



Effect of extrusion conditions on colour coordinates of breakfast snacks using corn-honey blends

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Abstract

In the present work honey powder was incorporated into corn flour for the development breakfast snacks using extrusion technology. The effect of composition, feed moisture, barrel temperature, and screw speed on color coordinates of corn-based honey powder incorporated extruded snacks were investigated in a co-rotating twin-screw extruder using response surface methodology. Experimental design with composition (0-40% honey powder), moisture content (12.5-22.5) temperature (110 to 190°C), screw speed (150 to 550 rpm) and feed proportion (5 to 15%) as independent variables which produced 30 different combinations, were studied using response surface methodology to investigate the effect of these variables on product responses viz. - L*(luminosity), a*(redness), b*(yellowness), c*(chroma), ΔE (total color difference) and hue angle of corn-based honey powder incorporated extruded snack. Multiple regression equations were obtained to describe the effects of each variable on product responses. Results showed that product responses were most affected by changes in barrel temperature. Increase in temperature decreased luminosity, while increasing redness and yellowness of extrudates in comparison to control (only corn) Response surface regression models were established to correlate the color coordinates of corn-based honey powder incorporated extruded snacks to the process variables.

Keywords: corn, honey, response surface methodology, extruded snacks, color, barrel temperature, screw speed

1. Introduction

Extrusion cooking which is a continuous cooking, mixing and forming process has been used extensively in the production of food ingredients and food such as breakfast cereals, baby foods, flat breads, snacks, meat and cheese analogues and modified starches etc (Anderson *et al.*, 1969; Meuser and van Lengerich, 1992) [4, 9]. Quality of extruded product varies depending on the extruder type, screw configuration, feed rate and die profile. Wheat flour, rice flour, maize grits, barley flour and their combinations along with byproducts of different industries like carrot and grape pomace, have been widely used in the extrusion industry and the effects of process variables on the physical and functional properties of extrudates have been studied (Yagci and Gogus, 2008; Altan *et al.*, 2008; Ali *et al.* 1996.) [12, 3, 2]. Similarly, effect of sucrose and fructose incorporation has also been studied (Kalichevsky and Blanshard, 1993) [7]. Utilization of different cereals in combination with different non cereal ingredients demands empirical modifications in processing conditions to yield optimum extruded product with lower cost. Since no scientific studies are available on extrusion processing of cereals by addition of honey. So, the objective of this study was the incorporation of honey into breakfast snacks based on corn flour, and to optimize the process variables (temperature, screw speed and feed proportion) to produce acceptable honey based extruded snack food by using a twin-screw extruder.

It is well known that colour is an important quality parameter that affects the acceptability of food by consumers. Millard reaction leads to change in colour during high temperature treatments of food products [Vallimael *et al.* 2006] [11]. The

isomerization of maltose to maltulose is very common in cereals, when subjected to heat processing [Garcia *et al.* 2004] [5]. The purpose of this study was to examine the effects extrusion process variables on the colour coordinates of corn – honey blended extrudates.

2. Materials and Methods

The corn (C-6) variety obtained from division of plant breeding and genetics, SKUAST-K was milled in lab mill 3030 (Perten, Sweden) to fineness that passes through 200mm sieve. Honey was procured from local market. The moisture content was determined by oven drying method (AACC, 2000) [1] and approximate amount of water was added to adjust the required moisture content of the blend as per the experimental design. The samples were tightly packed in PET jars and conditioned at temperature of 28°C for 24 hours. Samples were periodically stirred during the 24 hours of conditioning. Extrudates were manufactured from different combinations of composition, moisture, barrel temperature and screw speed.

Extruder and processing conditions

The extrusion was performed on co-rotating intermeshing twin screw extruder model BC 21 (Clextral, Firminy, France). The barrel diameter and its length to diameter ratio (L/D) were 2.5 mm and 16:1, respectively. The extruder had four barrel zones, temperature of the 1st, 2nd, and 3rd was maintained at 20, 30 and 40°C, respectively, throughout the study period; while the temperature in last zone (compression and die

section) was varied according to experimental design as shown in table 1. The extruder was equipped with torque indicator which showed percent of torque in proportion the current drawn by drive motor. Raw material was metered into extruder with a single screw volumetric feeder.

Experimental Design

The central composite rotatable design (CCRD) [3] was used

to incorporate four independent variables viz., composition, moisture content, screw speed and barrel temperature. This design required 30 experimental runs. This yielded five levels for each variable and permitted better assessment of their quadratic effects. The CCRD- coded levels and experimental ranges of 4 independent variables (Table 1) were selected on the basis of preliminary tests.

