

# Optimisation of sweet bread formulation by use of image processing and response surface methodology

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## RESEARCH PAPER

### Abstract

Bread is one of the most widely consumed food products in the world and bread making technology is one of the oldest technologies known. Sensory and nutritional qualities of bread can be affected by the type of ingredients and employed bread making technology. The amount of sweetener addition to produce sweet bread with optimum quality attributes (colour, texture and sensory properties) was investigated using response surface methodology. A central composite rotatable design with three independent variables, the amount of honey (0-10%), sugar (0-14%) and stevia (0-1.5 ml), was used to study the response variables including L\* (Y1), a\* (Y2) and b\* (Y3) for colour, hardness (Y4) and chewiness for texture (Y5), flavour (Y6) and appearance (Y7). Data analysis showed that the addition of honey improved the colour, texture and sensory attributes of sweet bread, while sugar had a negative effect on the colour of bread and stevia considerably improved the sensory properties of the bread. Applying a desirability function method, the optimum parameters were: addition of 6-7% honey, 4-5% sugar and 1.5 ml stevia. This optimum point lead to the production of highly quality bread in respect to colour, texture and sensory properties. The experimental values were very close to the predicted values and were not statistically different ( $P>0.05$ ).

**Keywords:** image processing, response surface methodology, sensory attributes, sweet bread formulation

## 1. Introduction

Wheaten foods have a very important role in the diet and culture of Asian countries since very early times. Bread is one of the most widely consumed food products in the world and bread making technology is one of the oldest technologies known. This technology has been evolving continuously as new materials, equipment and processes are being developed (Selomulyo and Zhou, 2007). The impacts of various ingredients on sensory and nutritional quality of bread have been widely studied (Barcenas and Rosell, 2005; Plessas *et al.*, 2005).

Honey is a natural biological product that comprises of simple sugars (70-80% glucose and fructose), water (10-20%) and other minor constituents, such as organic acids, mineral salts, vitamins, proteins, phenolic compounds and

free amino acids (Ouchemoukh *et al.*, 2007). It is liked by consumers for its nutraceutical value, characteristic flavour, sweetness, and texture (Subramanian *et al.*, 2007). Honey can be used in bread formulations to increase overall quality of the product and to extend its shelf life. However, liquid honey is viscous and difficult to disperse in the dough, limiting its use in the food industry (Glabe *et al.*, 1970). By contrast, honey powder (dry honey) made from liquid honey can be dispersed easier and so it has been more widely used in the bread-baking industry for improving bread quality. Addo (1997) examined the effects of honey on the rheological properties of frozen wheat flour dough and found that at 4-6% (flour basis) liquid or dry honey improved the rheological properties of frozen dough and the freshness of bread.

*Stevia rebaudiana*, a perennial herb native of Brazil and Paraguay, is used to produce a natural sweetener that is used in Asia and South America and has gained recent attention in many food and beverage multinational enterprises (Panpatil and Polasa, 2008). Steviol glycosides, which are up to 300 times sweeter than sucrose, are found in high concentrations in the leaves of *S. rebaudiana* (Brandle and Telmer, 2007). The advantages of steviol glycosides as a dietary supplement for humans are manifold: they are heat-stable, non-caloric, assist dental health by reducing the intake of sugar and open the possibility for use by diabetic and phenylketonuria patients and obese persons (Geuns, 2003).

Consumption of sugar-sweetened foods and beverages can significantly influence the glycemic index of each meal, as well as the diet as a whole (Willett *et al.*, 2002). Moreover, excessive intake of high calorie, high glycemic foods can result in exaggerated postprandial glucose and insulin levels and potentially lead to metabolic and hormonal changes that stimulate hunger levels and promote fat deposition (O'Keefe and Bell, 2007). In line with this view, studies to date suggest that the consumption of sugar-sweetened foods promotes positive energy balance, weight gain, and increases risks for type 2 diabetes (Malik *et al.*, 2006; Schulze *et al.*, 2004). Based on accumulating evidence suggesting high sucrose diets have adverse effects on bodyweight (Johnson *et al.*, 2007) and are associated with other medical complications, such as diabetes, cardiovascular disease, and cancer, the American Heart Association recently released a statement recommending discretionary sugar intake be limited to just over 30 g (100 calories) per day for women with 20 kg/m<sup>2</sup> body mass index and just over 45 g (150 calories) for men with 24 kg/m<sup>2</sup> body mass index (Mitka, 2009).

In university research laboratories, computer vision systems have been developed for product quality inspection and grading. Studies were carried out to analyse visual characteristics of bakery products (for example colour of muffins) (Zaid Abdullah *et al.*, 2000).

Response surface methodology (RSM) is a statistical method for determining and simultaneously solving multivariate equations (Mashkour *et al.*, 2013; Roy *et al.*, 2002). It usually uses an experimental design such as central composite rotatable design to fit a first- or second-order polynomial by a least significance technique. An equation is used to describe how the test variables affect the response and to determine the interrelationship among the test variables in the response. The contour plots can be used to study the response surfaces and locate the optimal parameters. No information is available in the literature on the effect of combined factors on the qualities of sweet bread using RSM. Hence, the objective of this work was to optimise the amount of sweeteners in respect to quality attributes like colour, texture and sensory properties.

## 2. Materials and methods

Commercial wheat flour was provided by Golha Co. Ltd. (Tehran, Iran). Honey powder was provided by Cactus (Decatur, IL, USA). Stevia extract with proportion 1:1 was provided by Giahehssans Co. Ltd. (Gorgan, Iran). Dry baker's yeast was obtained from Fariman Yeast Co. Ltd. (Mashhad, Iran). Butter was provided by Kalleh Co. Ltd. (Amol, Iran). Milk powder provided by Biomil, Behdashtkar Co. Ltd. (Rasht, Iran), sugar provided by Naghshe-Jahan (Esfahan, Iran), eggs, salt and food bag were purchased at a local market.

### Bread preparation

Bread samples were prepared using a traditional method as described by Hashemi Shahraki *et al.* (2014). In short, flour, fine sugar, honey powder and milk powder were uniformly mixed in a spiral mixer, followed by the addition of yeast and bread improver. The stevia extract was solved in water and used with water in formulation. The dough was prepared in the mixer for 2 min at 40 rpm, and 10 min at 70 rpm after the 2 eggs and water were added. The dough was rested in bulk for 12 min, divided into pieces of 100 g, rounded by hand and submitted to an extra fermentation period of 10 min. The dough was then kneaded, put in well-greased pans, proofed at 37 °C and 85% relative humidity for 2 h and baked in an electric oven set at a temperature of 180 °C for 20 min. Bread was removed from the pans and cooled at 25 °C for 1 h.

