L* | +4.13*A +46.12*B +3.46*C -0.812*AB -0.11*AC -0.20*BC | 0.9993 | <0.0001* |
| a* | -0.08*A +0.89*B -0.09*C | 0.9462 | <0.0001* |
| b* | -1.94*A -16.68*B -1.61*C +0.31*AB +0.05*AC +0.17*BC | 0.9930 | 0.0005* |
| Hardness (g.force) | -1048.01*A -13160.21*B -6504.24*C +253.25*AB +140.51*AC +763.47*BC | 0.9998 | 0.0001* |
| Stickiness (g.force) | -3141.57*A -30272.16*B -19381.34*C +581.99*AB +401.84*AC +1748.29*BC | 0.9999 | <0.0001* |
| A _w | -0.35*A -3.01*B -1.92*C +0.06*AB +0.04*AC +0.16*BC | 0.9968 | 0.0024* |
| Total carbohydrate (g/100g) | +7.31*A -45.14*B +77.13*C +0.63*AB -1.38*AC -0.34*BC | 0.9969 | 0.0001* |
| Gross energy (Kcal/100g) | -1522.15*A -14471.63*B -9477.67*C +277.29*AB +194.85*AC +838.50*BC | 0.9927 | 0.0055* |
| Total sugar (%) | -49.10*A -404.39*B -263.49*C +8.00*AB +5.64*AC +22.69*BC | 0.9977 | 0.0017* |
| Reducing sugar (%) | -0.55*A +1.19*B +1.22*C | 0.9562 | <0.0001* |
| Non-reducing sugar (%) | -0.82*A +1.79*B +1.81*C | 0.9630 | <0.0001* |
| Total carotenoid (µg/100g) | -91.28*A +612.24*B -95.07*C | 0.9935 | <0.0001* |
| Aroma | +6.65*A -104.01*B +237.31*C +8.00*AB -334.52*AC -343.78*BC | 0.8446 | 0.0453* |
| Sweetness | -8.86*A -85.01*B -52.35*C +1.64*AB +1.09*AC +4.87*BC | 0.9447 | 0.0409* |
| Texture | +11.38*A +108.09*B +63.17*C -2.05*AB -1.32*AC -5.66*BC | 0.9992 | 0.0006* |
| Stickiness | +16.68*A +143.01*B +99.57*C -2.77*AB -2.06*AC -8.19*BC | 0.9899 | 0.0076* |
| Overall liking | +9.53*A +82.63*B +65.11*C -1.57*AB -1.29*AC -5.06*BC | 0.9947 | 0.0158* |

Note: A = Cereals, B=Fruits, C=Corn syrup and honey.

(407.50–434.00 kcal/100g), gluten-free cereal bars with pseudo-cereal cultivars (180.39 kcal/100g) (Agbaje et al., 2016; Carvalho, 2008; Lima et al., 2010). The gross energy from those cereal bars was significantly lower than HCB in this study. This can be attributed to the high content of puffed rice and fruit contents which led to a higher cereal to fruit ratio (Agbaje et al., 2016). Thus, the cereal bar composed of puffed rice, fruits, and sweetener can be considered a high gross energy value cereal bar.

3.2.7. Total carotenoid content

The total carotenoid content was analyzed as a function parameter because carotenoids can be found in the main ingredients (puffed rice, banana, and dates) of HCB (Steingass et al., 2020). The total carotenoid content in the HCB of this study was significantly different among the different treatments and ranged from 581.60 ± 0.07 to 4853.35 ± 1.71 µg/100g (Table 2). As can be seen on Table 2, HCB formulation 6 showed the highest content of total carotenoid (4853.35 ± 1.71 µg/100g) followed by formulation 3 (2959.39 ± 0.07 µg/100g) and formulation 2 (2696.41 ± 0.19 µg/100g) because in formulation 6 the combination of cereals and fruits was higher, and the sweetener was lower than other formulations. The high content of cereals and fruits, along with the low content of sweetener (resulting in low water activity), can increase the total carotenoid content. Carotenoid compounds can be detected when the product contains a high content of carotenoid source product in a low water activity environment (Mezzomo and Ferreira, 2016).