Table 1: Process variables used in the central composite rotatable design (CCRD) for four independent variables

Process variables	Code	Variables Level Codes				
		-2	-1	0	+1	+2
Composition (Corn:honey)	A	100:0	90:10	80:20	70:30	60:40
Moisture content (%)	B	12.50	15	17.50	20	22.50
Screw speed (rpm)	C	150	250	350	450	550
Barrel temperature (°C)	D	110	130	150	170	190

Colour Analysis

The colour measurement of extrudates was performed with a hunterlab colorimeter (model) as described by Lambert *et al.* (2006). Each measurement was replicated 6 times and average values were considered. Total colour difference (ΔE).chroma values (c*) and hue angle (°) were evaluated from the colour parameters L* (brightness), a* (redness) and b* (yellowness) using

$$\Delta E = \sqrt{(L - L^*)^2 + (b - b^*)^2 + (c - c^*)^2}$$

$$\text{Chroma } (c^*) = \sqrt{a^2 + b^2}$$

$$\text{Hue angle } (^\circ) = \tan^{-1} \left(\frac{b}{a} \right)$$

The control (c-6) was used as reference to calculate ΔE

Statistical analysis

Responses obtained as a result of the proposed experimental design were subjected to regression analysis in order to assess the effects of composition, moisture content, screw speed and barrel temperature on product characteristics. Second order polynomial regression models were established for the dependent variables to fit experimental data for each response using statistical software Design-Expert 8 (Stat-Ease Inc, Minneapolis, MN, USA).

$$y_i = b_0 + \sum_{i=1}^4 b_i x_i + \sum_{i=1}^4 b_{ii} x_i^2 + \sum_{i=1}^4 \sum_{j=1}^4 b_{ij} x_i x_j$$

where, xi (i = 1, 2, 3, 4) are independent variables (Composition, Moisture, Screw speed and Barrel temperature respectively) and b₀, b_i, b_{ii}, and b_{ij} are coefficient for intercept, linear, quadratic, and interactive effects respectively. Data was analyzed by multiple regression analysis and statistical significance of terms was examined by analysis of variance (ANOVA) for each response. The adequacy of regression model was checked by correlation coefficients. The lack of fit was used to judge the adequacy of model fit.

3. Results and Discussion

Response surface methodology revealed that the models for all the parameters (L*, a*, b*, c*, ΔE and hue angle) were significant. None of the models showed significant lack of fit (Table 2), indicating that all the second order polynomial models correlated well with the measured data.

The data on mean values of colour coordinates revealed that the regression models for L*, a*, b*, c*, ΔE and hue angle were highly significant with a high correlation coefficient (R² 0.9691, 0.9775, 0.9383, 0.9341, 0.9048, 0.9773 respectively). The predicted R-square was found in reasonable agreement with adjusted R-square for all the parameters. Adequate precision greater than 4 is desirable. All the parameters showed high adequate precision (Table 2.).

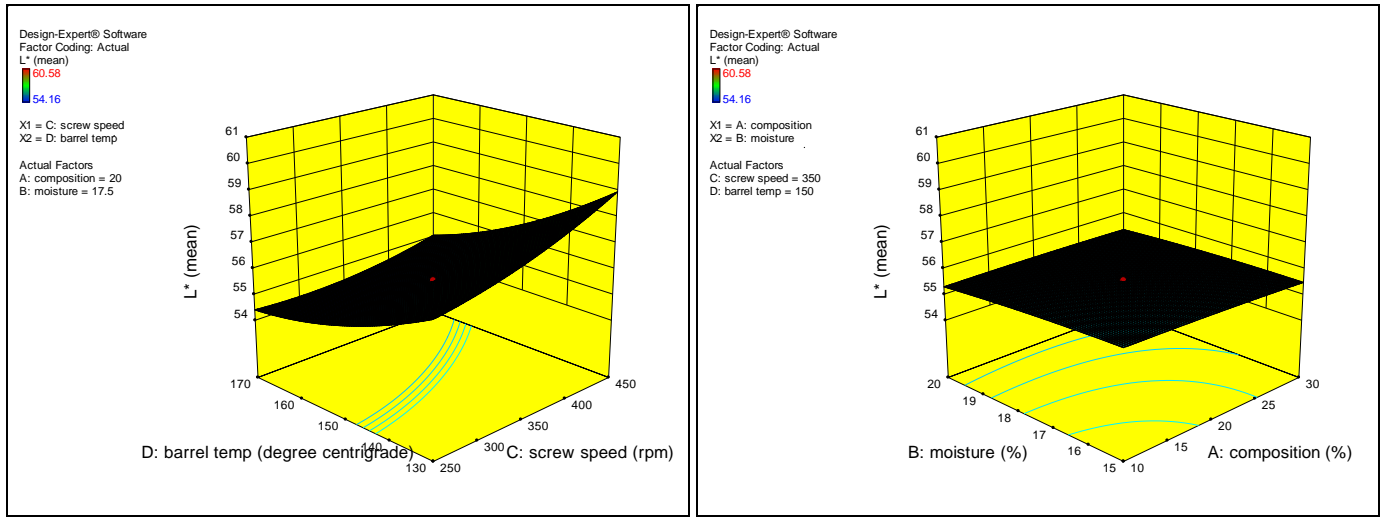
Table 2: ANOVA and model statistics for the colour parameters of corn based apple and honey incorporated breakfast snacks