### Sensory evaluation of bread quality

The sensory evaluation was performed using a descriptive test 24 h after baking the bread (ISO, 1987). For this purpose 10 panellists were chosen and each panellist was trained for the purpose. The evaluated sensory attributes were taste (including aroma, taste, mouth feel and sweetness, each scoring up to 25 points) and appearance (shape, volume, colour and baking homogeneity, each scoring up to 25 points). Total score of each sensory evaluation for one sample was 100 points. Tests were replicated 3 times.

### Texture analysis

Texture profile analysis (TPA) of bread was carried out using a texture analyser (CNS Farnell, Borehamwood, UK). A cylindrical probe of 19 mm diameter was attached to the crosshead. The probe speed was 30 mm/min. Bread loaves were cut into rectangular slices and placed under the probe. The texture properties of hardness, springiness, chewiness, gumminess and cohesiveness were evaluated. All tests were conducted in triplicate and average values were reported. Bread slices were compressed twice to give a TPA from which three primary textural parameters were obtained (Pons and Fiszman, 1996): hardness (bread

firmness), springiness, and cohesiveness, as calculated by the equipment software. Hardness values 1 and 2 were the maximum peak forces ( $\times g$ ) during the first and second cycles, respectively. Cohesiveness was the ratio between the second cycle area and the first cycle area. Springiness was defined as the height in mm the food sample recovered during the time that elapsed between the end of the first cycle and the start of the second cycle. Gumminess was the product of hardness 1 and cohesiveness. Chewiness was the product of gumminess 1 and springiness.

### Crust colour

For colour evaluation of the bread a computer vision system (CVS) was used. The general methodology to convert RGB images into  $L^*a^*b^*$  units is described by Hashemi Sharahraki *et al.* (2013, 2014). A brief description of each step is as follows:

- Image acquisition: images were captured using an image acquisition system for colour digital camera similar to that developed by (Papadakis *et al.*, 2000), namely:
  - Samples were illuminated using four fluorescent lamps (length of 60 cm) with a colour temperature of 6,500 k (Natural Daylight, 10 W; Philips, Eindhoven, the Netherlands) and a colour rendering index (Ra) close to 95%. The four lamps were arranged as a square 35 cm above the sample and at an angle of 45° with the sample plane to give a uniform light intensity over the food sample.
  - A colour digital camera (CDC) Power Shot SX40 HS (Canon, Ota, Japan) was located vertically at a distance of 15 cm from the sample. The angle between the camera lens axis and the lighting sources was around 45°. The setting of the camera is given by Hashemi Sharahraki *et al.* (2013).
  - Images were captured with the mentioned CDC at resolution (4,000  $\times$  3,000 pixels). The images were imported directly in the computer in TIFF format without compression.
- Image pre-processing: the digital images must be pre-processed to improve their quality before they are analysed. Using digital filtering the noise associated with the image can be removed and the contrast enhanced.
- Conversion of RGB images into  $L^*a^*b^*$  units: ImageJ software (version 4.4 trial; NIH, Bethesda, MD, USA) was used for analysis of the image. In this stage the illumination standard ( $D_{65}$ ) had been applied.

### Optimisation procedure using response surface methodology

The procedure was based on the hypothesis that quality attributes (colour, texture and sensory property) of sweet bread was functionally related to the amount of sweetener, and attempts were made to fit multiple regression equations describing the responses. Three coded independent variables

in the process were the amounts of honey (X1), sugar (X2) and stevia (X3) as shown in Table 1. Three levels of each of the independent variable were chosen for the study, thus seventeen combinations including three replicates of the centre point were performed in random order, based on a central composite rotatable experimental design for three factors as shown in Table 1. The dependent variables considered included  $L^*$  (Y1),  $a^*$  (Y2),  $b^*$  (Y3) as indicating colour, hardness (Y4) and chewiness for texture, (Y5), flavour (Y6) and appearance (Y7) for sensory properties.

Target colour values were determined using a sensory evaluation method. Panellists were asked to choose the best bread according to their colour qualities, then the colour of the selected breads were analysed by the image processing method quantitatively using the CVS machine and the optimum levels of  $L^*$  (light/dark),  $a^*$  (red/green) and  $b^*$  (yellow/blue) were determined. Optimum levels were chosen for optimisation of quality attributes (hardness and chewiness) and the maximum sensory scores were chosen as the target levels to optimise the amount of sweeteners.