3.2.8. Sensory evaluation

The HCB showed sensory rating scores in the range from dislike slightly to like very much: appearance (6.8–7.4), color (6.8–7.4), aroma (6.5–7.3), flavor (6.3–7.4), texture (4.7–6.9), stickiness (5.5–6.7), aftertaste (6.0–6.6), and overall liking (5.0–7.1) as shown in Table 3. The sensory evaluation results indicate that the combination of cereals, fruits, and sweeteners in the cereal bar affected the preference rating score of HCB. The increase of cereals, fruits, and sweeteners caused the preference rating score to increase individually, however, the increase of cereals to more than 63% of the formulation caused a decrease in preference rating score. Table 3 also shows that formulation 1 provided a higher preference rating score than other formulations because of the low content of cereals and fruits and the high content of sweeteners. Many studies revealed the same direction as this research. The development of HCB using different types of cereals such as fruit pulp, cereal kernel, toasted rice, puffed rice, quinoa, flaxseed, and almond can provide a distinct appearance, aroma, and flavor with a high preference rating score and overall acceptability as suggested in Srebemich et al. (2016) and Kaur et al., (2018). In addition, HSB with oligosaccharides and sweeteners can provide high consumer acceptability without compromising on taste and texture, and provide exceptional consumer acceptability (Megala and Hymavathi, 2011).

3.2.9. Regression model fitting for HCB optimization

The physicochemical and sensory properties of HCB were carried over to obtain the optimal content of cereals, fruits, and sweeteners using

