Bulgarian Chemical Communications, Volume 46, Special issue B (pp. 25 – 29) 2014

The effect of extrusion variables on the color of apple pomace - wheat semolina extrudates

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Received October 2, 2014; Accepted December 20, 2014

Apple pomace - wheat semolina blends were extruded in a laboratory single screw extruder (Brabender 20 DN, Germany) with screw diameter 19 mm and die diameter 5 mm. Effects of feed composition, moisture content, screw speed, and barrel temperature on color of the extruded products were studied. Response surface methodology with combinations of feed composition (10, 30, 50, 70, 90%), moisture content (17, 20, 23, 26, 29%), screw speed (120, 150, 180, 210, 240 rpm), and barrel temperature (130, 140, 150, 160, 170°C) was applied. Feed screw speed was fixed at 70 rpm. The compression ratio of the screw was 3:1. The temperatures of the feed and II-nd zone were 150 and 160ºC, respectively. The color changes of apple pomace - wheat semolina blends during extrusion were measured in CIE Lab color system using a colorimeter Colorgard 2000 (BYK – Gardner Inc., USA). The total color differences between the extruded and non-extruded samples were expressed by ΔE. The average ΔE values ranged from 6.52 to 10.94. Statistical analysis showed that feed composition, feed moisture content, and barrel temperature had an effect on the total color differences ($P<0.05$) whereas the screw speed had no effect on the color.

***Keywords*:** color, extrusion, apple pomace

INTRODUCTION

In many areas of the food industry, extrusion is an important manufacturing method. The processing conditions used in extrusion cooking - high temperature, pressure, and low moisture content of the feed - often give rise to a colored product or even a change in the color of the raw feed even though the residence time is low. It is logical to assume that the conditions of extrusion processing directly affect the color of the product although post-extrusion treatment also has a role to play [1-3]. Harper [4] mentioned that fading of color components is a common occurrence in extruded foods.

Color is perceived three dimensionally, based on responses of three different receptors (red, green, and blue) in the human eye [5]. The Judd–Hunter L, a, b and CIE Lab L^*, a^*, b^* are alternative color scales used to measure the degree of lightness (L), the degree of redness (+a) or greenness (-a), and the degree of yellowness (+b) or blueness (-b), with the CIE Lab scale being most commonly used for the evaluation of color in foods [6]. Conversion of a^* and b^* readings to hue and chroma values gives results more closely associated with human perception [7].

The aim of this investigation was to study the effect of extrusion variables on the color of extruded apple pomace - wheat semolina blends.

EXPERIMENTAL

Materials

Apple pomace is a by-product obtained during juice processing. Commercial apples (Granny Smith variety) are refrigerated and stored until the juice processing. The apple pomaces are dried a laboratory heat dryer at 60°C. The dried pomaces were ground using a hammer mill then mixed with commercial wheat semolina and distilled water to be obtained the desired ratios (Table 1). The prepared wet samples were placed and kept in sealed plastic bags for 12 h in a refrigerator at 5°C. The samples were tempered for 2 h at room temperature prior to extrusion.

Extrusion

The samples were extruded in a laboratory single screw extruder (Brabender 20 DN, Germany). The extruder barrel (476.5 mm in length and 20 mm in diameter) contained three sections and independently controlled die assembly electric heaters. The feed screw speed was fixed at 70 rpm. The screw speed was 120, 150, 180, 210, 240 rpm according to the experimental design (Table 1). The compression ratio of the screw was 3:1. The temperatures of the feed and kneading zone were 150 and 160ºC, respectively. The temperature of

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Table 1. Independent variable values and corresponding levels

Independent variables	Levels				
	- 2	**- 1**	**0**	**+ 1**	**+ 2**
Apple pomace / wheat semolina (C_{pom}), % - X_1	10	30	50	70	90
Feed moisture content (W), % - X_2	17	20	23	26	29
Screw speed (n), rpm – X_3	120	150	180	210	240
Final cooking zone temperature (Tm), °C – X_4	130	140	150	160	170

Table 2. Color parameters (L^*, a^*, and b^* values) of non-extruded apple pomace – wheat semolina blends

Apple pomace content (%)	L^*	a^*	b^*
10	89.28	1.99	24.54
30	83.24	3.36	28.74
50	80.31	4.00	30.09
70	80.45	3.98	30.46
90	81.26	3.79	29.76

the final cooking zone was 130, 140, 150, 160, 170°C. The die diameter was 5 mm.

Total color difference (ΔE)

The extrudates were finely ground using a laboratory hammer mill. The color parameters determined for the raw blends (non-extruded) and extruded samples included L^*, a^* and b^* values (CIE Lab system) using a colorimeter Colorgard 2000, BYK – Gardner Inc., USA. Total color difference (ΔE) was calculated applying the equation

$$\Delta E = \sqrt{(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2} \quad (1)$$

where L, a, and b are the values for the extruded samples; L_o, a_o, and b_o are the values for the raw blends (Table 2).

The color parameters are the mean values of ten observations.