Term	Response to models					
	L*	a*	b*	c*	ΔE	Hue angle (°)
R-square	0.9691	0.97775	0.9383	0.9341	0.9048	0.97773
Adjusted R-square	0.9403	0.9564	0.8808	0.8726	0.8160	0.9560
Predicted R-square	0.8236	0.8702	0.6445	0.6577	0.4517	0.8690
Adequate precision	20.831	26.294	15.272	13.411	11.906	25.187
CV	0.81	7.74	1.22	1.32	3.18	0.54
Lack of fit	NS	NS	NS	NS	NS	NS

NS: non-significant

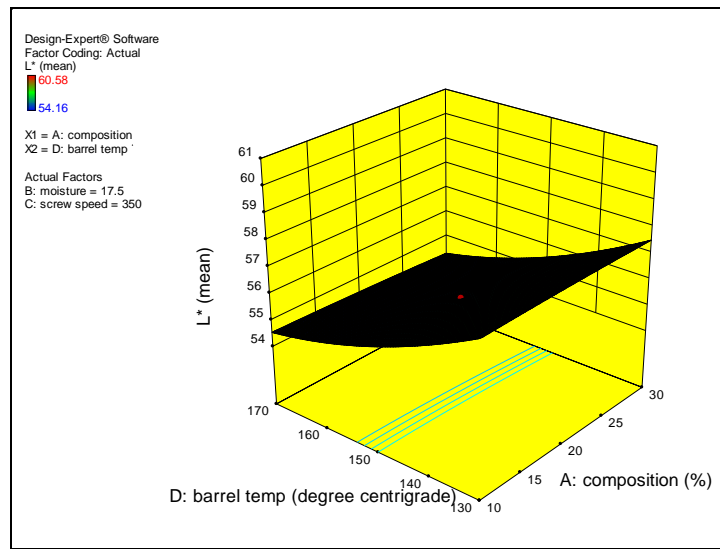
Luminosity (L*) of extrudates ranged from 52.10 and 57.42 whereas redness (a*) and yellowness (b*) were in range of 1.02 to 6.83 and 36.83 to 42.86 respectively. Figs. 1, 2, 3, 4, 5 and 6 demonstrates response surface plots of different colour

coordinates versus two independent variables. The models developed for luminosity (L*), redness (a*), yellowness (b*), chroma (c*), hue angle, and total colour difference (ΔE) are given below in equations (1 to 6) respectively.



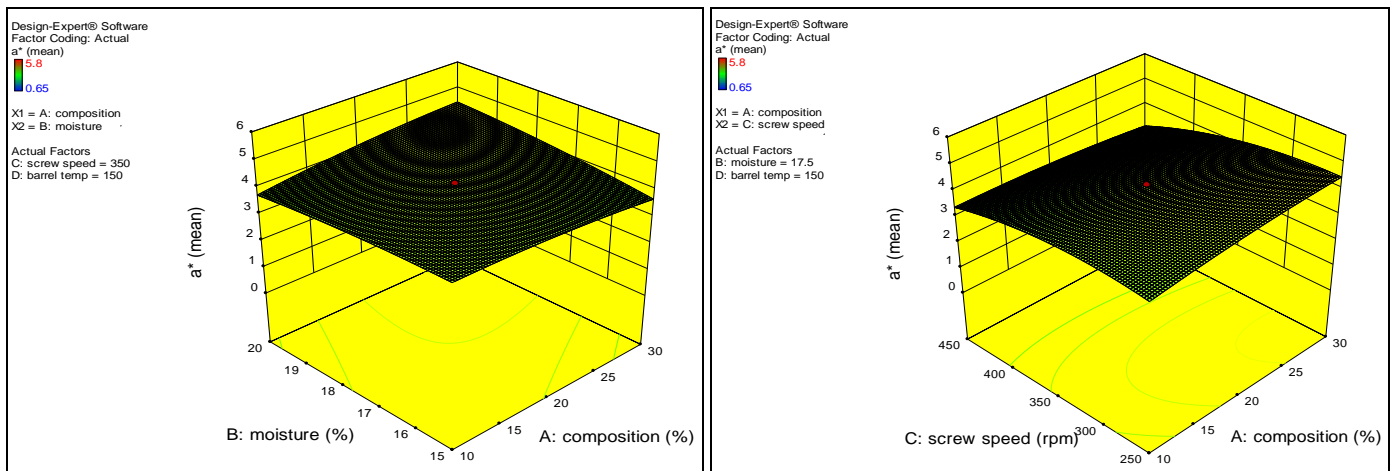
(a)