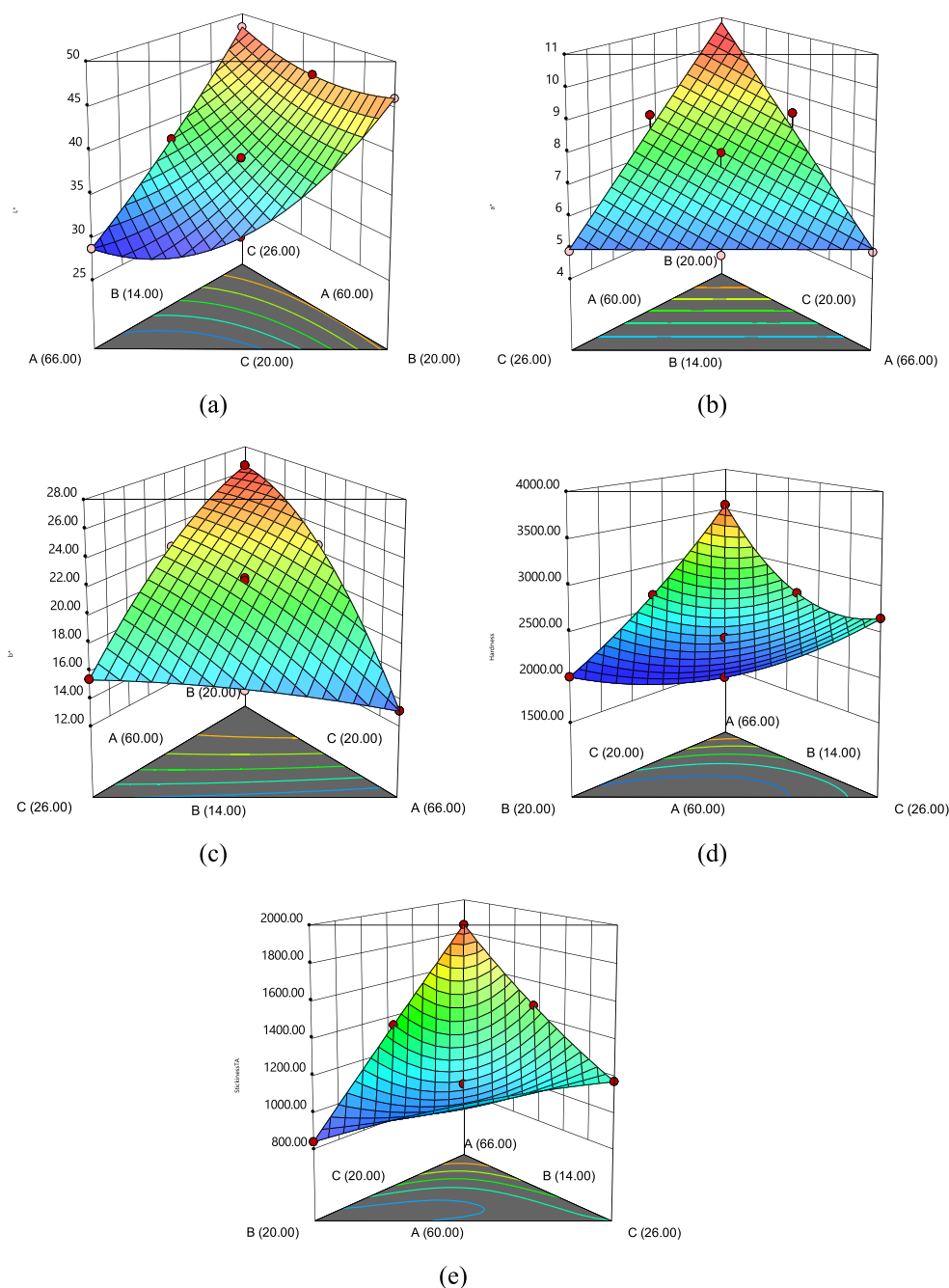


Figure 1. The response surfaces demonstrate regression model between cereals (A), fruits (B), and sweetener (C) of (a) L^* value, (b) b^* value, (c) a^* value, (d) hardness, and (e) stickiness.

RSM. There were 17 responses from the HCB that can be established via the regression model. There were four responses (L^* , reducing sugar, non-reducing sugar, and total carotenoid) that can be fitted to the linear regression model whereas the rest were fitted to the quadratic model with interaction effects. Cereals, fruits, and sweeteners individually affected color value (L^* , a^* , and b^*), hardness, stickiness, a_w , total carbohydrate, gross energy, reducing sugar, non-reducing sugar, total carotenoid content, and sensory attributes (sweetness, texture, stickiness, and overall liking). However, cereals with sweeteners mixture and fruits with sweeteners mixture also separately affected toward aroma attribute as shown in Table 4.

The color value (L^* , a^* , and b^*), hardness, and stickiness were mainly affected by fruit content. Increasing fruit content increased the L^* and a^* value and decreased the b^* value, hardness, and stickiness.

Nevertheless, the mixture of cereals, fruits, and sweeteners affected the L^* to be increased while the b^* was decreased as shown in Figure 1a and Figure 1c. Increasing the content of dry ingredients and fruits can cause the lightness to increase and cause the product to present a higher yellow color as suggested by Pallavi et al. (2015) and (Srebernich et al., 2016). In addition, cereals, fruits, and sweeteners caused the hardness and stickiness to be decreased when added alone. However, when added in combination, those ingredients, particularly fruits and sugar, caused the hardness, and stickiness to increase as shown in Fig. 1d and Fig. 1e. The increase in hardness and stickiness occurred due to the migration of moisture between the carbohydrates (such as starches, pectins, sugars, and maltodextrin) and the proteins (Srebernich et al., 2016).