**Table 1. Coded values of the independent variables.**

Variable	-1	0	1
$X_1$ (%)	0	5	10
$X_2$ (%)	0	7	14
$X_3$ (cc)	0	0.75	1.5

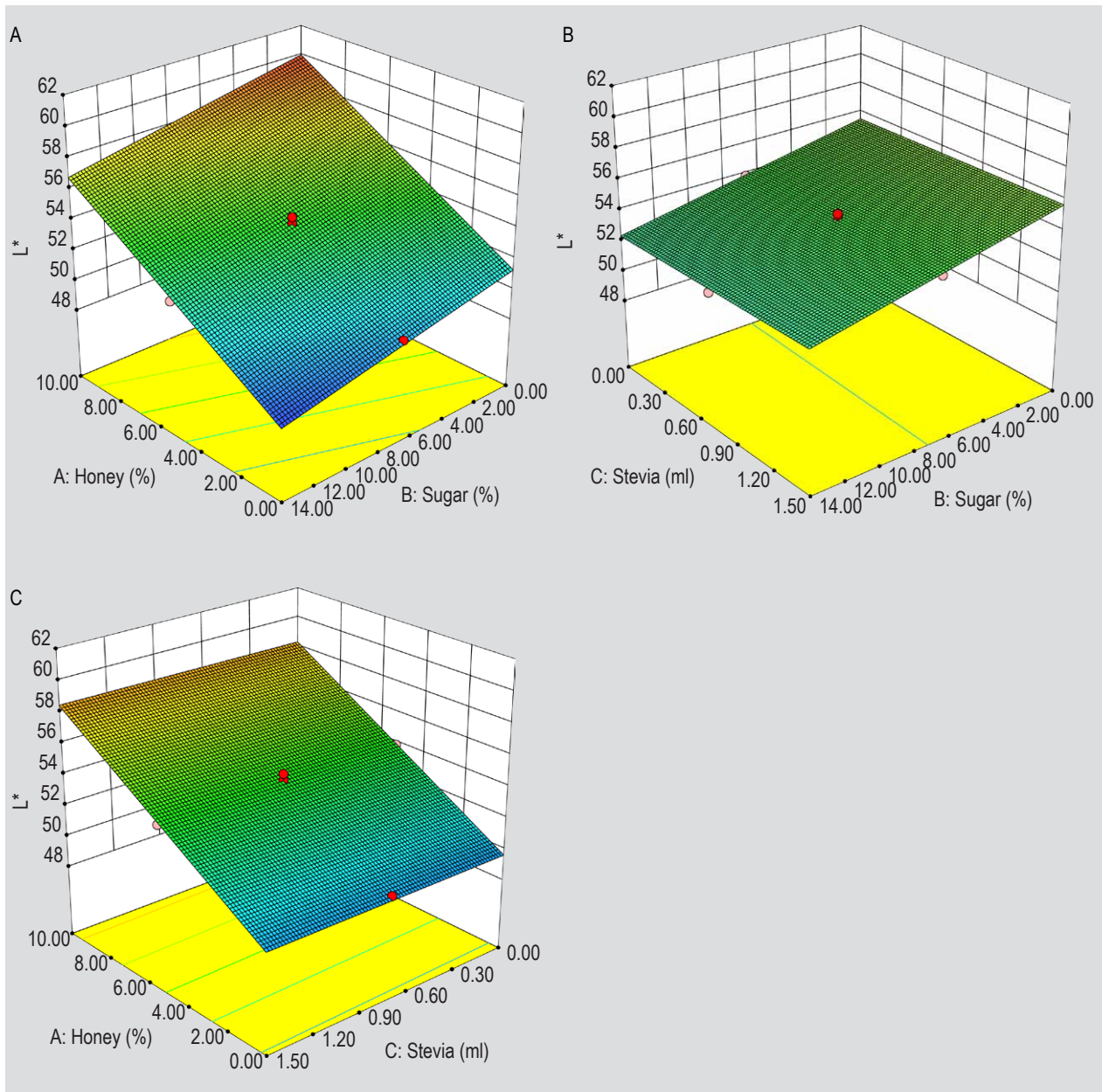
## 3. Results and discussion

### Colour

The effect of sweetener concentration on the  $L^*$  value are shown in Figure 1. It can be seen that the  $L^*$  value increased with increasing honey content and decreased with increasing sugar content ( $P < 0.05$ ), while different stevia concentrations led to no significance change in the  $L^*$  value of the bread crust. The results for ANOVA are shown in Supplementary Table S1. A linear model was able to describe colour changes due to sweetener addition. The high correlation coefficient ( $R^2 = 98.94$ ) showed a suitable correlation between this model and the experimental data. Model and coefficients are shown in Equation 1:

$$L^* = 51.22294 + 0.87(X1) - 0.22857(X2) + 0.106667(X3) \quad (1)$$

Where  $X1$  = honey,  $X2$  = sugar and  $X3$  = stevia.



**Figure 1. Variation of the L\* value in relation to different sweeteners addition. (A) Interaction effect of honey (%) and sugar (%) on L\* value. (B) Interaction effect of stevia (ml) and sugar (%) on L\* value. (C) Interaction effect of honey (%) and stevia (ml) on L\* value of produced bread crust.**

Variations of the a\* value for the bread crust as affected by different sweetener concentrations are shown in Figure 2. As can be seen, the a\* value decreased significantly with increasing honey and sugar contents ( $P < 0.05$ ) but there was change with increasing stevia levels. The b\* value changes were similar to a\* value changes (Figure 3). The results for ANOVA are shown in Supplementary Table S1. The linear models with high correlation coefficient,  $R^2 = 98.65$  for the a\* and  $R^2 = 95.72$  for the b\* value, were selected as the best models to describe the colour changes due to sweetener addition and showed a suitable correlation

with the experimental data. The models and coefficients of model are cited in Equation 2 and 3:

$$a^* = 20.14647 - 0.41(X1) - 0.10857(X2) + 0.053333(X3) \quad (2)$$

$$b^* = 34.93059 + 0.312(X1) + 0.05(X2) - 0.09333(X3) \quad (3)$$

Where X1 is honey, X2 is sugar and X3 is stevia.