(b)



(c)

Fig 1: (a) Response surface plot for L^* as function of moisture and composition. (b): Response surface plot for L^* as function of barrel temperature and screw speed. (c): Response surface plot for L^* as function of barrel temperature and screw speed.



(a)

(b)

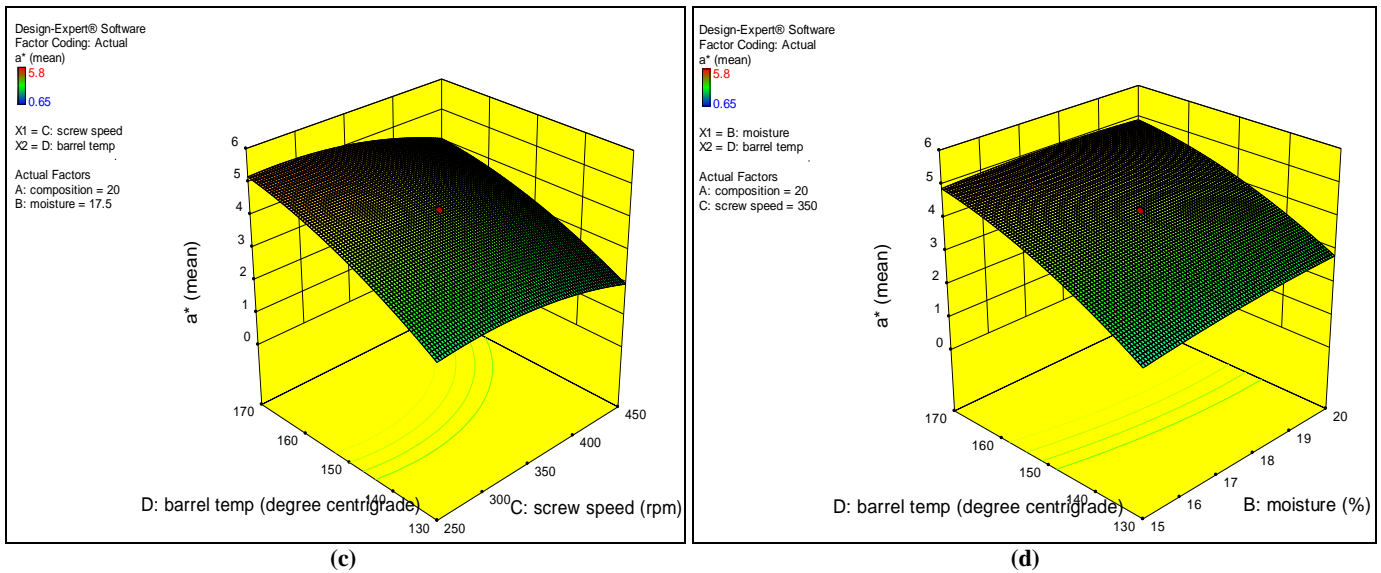


Fig 2: (a) Response surface plot for a^* as function of moisture and composition. (b): Response surface plot for a^* as function of screw speed and moisture (c): Response surface plot for a^* as function of barrel temperature and screw speeds (d) : Response surface plot for a^* as function of barrel temperature and moisture.