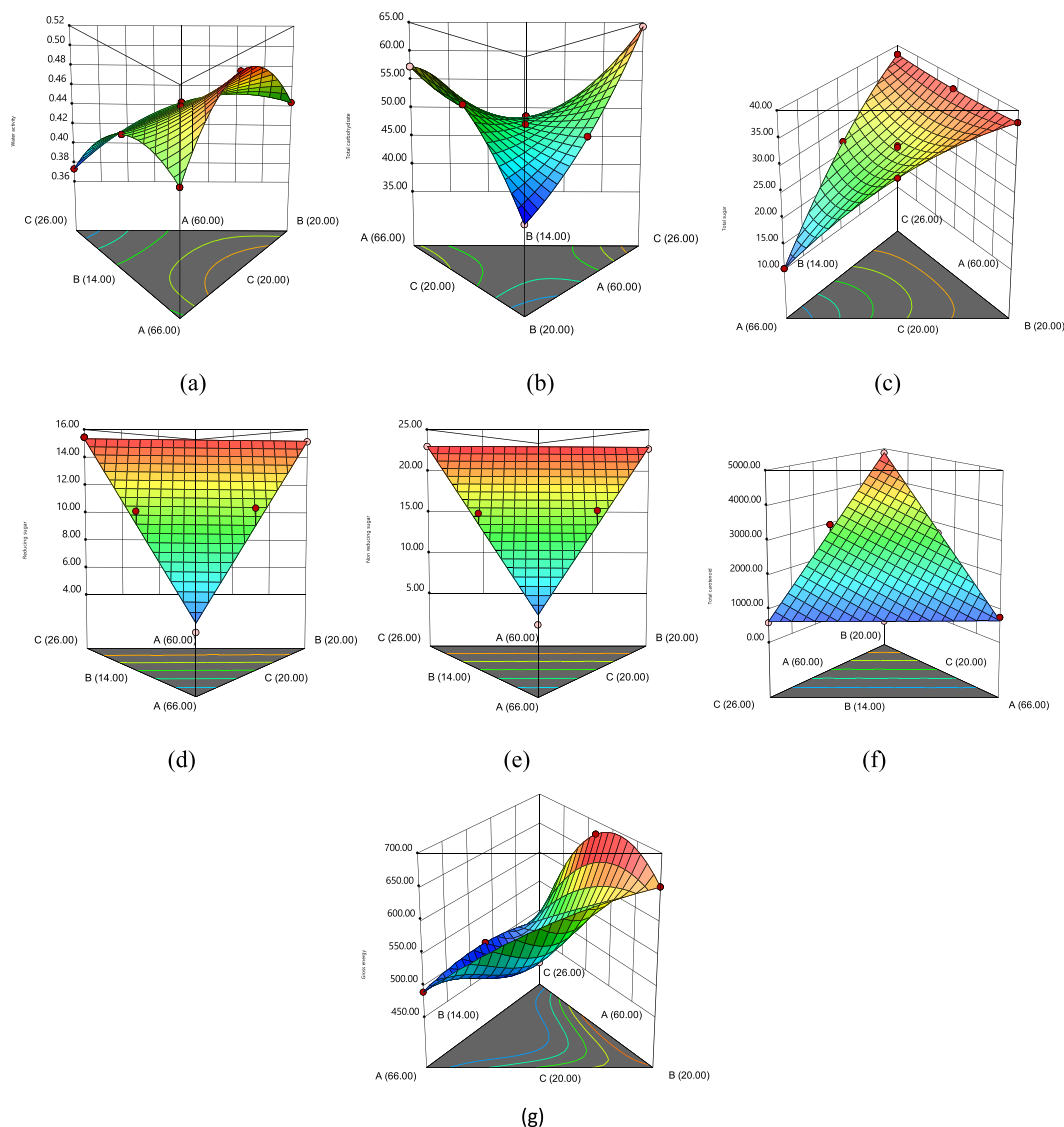


Figure 2. The response surfaces demonstrate regression model between cereals (A), fruits (B), and sweetener (C) of (a) water activity, (b) total carbohydrate content, (c) total sugar, (d) total reducing sugar, (e) total non-reducing sugar, (f) total carotenoid content, and (g) gross energy.

The chemical properties (total carbohydrate, reducing sugar, non-reducing sugar, and total carotenoid) were affected by fruits or sweeteners, while the water activity, gross energy, and total sugar were affected by the interaction effect of cereals, fruits, and sweeteners. The composition of fruits and sweeteners consisting of glucose or fructose plays a role in a product's food chemical properties. Depending on the food system in which it is incorporated, the greater relative glucose or fructose (i.e. sugar or tetraterpene (carotenoid)) in fruits and sweeteners can particularly affect all the chemical content when used at higher concentrations, in highly acidic solutions, or in baked/cooked systems (Clemens et al., 2016). Increasing fruits and sweeteners separately affected reducing sugar and non-reducing sugar to be increased (Figure 2d and Figure 2e). Only fruit content affected the total carotenoid content (Figure 2f). Sweetener affected the total carbohydrate (Figure 2b). The interaction effect of cereals, fruits, and sweeteners was also exhibited in water activity (Figure 2a), total sugar (Figure 2c), and gross energy (Figure 2g).