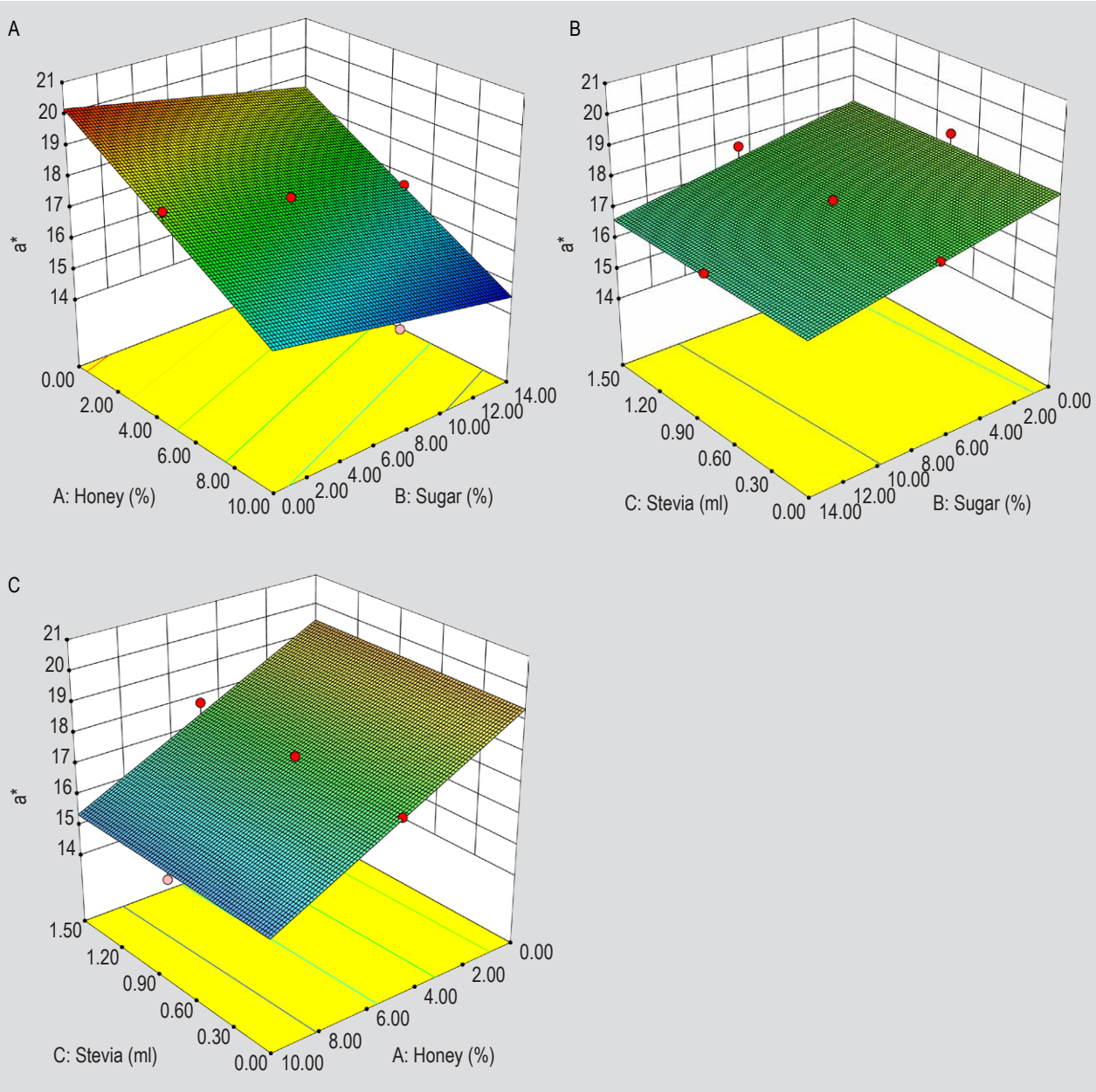
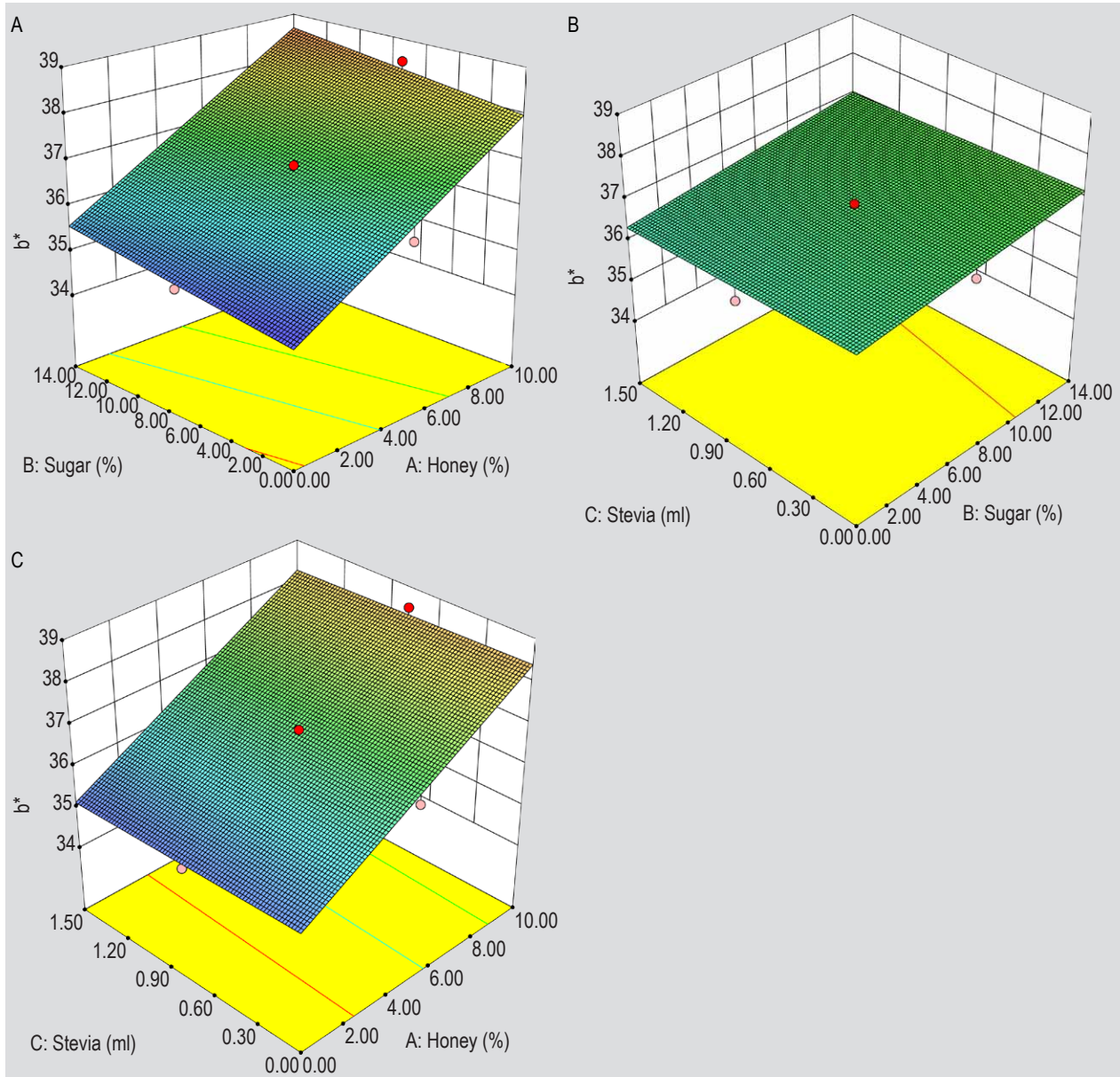


Figure 2. Variation of the a\* value in relation to different sweetener addition. (A) Interaction effect of honey (%) and sugar (%) on the a\* value. (B) Interaction effect of stevia (ml) and sugar (%) on the a\* value. (C) Interaction effect of honey (%) and stevia (ml) on the a\* value of produced bread crust.