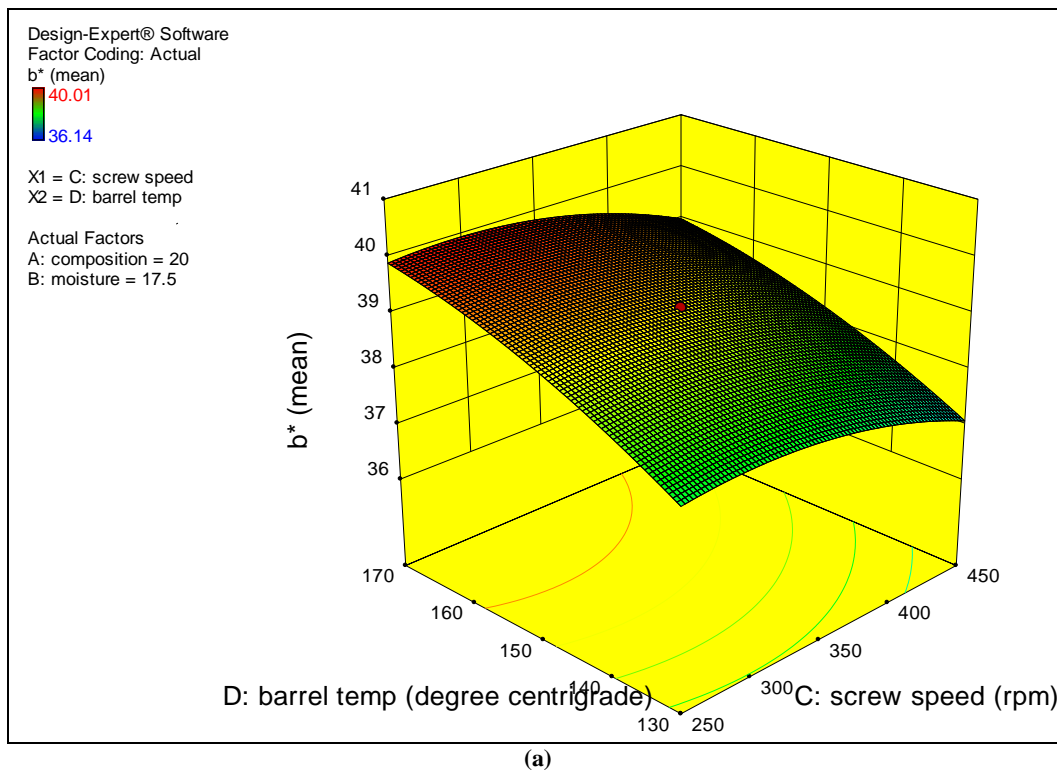
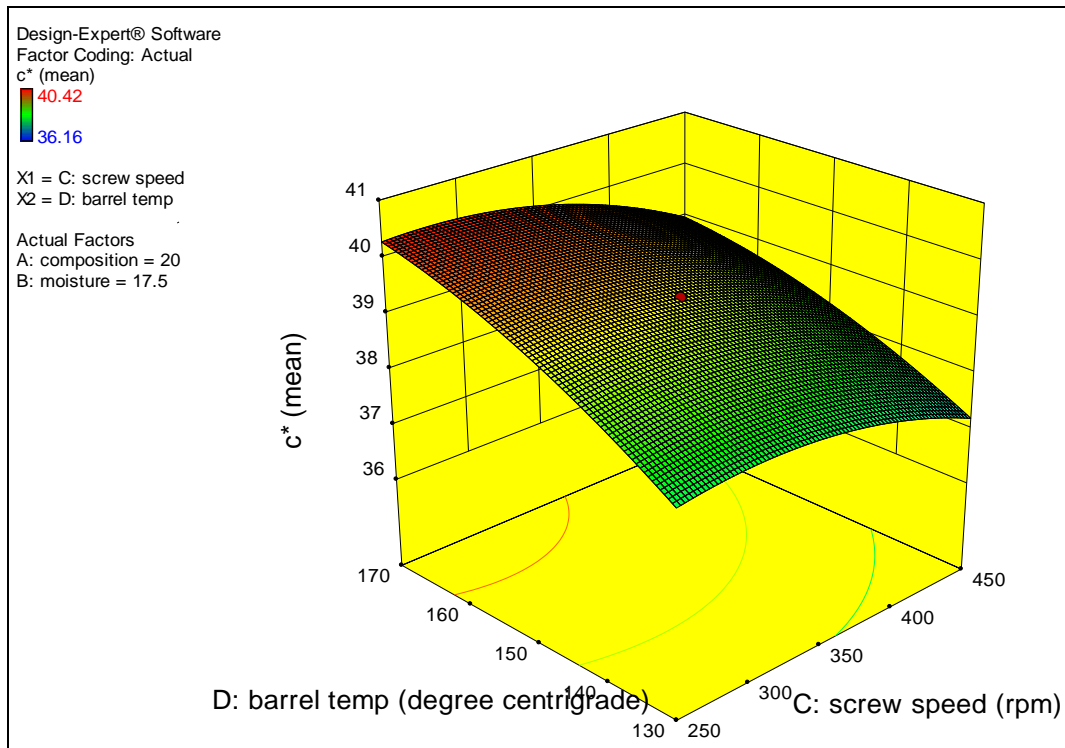