The cereals, fruits, and sweeteners were separately affected sensory properties. Increasing cereals, fruits, and sweeteners increased the aroma, texture, stickiness, and overall liking (Figure 3c–Figure 3e) and decreased the sweetness (Figure 3b). The single factor effect of cereal and sweetener increased the aroma and overall liking (Fig. 3a and Fig. 3e),

while increasing fruit content increased the texture, stickiness, and overall liking (Fig. 3c–Fig. 3e). These findings demonstrate the same findings as Megala and Hymavathi (2011) and Srebernich et al. (2016), which indicated the main ingredients that affected the sensory evaluation rating score were cereals, fruits, and sugar.

In addition, the sweetness of HCB was only affected by the interaction of fruits and sweeteners: increasing fruits and sweeteners altogether increased the sensory rating score of sweetness (Figure 3b), which is in line with the findings of Srebernich et al. (2016). The RSM of all significant responses was overlaid to optimize the content of the main ingredient. The optimized content of cereals, fruits, and sweeteners was 60.45%, 19.55%, and 20%, respectively. The approximation error from the observation value from the optimized HCB was in the range of 0.08–6.83% which was less than 10%, resulting in an optimization prediction that can provide validation to the HCB product (Table 5). The sensory rating scores of optimized HCB were in the range of *like slightly* to *like moderately* (6.5–7.5). The texture, flavor, crispiness, and sweetness were also found to be important cereal bar characteristics which affected the product acceptance (95.5%) and purchase intention (92.5%) of the HCB (Eq. 2 and Eq.3).

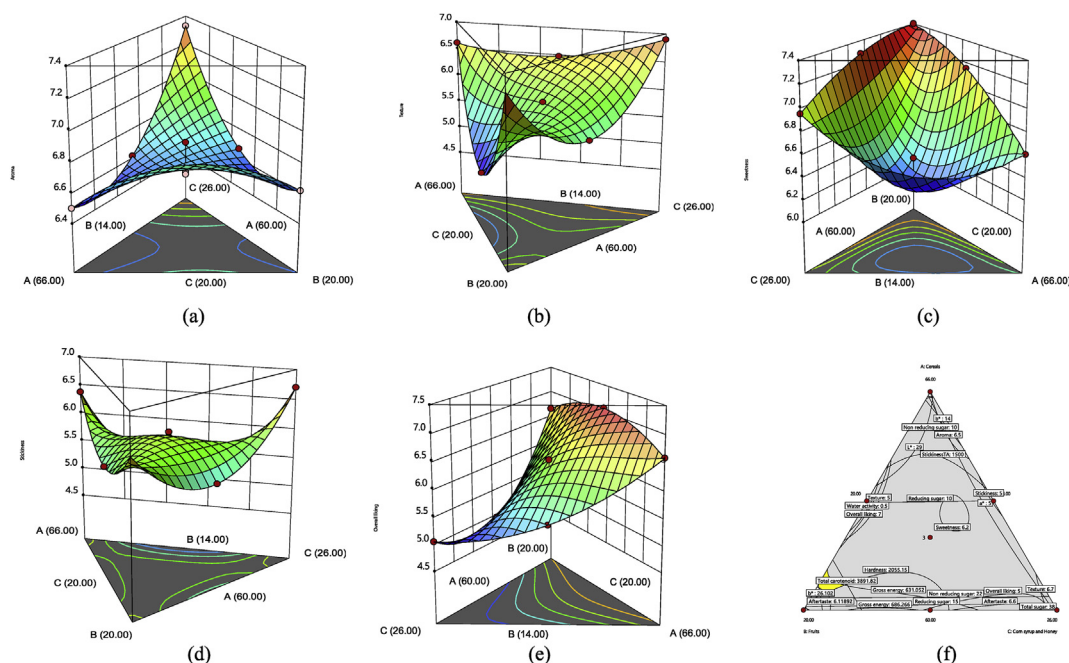


Figure 3. The response surfaces demonstrate regression model between cereals (A), fruits (B), and sweetener (C) of sensory evaluation; (a) aroma, (b) texture first bite, (c) sweetness, (d) stickiness, and (e) overall liking, with (f) the overlay plot from significant properties of HCB.