**Figure 3.** Variation of the  $b^*$  value in relation to different sweeteners addition. (A) Interaction effect of honey (%) and sugar (%) on the  $b^*$  value. (B) Interaction effect of stevia (ml) and sugar (%) on the  $b^*$  value. (C) Interaction effect of honey (%) and stevia (ml) on the  $b^*$  value of produced bread crust.

### Texture

The effect of each sweetener on bread texture of produced bread is shown in Figure 4 and 5. As can be seen, sample hardness and chewiness were decreased significantly ( $P < 0.05$ ) by increasing honey and sugar content, with honey was more effective than sugar. Stevia had no significant effect on the sample texture. The results of ANOVA are shown in Supplementary Table S2. Quadratic models with high correlation coefficient,  $R^2 = 99.77$  for hardness and  $R^2 = 9.92$  for chewiness, were the best models for predicting the sample texture with sweetener addition. Coefficients for the models are shown in Equation 4 and 5:

$$\begin{aligned} \text{Hardness} = & 140.9131 - 13.9891(X1) - 1.42936(X2) - \\ & 0.10066(X3) + 0.146667(X1)(X2) + 0.146667(X1)(X3) \\ & + 0.066667(X2)(X3) + 0.02873(X1)^2 + 0.02873(X2)^2 - \\ & 0.78623(X3)^2 \end{aligned} \quad (4)$$

$$\begin{aligned} \text{Chewiness} = & 97.82827 - 4.49177(X1) - 0.48984(X2) + \\ & 2.141502(X3) + 0.0225(X1)(X2) + 0.003333(X1)(X3) \\ & - 0.03571(X2)(X3) + 0.233577(X1)^2 + 0.003866(X2)^2 - \\ & 1.26322(X3)^2 \end{aligned} \quad (5)$$

Where X1 is honey, X2 is sugar and X3 is stevia.

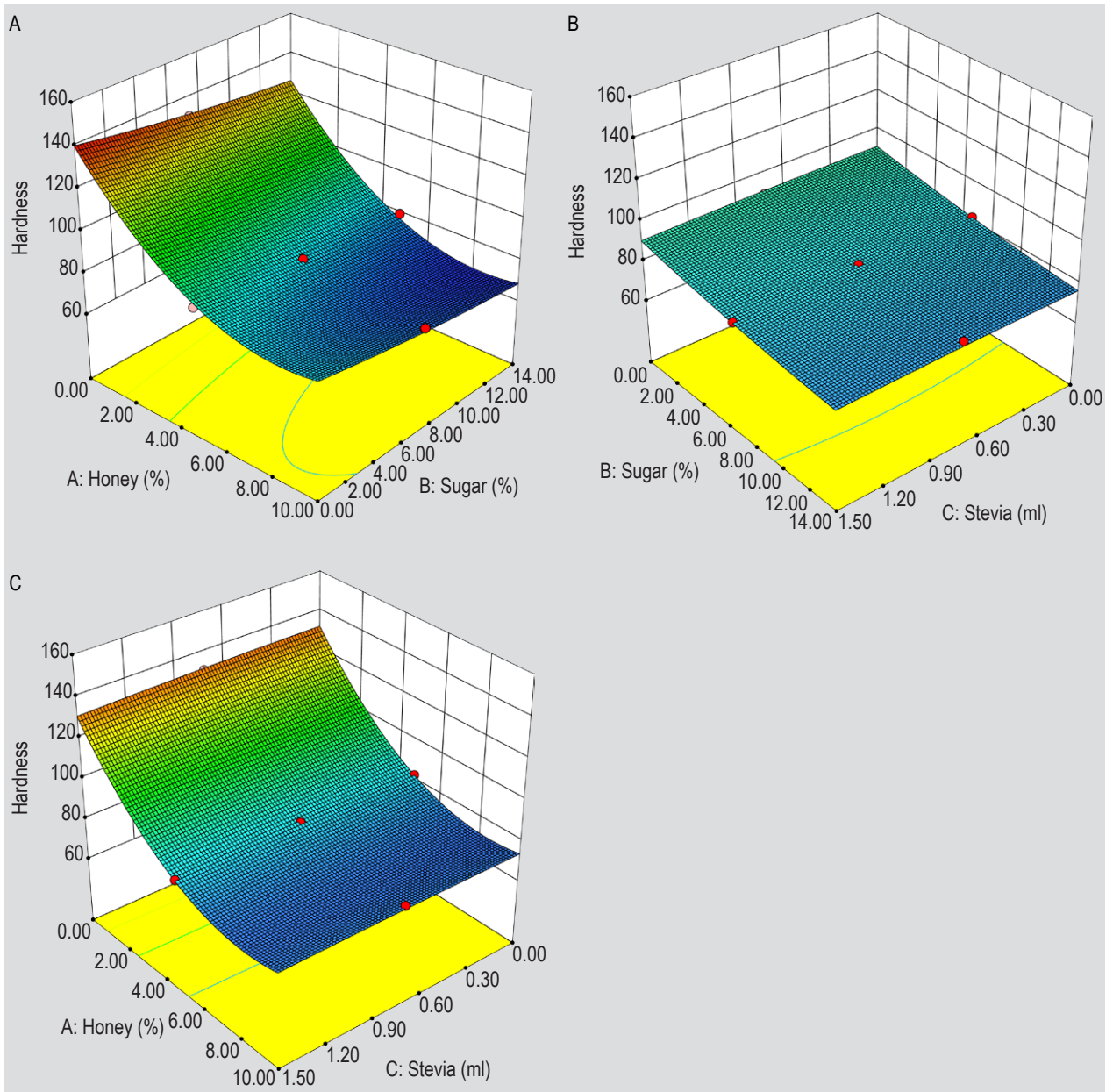
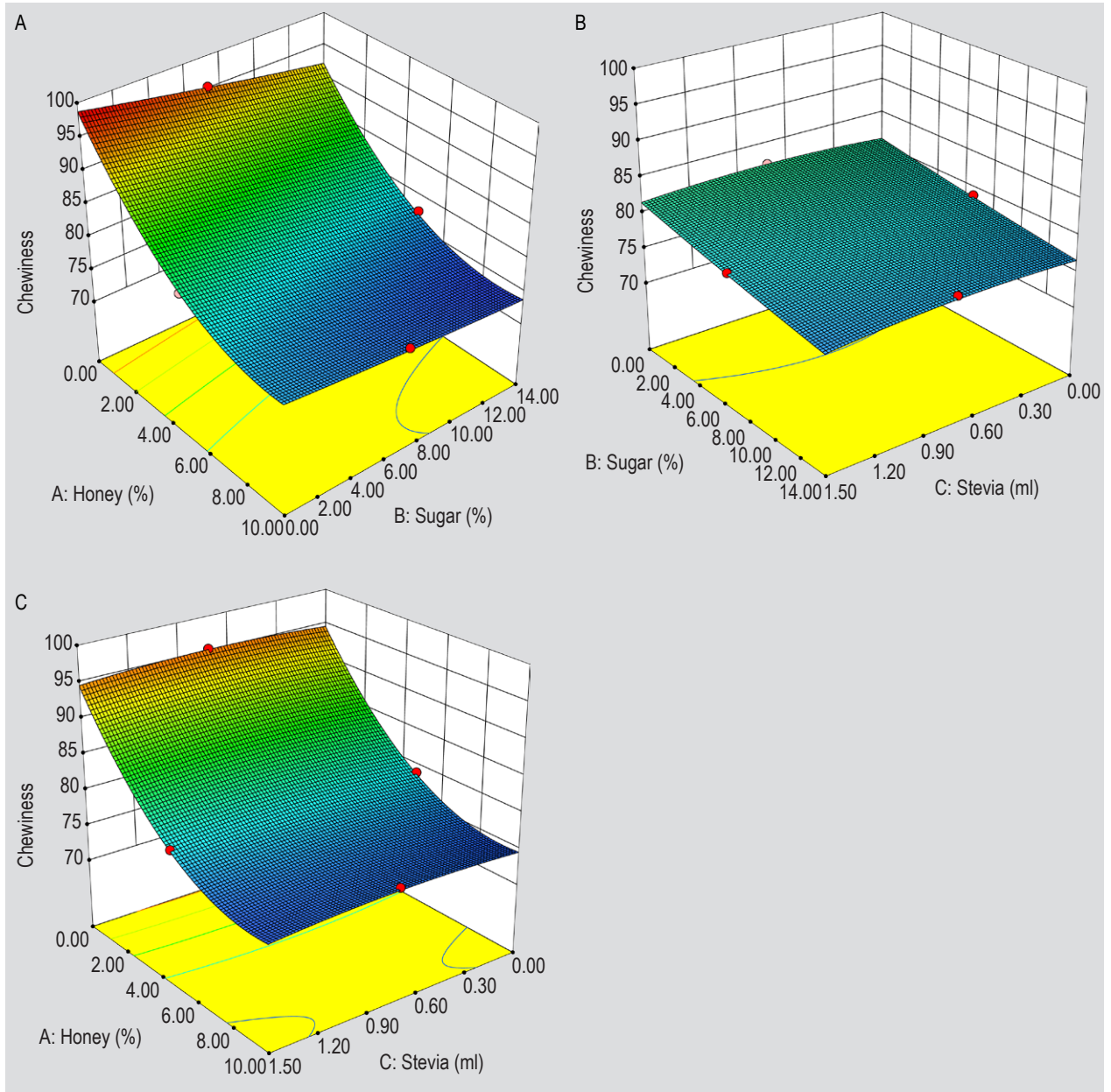