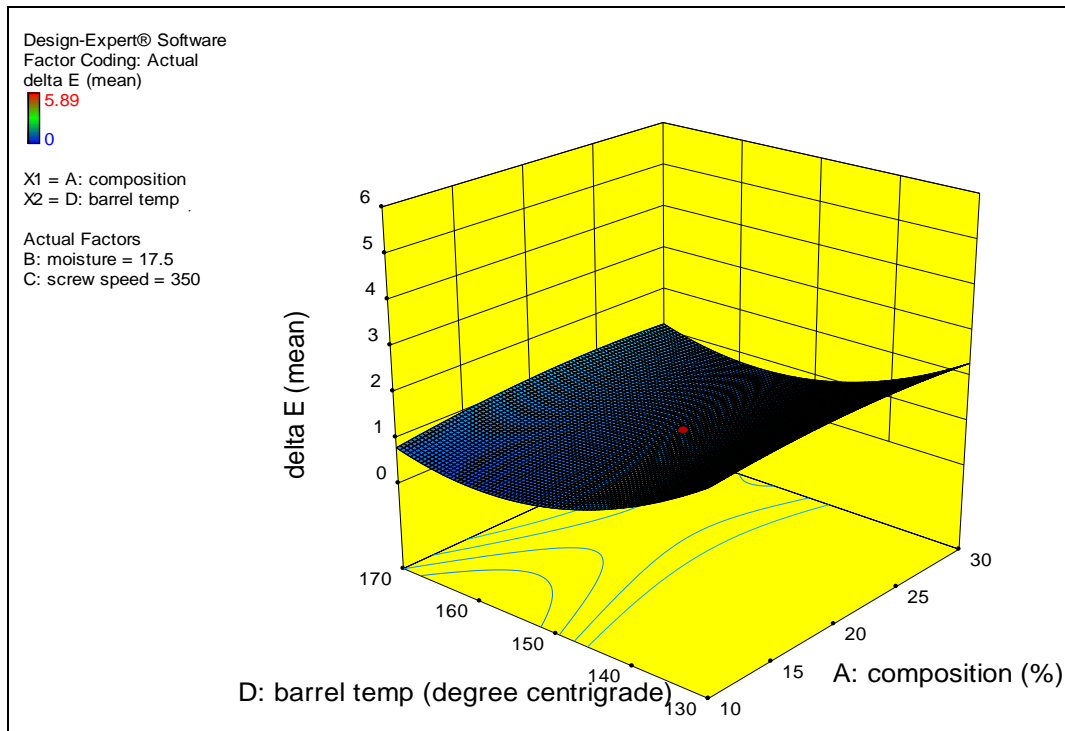