Table 5. The validation of HCB responses with approximation error.

| Responses | Prediction values | Observation values | Approximation error (%) |
|-----------------------------|-------------------|--------------------|-------------------------|
| L* | 45.56 | 45.78 ± 0.88 | 0.48 |
| a* | 8.58 | 9.05 ± 0.54 | 5.58 |
| b* | 18.88 | 19.80 ± 0.60 | 4.87 |
| Hardness (g.force) | 2091.76 | 2062.98 ± 19.39 | 1.37 |
| Stickiness (g.force) | 916.02 | 915.25 ± 1.74 | 0.08 |
| A _w | 0.46 | 0.45 ± 0.01 | 2.17 |
| Total carbohydrate (g/100g) | 64.31 | 66.61 ± 0.12 | 3.58 |
| Gross energy (Kcal/100 g) | 643.42 | 645.50 ± 0.02 | 0.32 |
| Total Sugar (%) | 36.70 | 37.34 ± 0.63 | 1.74 |
| Reducing sugar (%) | 14.34 | 15.32 ± 0.01 | 6.83 |
| Non-reducing sugar (%) | 21.65 | 20.53 ± 0.09 | 5.17 |
| Total carotenoid (µg/100g) | 4536.11 | 4434.87 ± 0.09 | 2.23 |
| Aroma | 6.7 | 7.0 ± 0.8 | 4.48 |
| Sweetness | 7.4 | 7.5 ± 0.8 | 1.35 |
| Texture | 6.1 | 6.7 ± 0.8 | 9.83 |
| Stickiness | 6.1 | 6.5 ± 0.6 | 6.55 |
| Overall liking | 6.8 | 7.2 ± 0.6 | 5.88 |

Note: Desirability from the optimization as 0.594.

$$\text{Product acceptance} = -7.46 - 0.79 * \text{Appearance} + 0.56 * \text{Sweetness} + 1.35 * \text{Texture} + 0.58 * \text{Crispiness} + 0.80 * \text{Flavor} - 0.67 * \text{Stickiness} \quad (\text{Eq. 2})$$

$$\text{Purchase intention} = -4.87 + 0.38 * \text{Sweetness} + 0.85 * \text{Texture} + 0.47 * \text{Crispiness} + 0.51 * \text{Flavor} - 0.44 * \text{Stickiness} \quad (\text{Eq. 3})$$

The HCB attributes of texture, flavor, crispiness, and sweetness were important were cereal bar characteristics which affected the product acceptance and purchase intention of the HCB. The results were in the same trend as Appelt et al. (2015), Megala and Hymavathi (2011), Srebernic et al. (2016), and Yadav and Bhatnagar (2015) which suggested that there are many ingredients such as puffed rice, roasted nut, cereal seed, mixed fruits, and sugar which can affect the consumer acceptance, product acceptance, and purchase intention of cereal bars. Those ingredients can cause variation in texture, flavor, crispiness, and sweetness in the higher gross energy cereal bars developed in this study. The results

suggested the possibility of development of high-energy cereal bars based on local ingredients from industrial food waste material in Southern Thailand. The mixed ingredients (puffed Southern Thai rice, banana chips, date fruit, honey, and corn starch), which can be found in Southern Thailand, can be used to develop high-energy cereal bars with high consumer acceptance, product acceptance, and purchase intention. These findings can be useful for the production of cereal bars with healthier characteristics which reduce the environmental impact caused by the industrial processing of agricultural raw materials.