Experimental design and data analysis

The effect of feed composition (apple pomace/wheat semolina) - X_1, feed moisture content - X_2, screw speed – X_3, and temperature of final cooking zone – X_4 on color (response, y) of the extruded products was investigated using response surface methodology (Table 1). A central composite rotatable design was used: $2k+2.k+n_o$, where k is the number of the independent variables, n_o the replicates of the center point (n_o=5).

A regression model is the following:

$$y = b_0 + \sum_{i=1}^{n} b_i . x_i + \sum_{i=1}^{n} b_{ii} . x_i^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} . x_i . x_j \quad (2)$$

where b_0, b_i, b_{ii}, and b_{ij} are constant coefficients.

SYSTAT statistical software (SPSS Inc., Chicago, USA, version 7.1) and Excel were used to analyze the data results.

RESULTS AND DISCUSSION

The total color differences between the extruded and non-extruded samples expressed by ΔE are given in Table 3. The extrudates were darker in color compared to their raw blends. L^* values of the extruded samples (from 72.06 to 83.03) were lower than Lo values of the raw blends (from 80.31 to 89.28). This may be due to the formation of brown pigments through non-enzymatic reactions that occur during the product processing.

Our results show that the total color difference of the extruded apple pomace - wheat semolina blends increases from 8.24 to 10.41 (L^* value decreases from 77.14 to 72.11) with raising the feed moisture content from 17 to 29% at apple pomace content 50%, temperature of final cooking zone 150ºC, and screw speed 180 rpm. Gujska and Khan[8] have extruded high starch fractions of navy, pinto, and garbanzo beans with different feed moisture contents. They have reported that increasing moisture content resulted in decreased L^* values of the extruded beans.

L^* value of the extruded apple pomace - wheat semolina blends increases from 75.61 to 82.96 with raising the screw speed from 120 to 240 rpm at apple pomace content 50%, feed moisture content 23%, and temperature of final cooking zone 150ºC. Similar finding was reported by Kannadhason et al. [9].

The results of the statistical analysis of variance (ANOVA) for the color show that 6 effects have P-values less than 0.05 indicating that they are significantly different from zero at the 95.0% confidence level. The R-squared statistic is 0.80; the standard error of the estimate - 0.89, the mean absolute error - 0.45. The regression equation describing the effect of extrusion variables on the total color difference (ΔE) of extruded apple pomace - wheat semolina blends is given in Table 4. The coefficients in the regression equation can be

used to examine the significance of each term relative to each other when used with coded values. Statistical analysis showed that feed composition, feed moisture content, and temperature of final cooking zone had an effect on the total color differences ($P<0.05$), whereas screw speed had no effect on the color. Each of the estimated effects and interactions are shown in the standardized diagram (Figure 1). The linear effect due to the feed composition of the apple pomace - wheat semolina blend had mostly influence on the total color difference followed by squared and linear effects due to the feed moisture content.

The effect of changes in feed moisture content and feed composition on the total color differences of the samples is given in Figure 2. ΔE values increased with an increase in moisture content and apple pomace content in the blends.

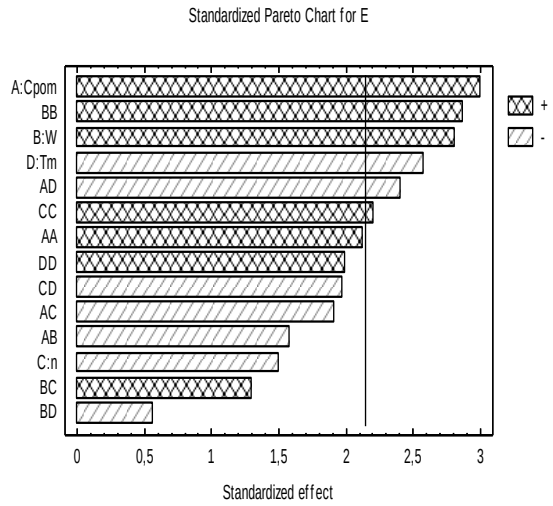

Fig. 1. Estimated effects of regression model coefficients on the total color differences.

Table 3. Total color differences of extruded apple pomace – wheat semolina blends

№	L^*	a^*	b^*	ΔE
1.	81.02	3.47	22.54	6.59
2.	72.40	4.66	23.91	10.40
3.	78.18	3.94	23.67	7.19
4.	73.67	5.41	22.07	10.88
5.	79.46	3.94	22.86	7.01
6.	73.34	4.48	24.03	9.60
7.	75.34	4.35	23.41	9.58
8.	72.06	5.97	23.73	10.94
9.	83.03	3.36	22.22	6.52
10.	73.91	4.84	22.53	10.31
11.	76.53	4.20	22.70	9.07
12.	78.77	3.72	22.30	8.34
13.	79.08	4.04	23.38	6.82
14.	77.38	4.48	24.64	6.60
15.	80.57	3.53	21.30	7.91
16.	77.07	4.12	23.31	7.91
17.	80.66	4.00	22.45	9.09
18.	76.84	5.14	22.61	8.51
19.	77.14	4.57	22.51	8.24
20.	72.11	5.19	23.79	10.41
21.	75.61	4.01	21.52	9.77
22.	82.96	3.92	22.59	7.95
23.	73.02	5.62	24.46	9.35
24.	82.54	4.22	22.35	8.06
25.	81.98	4.00	22.49	7.18
26.	80.53	4.53	23.12	6.99
27.	80.18	3.76	23.28	6.79
28.	80.06	3.46	22.89	7.23
29.	80.13	3.88	23.19	6.88