Fig 3: (a) Response surface plot for b^* as function of barrel temperature and screw speed.



(a)

Fig 4: (a) Response surface plot for c* as function of barrel temperature and screw speed.



(a)

Fig 5: (a) Response surface plot for as ΔE function of barrel temperature and composition.

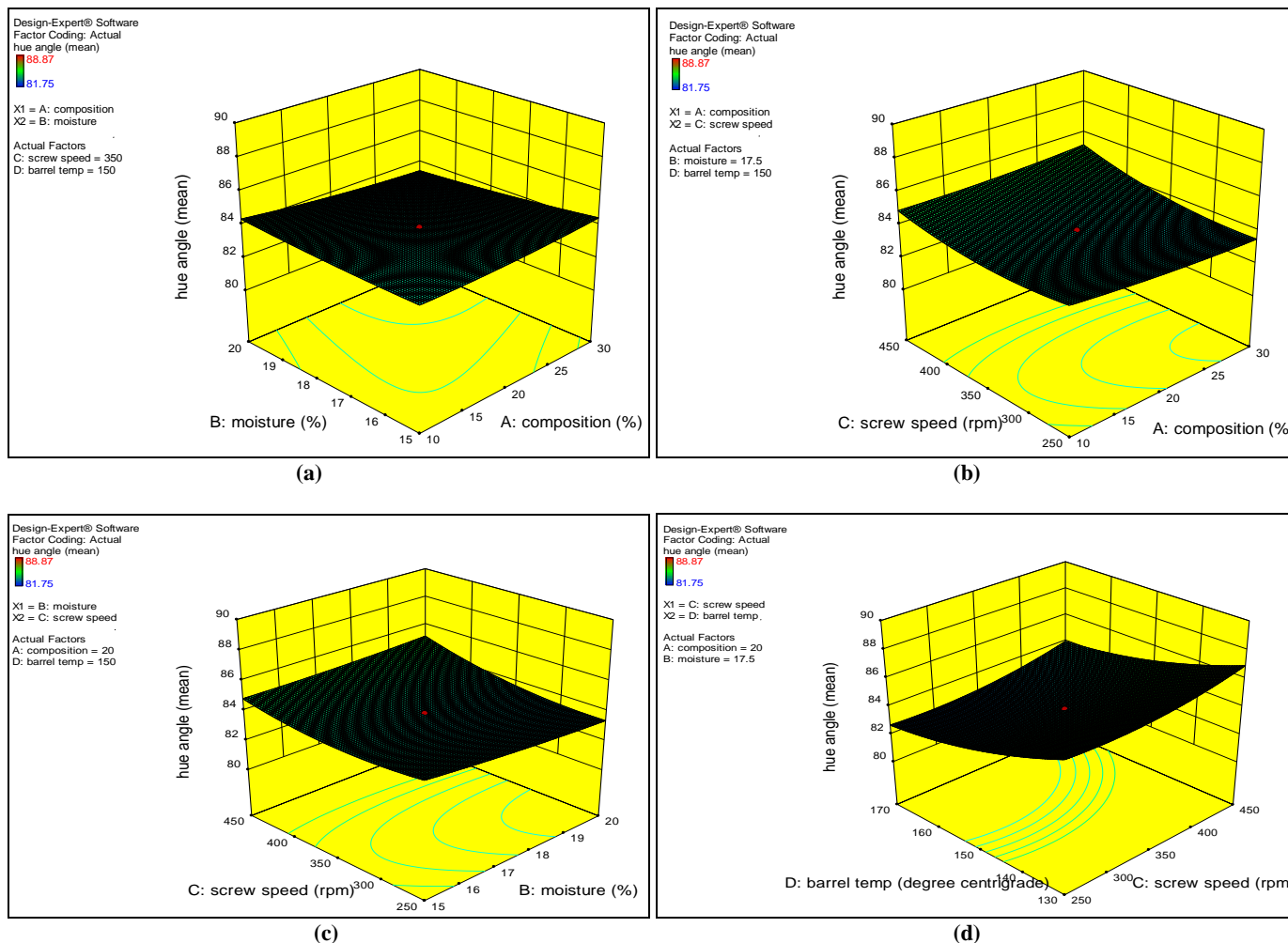


Fig 6: (a) Response surface plot for hue angle as function of composition and moisture. (b): Response surface plot for hue angle as function of hue angle composition and screw speed (C): Response surface plot for hue angle as function of hue angle moisture and screw speed (d): Response surface plot for hue angle as function of hue angle barrel temperature and screw speed.

$$L^* = 58.62 - 0.23B + 0.82C - 1.78D - 0.28AD - 0.41CD + 0.48C^2 + 0.47D^2 \quad (1)$$

$$a^* = 4.74 + 0.17B - 0.48C + 1.29D + 0.41AB - 0.21AC - 0.40BC - 0.19BD - 0.33CD - 0.16A^2 - 0.43C^2 - 0.28D^2 \quad (2)$$

$$b^* = 38.51 - 0.79C - 0.106D + 0.32A^2 + 0.46B^2 + 0.23C^2 + 0.20D^2 \quad (3)$$

$$c^* = 38.13 - 0.84C - 0.93D + 0.47A^2 + 0.61B^2 + 0.36C^2 + 0.36D^2 \quad (4)$$

$$\Delta E = 0.48 + 0.42A - 1.15D + 0.47B^2 + 0.74C^2 + 0.95D^2 \quad (5)$$

$$\text{Hue angle} = 82.98 - 0.21B + 0.60C - 1.98D - 0.61AB + 0.29AC + 0.55BC + 0.44CD + 0.29A^2 + 0.23B^2 + 0.66C^2 + 0.40D^2 \quad (6)$$

The negative coefficients of linear terms of temperature (D) and positive coefficients of screw speed (C) in equation (1) indicates that luminosity decreased with an increase in barrel temperature (D) and increased with increase in screw speed (C). When the level honey powder was increased, the values of L* (luminosity) tend to decrease. The increased darkening of extrudates with addition of honey powder might be due to presence of mono- and disaccharides in honey, which may

have underwent enhanced caramelization and maillards reaction. (Maga and Kim, 1989) [8]. However, the luminosity of extrudates increased with decrease in moisture content. These results are in accordance with the results shown by Gutkoski and EL-Dash (1999) [6]. L* value of extrudates increased at higher screw speeds, probably due to lower residence time at higher screw speeds. The reduction in L* values of the extrudates on increasing temperature may be attributed to the occurrence of Maillard reaction at high temperatures (Sacchetti *et al.*, 2004) [10]. The fitted regression equation (2) shows that with the increase in moisture content (B) and barrel temperature (D), the values of redness (a*) increased whereas with the increase in screw speed (C) these values were decreased. The positive coefficients of linear terms of composition, temperature and moisture indicated that with the increase in these variables a* (redness) value increased, while as the negative coefficients of screw speed indicates that a* values decreased with increase in screw speed. This may be due to the occurrence of browning reaction (caramellization of sugars), taking place during extrusion due to processing honey (Maga and Kim, 1989) [8]. The process conditions normally used in the thermoplastic extrusion (high temperature and low moisture content) are

known to favour the reaction between reducing sugars and amino acids, that results in either colour degradation or formation of desirable colour compounds.