Figure 4. Variation of sample hardness (N) in relation to different sweeteners addition. (A) Interaction effect of honey (%) and sugar (%) on sample hardness (N). (B) Interaction effect of stevia (ml) and sugar (%) on sample hardness (N). (C) Interaction effect of honey (%) and stevia (ml) on sample hardness (N) of produced bread.



**Figure 5.** Variation of chewing ability of produced bread in relation to different sweeteners addition. (A) Interaction effect of honey (%) and sugar (%) on sample chewing ability. (B) Interaction effect of stevia (ml) and sugar (%) on sample chewing ability. (C) Interaction effect of honey (%) and stevia (ml) on chewing ability of produced bread.

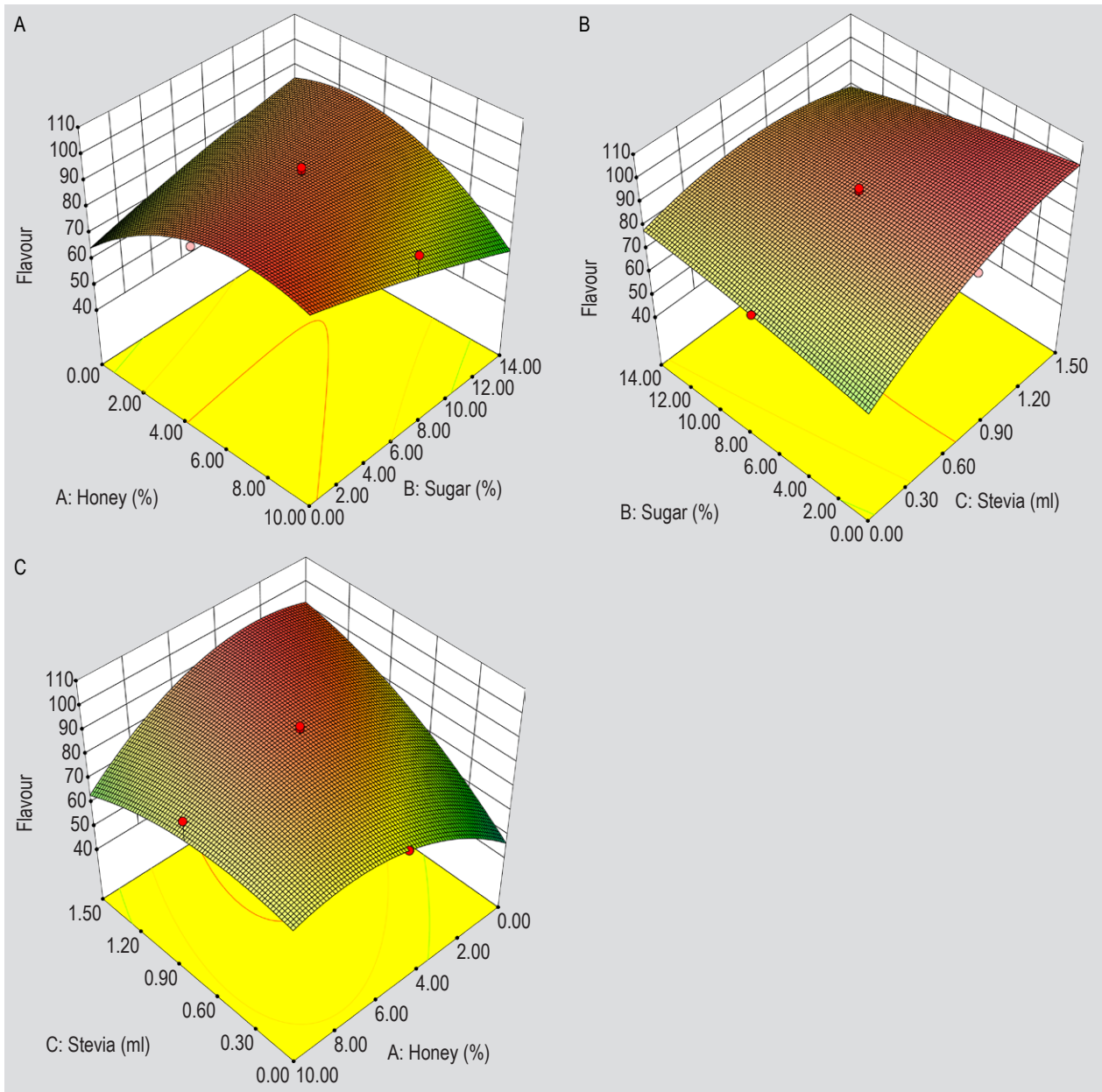
**Sensory evaluation**

The variation in bread flavour and appearance are shown in Figure 6 and 7, respectively. As can be seen, only changes in stevia content resulted in significant changes in bread flavour ( $P < 0.05$ ). By increasing the honey content the appearance of the bread was improved ( $P < 0.05$ ), while increasing sugar resulted in a significant decrease in product appearance scores ( $P < 0.05$ ). Stevia had no significant effect on the appearance. The results of ANOVA are shown in Supplementary Table S3. Quadratic models with high correlation coefficients,  $R^2 = 93.01$  for flavour and  $R^2 =$

99.45 for appearance, provided the best models to describe flavour and appearance changes of samples with sweetener addition. The models are shown in Equation 6 and 7:

$$\text{Flavour} = 26.82817 + 11.01183(X1) + 3.015594(X2) + 60.81221(X3) - 0.36429(X1)(X2) - 3.8(X1)(X3) - 1.52381(X2)(X3) - 0.55718(X1)^2 - 0.02918(X2)^2 - 13.2081(X3)^2 \quad (6)$$

$$\text{Appearance} = 80.84729 + 1.324211(X1) + 1.081579(X2) - 1.61192(X3) - 0.14321(X1)(X2) - 0.03(X1)(X3) - 0.00238(X2)(X3) - 0.02152(X1)^2 - 0.03445(X2)^2 + 1.443505(X3)^2 \quad (7)$$



**Figure 6. Variation of produced bread flavour in relation to different sweeteners addition. (A) Interaction effect of honey (%) and sugar (%) on sample flavour. (B) Interaction effect of stevia (ml) and sugar (%) on sample flavour. (C) Interaction effect of honey (%) and stevia (ml) on flavour of produced bread.**

Where X1 is honey, X2 is sugar and X3 is stevia.

Our results showed a considerable effect from honey addition on colour, texture and sensory attributes of produced breads and are in agreement with the results of Tong *et al* (2010).