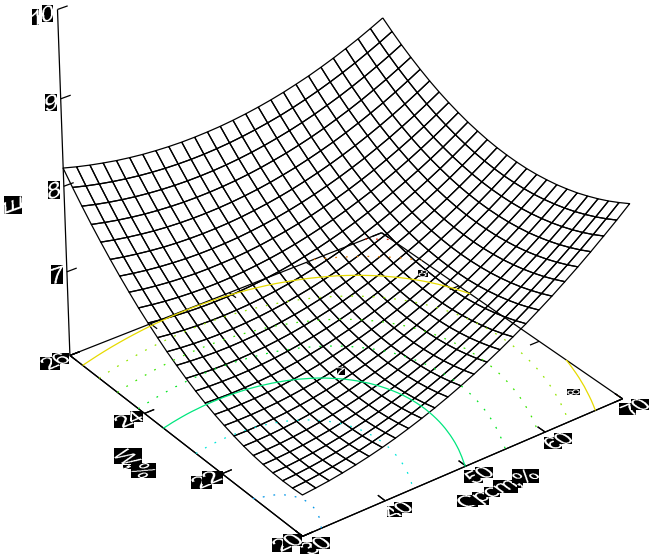

Fig. 2. Effect of feed moisture and feed composition on the total color difference (ΔE) of extruded apple pomace - wheat semolina blends.

Table 4. Regression equation coefficients for total color differences of extruded apple pomace – wheat semolina blends in terms of coded variables (correlation coefficient, $R^2 = 0.80$)

Variables	Coefficients
Constant	+60.6185
X_1	+0.6012*
X_2	- 2.0634*
X_3	+0.0181
X_4	- 0.5978*
X_1X_1	+0.0009
X_2X_2	+0.0560*
X_3X_3	+0.0004*
X_4X_4	+0.0035
X_1X_2	- 0.0059
X_1X_3	- 0.0007
X_1X_4	- 0.0027*
X_2X_3	+0.0032
X_2X_4	- 0.0042
X_3X_4	- 0.0015

X_1 - feed composition (%), X_2 - feed moisture (%), X_3 - screw speed (rpm), X_4 - barrel temperature (°C).
*Significant at 95% CI.

CONCLUSION

The effect of extrusion variables on the color of apple pomace - wheat semolina extrudates was studied. The color changes of apple pomace - wheat semolina blends during extrusion were measured in CIE Lab color system using a colorimeter Colorgard 2000 (BYK – Gardner Inc., USA). The total color differences between the extruded and non-extruded samples were expressed by ΔE. The average ΔE values ranged from 6.52 to 10.94. Statistical analysis showed that feed composition, feed moisture content, and temperature of final cooking zone had an effect on the total color differences ($P<0.05$), whereas screw speed had no effect on the color.

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ВЛИЯНИЕ НА НЯКОИ ПАРАМЕТРИ НА ЕКСТРУДИРАНЕ ВЪРХУ ЦВЕТА НА ЕКСТРУДАТИ ОТ ЯБЪЛКОВИ ПРЕСОВКИ И ПШЕНИЧЕН ГРИС

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Постъпила на 2 октомври, 2014 г.; приета на 20 декември, 2014 г.

(Резюме)

Смеси от ябълкови пресовки и пшеничен грис са екструдирани на едношнеков лабораторен екструдер (Brabender 20 DN, Германия) с диаметър на шнека 19 mm и диаметър на дюзата на матрицата 5 mm. Изследвано е влиянието на съдържанието на ябълкови пресовки, влажността, честотата на въртене на шнека и температурата на матрицата върху цвета на екструдираните продукти. Приложен е метода на повърхността на отражението със следните комбинации: съдържание на ябълкови пресовки (10, 30, 50, 70, 90%), влажност (17, 20, 23, 26, 29%), честота на въртене на шнека (120, 150, 180, 210, 240 min^{-1}) и температура на матрицата (130, 140, 150, 160, 170°C). Честотата на въртене на дозиращия шнек се фиксира на 70 min^{-1}. Степента на компресия на шнека е 3:1. Температурите на първа и втора зона са фиксирани съответно на 150 и 160°C. Цветът на екструдатите е измерен с колориметър Colorgard 2000, BYK – Gardner Inc., USA. Цветовите разлики между екструдираните и неекструдираните проби са изразени от ΔE. Средните стойности на ΔE варират от 6,52 до 10,94. Статистическият анализ показва, че съдържанието на ябълкови пресовки, влажността и температурата на матрицата оказват влияние върху цветовите разлики ($P < 0.05$), докато честотата на въртене на шнека не влияе върху цвета.