The negative coefficients of linear terms of barrel temperature (D) and screw speed (C) (equations 3-4) indicated that b^* (yellowness), and c^* (chroma) decreased with increase in barrel temperature (D) and screw speed (C). Increase in temperature and screw speed decreased the b^* value of the product, whereas increase in feed proportion increased the b^* value of the product. Chroma or saturation or colourfulness is the difference between the colour against the gray. It describes the vividness or dullness of a colour. The c^* value increased

with the fall in temperature, due to increase in the coordinate b^* .

The negative coefficients of linear terms of barrel temperature (D) and positive coefficients of screw speed (C) in equations (5-6) indicates that total colour difference (ΔE) and hue angles decreases with an increase in barrel temperature and increased with increase in screw speed (C). Hue is the first element in the colour-order system by which we distinguish red from green, blue from yellow, etc.. The total colour difference values (ΔE) increased with composition and moisture content whereas high temperature resulted in decrease in ΔE .

Table 3: Effect of extrusion conditions on colour coordinates

Composition (%)	Moisture (%)	Screw speed (rpm)	Temp. (°C)	L*	a*	b*	c*	ΔE	hue angle
90:10	15	250	130	54.53	2.09	41.39	41.44	3.62	87.10
70:30	15	250	130	54.46	2.16	41.674	41.72	4.618	87.03
90:10	20	250	130	54.32	2.89	41.88	41.98	4.22	86.05
70:30	20	250	130	54.28	3.57	42.86	43.00	5.89	85.23
90:10	15	450	130	55.93	2.84	39.88	39.98	3.43	85.92
70:30	15	450	130	55.83	1.6	39.98	40.012	4.77	87.70
90:10	20	450	130	55.64	1.8	39.95	39.99	4.30	87.42
70:30	20	450	130	55.52	2.84	39.88	39.98	3.43	85.92
90:10	15	250	170	52.28	5.61	39.21	39.60	1.26	81.85
70:30	15	250	170	52.26	5.22	39.43	39.77	1.52	82.45
90:10	20	250	170	52.18	5.87	39.62	40.05	1.86	81.57
70:30	20	250	170	52.10	6.83	39.73	40.31	1.94	80.25
90:10	15	450	170	53.78	5.87	37.76	38.21	1.42	81.16
70:30	15	450	170	52.48	3.73	37.93	38.11	1.69	84.38
90:10	20	450	170	52.42	3.42	38.21	38.36	1.450	84.88
70:30	20	450	170	52.31	3.65	36.83	37.00	3.16	84.34
100:0	17.5	350	150	53.71	3.93	38.89	39.08	0.00	84.22
60:40	17.5	350	150	53.54	4.31	40.53	40.75	2.34	83.92
80:20	12.5	350	150	53.86	3.78	40.24	40.42	2.02	84.64
80:20	22.5	350	150	53.31	4.89	40.28	40.57	2.06	83.07
80:20	17.5	150	150	53.41	3.84	40.28	40.46	1.97	84.55
80:20	17.5	550	150	56.38	2.28	38.43	38.49	4.32	86.60
80:20	17.5	350	110	57.42	1.02	40.92	40.93	5.88	88.52
80:20	17.5	350	190	52.21	6.28	37.54	38.06	2.12	80.50
80:20	17.5	350	150	53.26	4.74	38.51	38.80	0.480	82.98
80:20	17.5	350	150	53.26	4.74	38.51	38.80	0.480	82.98
80:20	17.5	350	150	53.26	4.74	38.51	38.80	0.480	82.98
80:20	17.5	350	150	53.26	4.74	38.51	38.80	0.480	82.98
80:20	17.5	350	150	53.26	4.74	38.51	38.80	0.480	82.98
80:20	17.5	350	150	53.26	4.74	38.51	38.80	0.480	82.98

Conclusions

All the four extrusion parameters *viz.*, composition, moisture, screw speed and barrel temperature affected colour coordinates of corn-honey apple incorporated extrudates. within the experimental range the barrel temperature and screw speed were the most important factors for all parameters of extrudates. This can be concluded that extrusion processing can prove to be an efficient method for the production of quality extruded snacks, provided that the operating conditions are precisely controlled.

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