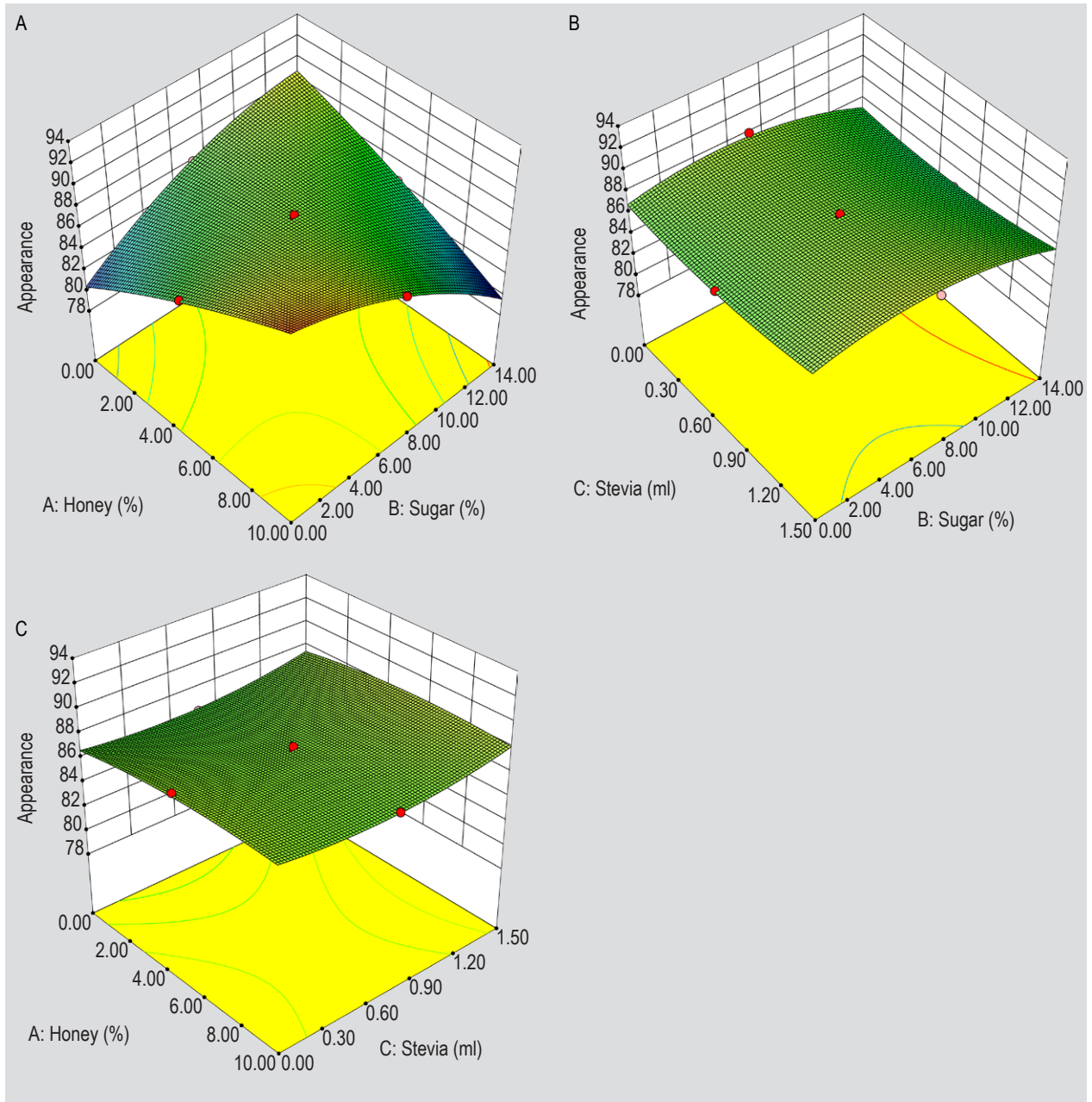


Figure 7. Variation of produced bread appearance in relation to different sweeteners addition. (A) Interaction effect of honey (%) and sugar (%) on sample appearance. (B) Interaction effect of stevia (ml) and sugar (%) on sample appearance. (C) Interaction effect of honey (%) and stevia (ml) on appearance of produced bread.

### Optimisation

The optimisation information and range of the factor that were used for optimisation are summarised in Table 2. The  $L^*a^*b^*$  values of the breads by panellists were measured by CVS and considered as a target point in optimisation. Results for bread  $L^*a^*b^*$  values with the highest sensory evaluation scores (selected by panellists) are shown in Table 3. Minimum hardness and chewiness, maximum flavour and appearance scores were considered. The optimisation was carried out in 13 solutions (not shown). The selected

values of four factors and the best results are shown in Figure 8. As shown in Figure 9, the lowest desirability was obtained for yellowness ( $b^*$ ) and highest desirability was obtained for all factors and lightness ( $L^*$ ).

### 4. Conclusions

The addition of honey to formulations improved the colour, texture and sensory attributes of produced sweet breads, while sugar had a negative effect on the colour, and stevia improved the sensory properties considerably. The results

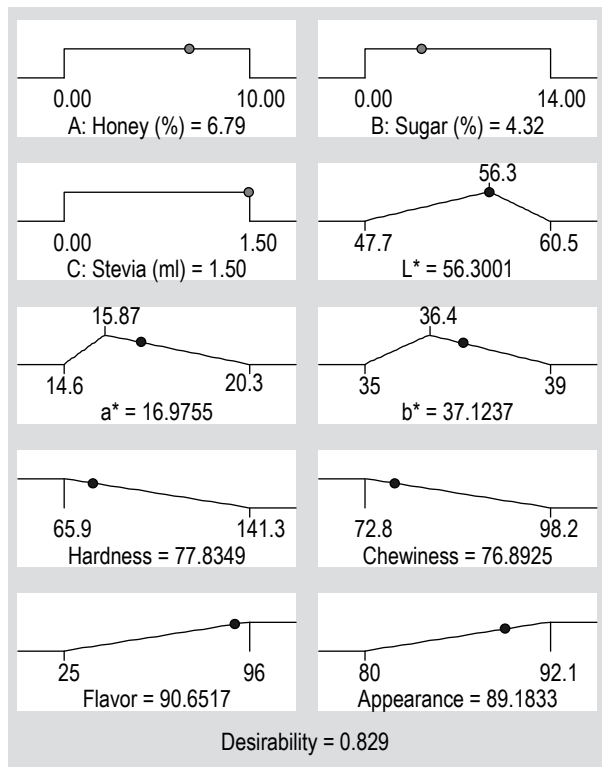
**Table 2. Summary of the optimisation information and range of the factor that was used for optimisation.**

Constraints		Lower limit	Upper limit	Lower weight	Upper weight	Importance
Name	Goal					
Honey	is in range	0	10	1	1	3
Sugar	is in range	0	14	1	1	3
Stevia	is in range	0	1.5	1	1	3
L*	target=56.3	47.7	60.5	1	1	3
a*	target=15.8	14.6	20.3	1	1	3
b*	target=36.4	35	39	1	1	3
Hardness	minimise	65.9	141.3	1	1	3
Chewiness	minimise	72.8	98.2	1	1	3
Flavour	maximise	25	96	1	1	3
Appearance	maximise	80	92.1	1	1	3

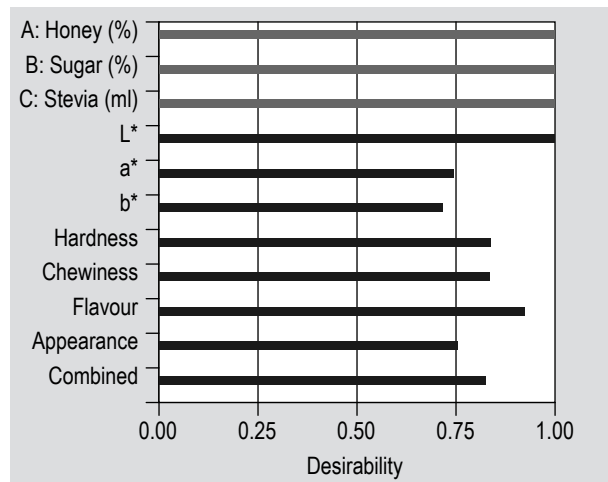
L\* = light/dark; a\* = red/green; b\* = yellow/blue.

**Table 3. Quantity of L\*a\*b\* values obtained with sensory optimal test.**

Colour index	Value
L* (light/dark)	56.3
a* (red/green)	15.8
b* (yellow/blue)	36.4



**Figure 8. Selected values of four factors and the best results.**



**Figure 9. Desirability values for factors and responses. L\* = light/dark; a\* = red/green; b\* = yellow/blue.**

of this study showed that the addition of 6-7% honey, 4-5% sugar and 1.5 ml stevia lead to a highly quality bread with respect to colour, texture and sensory properties. Using the optimised sweetener values in the industry can improve the quality characteristics of sweet bread and decrease the sugar consumption in the sweet bread formulations. Image processing is a simple and relevant method for colour parameter measurements in food materials.

### Supplementary material

Supplementary material can be found online at <http://dx.doi.org/10.3920/QAS2012.0151>.

Table S1. ANOVA for response surface linear model for L\*a\*b\* values.

Table S2. ANOVA for response surface quadratic model for hardness and chewiness.

Table S3. ANOVA for response surface quadratic model for flavour and appearance.

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