4. Conclusion

In conclusion, the study finds that it is possible to develop a high-energy cereal bar with satisfactory texture properties and high

consumer acceptance rating using cereals (puffed rice, roasted Bambara nut, and sesame seed), fruits (banana chips and dates), and sweeteners (corn syrup and honey) sourced from the southern part of Thailand. The optimization process showed the optimal amount of cereals, fruits, and sweeteners which can produce an acceptable HCB to be 60.45%, 19.55%, and 20%, respectively. The HCB made from the optimized formula provided textural properties (hardness at 2062.98 ± 19.39 g. force and stickiness at 915.25 ± 1.74 g. force), low water activity (0.45 ± 0.01), high gross energy (645.50 ± 0.02 kcal/100g), and moderate sensory evaluation rating scores (6.5–7.5) The cereal bar consisting of puffed rice, roasted Bambara nut, sesame seed, banana chips, dates, corn syrup, and honey can be considered a convenient product which offers functional ingredients, nutrients, and high gross energy.

Declarations

Author contribution statement

Raj nibhas Sukeaw Samakradhamrongthai: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Taruedee Jannu: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Gerry Renaldi: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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References

- Agbaje, R., Hassan, C.Z., Norlelawati, A., Rahman, A.A., Huda-Faujan, N., 2016. Development and physico-chemical analysis of granola formulated with puffed glutinous rice and selected dried Sunnah foods. *Int. Food Res. J.* 23 (2), 498–506.
- Ahmad, A., Irfan, U., Amir, R.M., Abbasi, K.S., 2017. Development of high energy cereal and nut granola bar. *Int. J. Agric. Biol. Sci.* 13–20. *ISSN (2522-6584) SEP & OCT.*
- AOAC, 2019. Official method of analysis chemists. In: Horwitz, W. (Ed.), *Method 950.46*, 21th ed. Official Method of Analysis Chemists, Maryland, USA.
- Appelt, P., da Cunha, M.A.A., Guerra, A.P., Kalinke, C., de Lima, V.A., 2015. Development and characterization of cereal bars made with flour of jaboticaba peel and okara. *Acta Sci. Technol.* 37 (1), 117–122.
- Arora, A., Choudhary, D., Agarwal, G., Singh, V.P., 2008. Compositional variation in β -carotene content, carbohydrate, and antioxidant enzymes in selected banana cultivars. *Int. J. Food Sci. Technol.* 43, 1913–1921.
- Barboza, L.M.V., Freitas, R.J.S., Waszczyński, N., 2003. Desenvolvimento de produtos e análise sensorial. *Brasil Aliment.* 18, 34–35.
- Carvalho, M.G., 2008. Cereal Bar with almond chichá, sapucaya, and Brazil-Gurgueia, complete with pineapple bark. Brazil. Federal -University of Ceará, Fortaleza. MSc Thesis.
- Clemens, R.A., Jones, J.M., Kern, M., Lee, S.-Y., Mayhew, E.J., Slavin, J.L., Zivanovic, S., 2016. Functionality of sugars in foods and health. *Compr. Rev. Food Sci. Food Saf.* 15, 433–470.
- Cömet, E.D., Mogol, B.A., Gökmen, V., 2019. Relationship between color and antioxidant capacity of fruits and vegetables. *Curr. Res. Nutr. Food Sci.* 2, 1–10.
- Freitas, G.C., Moretti, R.H., 2006. Characterization and sensory evaluation of functional cereal bar high content protein and vitamin. *J. Food Sci. Technol.* 26, 318–324.
- Iuliano, L., Gonzalez, G., Casas, N., Moncayo, D., Cote, S., 2019. Development of an organic quinoa bar with amaranth and chia. *Food Sci. Technol.* 39, 218–224.
- Kaur, R., Ahluwalia, P., Sachdev, P.A., Kaur, A., 2018. Development of gluten-free cereal bar for gluten intolerant population by using quinoa as major ingredient. *J. Food Sci. Technol.* 55 (9), 3584–3591.
- Lawless, H., Heymann, H., 2010. *Sensory Evaluation of Food Science Principles and Practices*. Chapter 1, second ed. Ithaca, New York.
- Lima, J.C.R., Freitas, J.B., Czedler, L.P., Fernandes, D.C., Naves, M.M.V., 2010. Microbiological quality, acceptability, and nutritional value of cereal. *Boletim Centro de Pesquisa de Processamento de Alimentos* 28 (2), 331–343.
- Lins, A.C.A., Cavalcanti, D.T.B., Azoubel, P.M., Melo, E.A., Maciel, M.I.S., 2014. Effect of hydrocolloids on the physicochemical characteristics of yellow moinin structure fruit. *J. Food Sci. Technol.* 34 (3), 456–463.
- Megala, P., Hymavathi, T.V., 2011. Inulin and fructooligosaccharides incorporated functional fruit bar. *World Acad. Sci. Eng. Technol.* 59, 393–398.
- Meilgaard, M., Civille, G.V., Carr, B.T., 2007. *Sensory Evaluation Techniques*, fourth ed. CRC Press, Boca Raton.
- Mezzomo, N., Ferreira, S.R.S., 2016. Carotenoids functionality, sources, and processing by supercritical technology: a Review. *J. Chem.* 2016, 1–16 (Article ID 3164312).
- Palazzolo, G., 2003. Cereal bars: they're not just for breakfast anymore. *Cereal Foods World* 48, 70–72.
- Pallavi, B.V., Chetana, R., Ravi, R., Reddy, S.Y., 2015. Moisture sorption curves of fruit and nut cereal bar prepared with sugar and sugar substitutes. *J. Food Sci. Technol.* 52 (3), 1663–1669.
- Rothman, L., 2007. *The Use of Just-About-Right (JAR) Scales in Food Product Development and Reformulation in Consumer-Led Food Product Development*. CRC Press, Boca Raton, FL.
- Sethupathy, P., Suriyamoorthy, P., Moses, J.A., Chinnaswamy, A., 2020. Physical, sensory, in-vitro starch digestibility and glycaemic index of granola bars prepared using sucrose alternatives. *Int. J. Food Sci. Technol.* 55, 348–356.
- Sharma, G.K., 2011. Food processing technologies. *Technology focus*. Bull. Def. Res. Dev. Organ. 19 (5), 1–12.
- Shourideh, M., Taslimi, A., Azizi, M.H., Mohammadifar, M.A., 2012. Effects of D-Tagatose and inulin on some physicochemical, rheological, and sensory properties of dark chocolate. *Int. J. Biosci. Biochem. Bioinform.* 2, 314–319.
- Souza, A.H.P., Gohara, A.K., Pagamunici, L.M., Visentainer, J.V., Souza, N.E., Matsushita, M., 2014. Development, characterization, and chemometric analysis of gluten-free granolas containing whole flour of pseudo-cereals new cultivars. *Acta Scientiarum Technol. Maringa* 36 (1), 157–163.
- Srebernich, S.M., Gonçalves, G.M.S., Ormenese, R.C.S.C., Ruffi, C.R.G., 2016. Physico-chemical, sensory and nutritional characteristics of cereal bars with addition of acacia gum, inulin, and sorbitol. *Food Sci. Technol.* 36 (3), 555–562.
- Steingass, C.B., Vollmer, K., Metwali, E.M.R., Kadasa, N.M.S., Almaghrabi, O.A., Schweiggert, R., Carle, R., 2020. Chlorophyll and carotenoid patterns of middle eastern date (*Phoenix dactylifera*) fruit at different maturity stages. *Int. J. Agric. Biol.* 23, 845–850.
- Stone, H., Bleibum, R.N., Thomas, H.A., 2020. *Sensory Evaluation Practices*, fifth ed. Academic Press.
- Torres, E.R., Castro, E.S., Santana, R.F., Cardoso, J.C., Soares, C.M.F., Lima, Á.S., 2011. Cereal bar development using exotic fruit. In: *Proceedings of 11th ICEF Conference on Engineering and Food*. Food Process Engineering in a Changing World, Athens, Greece.
- Xiong, R., Meullenet, J.F., 2006. A PLS dummy variable approach to assess the impact of JAR attributes on liking. *Food Qual. Pref.* 17, 188–198.
- Yadav, L., Bhatnagar, V., 2015. Optimization of ingredients in cereal bar. *J. Food Sci. Res.* 6 (2), 273–278.
- Yamane, T., 1967. *Statistics, an Introductory Analysis*, second ed. Harper & Row, New York.