RESEARCH PAPER International Journal of Agricultural Engineering | Volume 10 | Issue 1 | April, 2017 | 37-42

e ISSN–0976–7223 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/10.1/37-42**

Effect of extrusion on colour characteristics of honey enriched whole grain cereal flour extrudates

HANUMAN BOBADE AND SAVITA SHARMA

Received : 08.01.2017; **Revised :** 11.02.2017; **Accepted :** 25.02.2017

See end of the Paper for authors' affiliation

Correspondence to :

HANUMAN BOBADE
Department of Agricultural Engineering, Maharashtra Institute of Technology, AURANGABAD (M.S.) INDIA
Email : hanu.chk@gmail.com

ABSTRACT : The work presented in this paper aimed at understanding the effects of extrusion processing parameters and level of honey on the colour properties of extrudates prepared from whole wheat flour, brown rice and whole maize flour. Whole grain Cereal flours (wheat, brown rice, maize) singly and in combination (in 3:4:3 proportion) were mixed with varying level of honey and mix was extruded through co-rotating twin screw extruder at different feed moisture and barrel temperatures. The resulting extrudates were evaluated for colour properties by Hunter Lab colorimeter. The results of this study revealed that L* value which represents lightness of extrudates feebly increased on increasing the feed moisture content while increasing the barrel temperature reduced the L* value of extrudates. Increased honey level in the feed also resulted in decreased L* value. It was observed that the a* value of extruded samples increased as a function of extrusion temperature and honey level in the feed. Similar to a* value, an increase in b* value of extrudates was also observed on increasing the extrusion temperature and honey level in the feed. The hue angle of the extrudates decreased on increase in extrusion temperature and honey level in the feed.

KEY WORDS : Extrusion, Whole grain cereals, Honey, Colour, Feed moisture

HOW TO CITE THIS PAPER : Bobade, Hanuman and Sharma, Savita (2017). Effect of extrusion on colour characteristics of honey enriched whole grain cereal flour extrudates. *Internat. J. Agric. Engg.*, **10**(1) : 37-42, **DOI: 10.15740/HAS/IJAE/10.1/37-42.**

Extrusion processing is one of the most versatile and convenient process in production of different kinds of foods. Extrusion cooking was first introduced in food and feed processing in the late 1950s. Since then, systems involved have grown in popularity, efficiency and flexibility. Extrusions cooking technology is mostly used for cereal and protein processing and plays an important role in the food industry as efficient manufacturing process. Extrusion technology has led to the production of a wide variety of cereal-based foods, including snacks and ready-to-eat breakfast cereals (Bailey *et al.*, 1991). Extrusion processed foods, which are also categorized as convenience foods, must arouse the pleasure of the consumer. Moreover, there is increased awareness amongst the consumers for more nutritious and functional foods. For this purpose, manufacturers enrich extruded products with variety of ingredients. Honey is one of the nutrient rich ingredients. Honey can be considered as a dietary supplement (Mendes *et al.,* 1998) as it contains some important components including alpha-tocopherol, ascorbic acid, flavonoids and phenolics (Turhana *et al.*, 2008).

Colour, glossiness and transparency are the most important characteristics of extruded foods. For this purpose, manufacturers create new products with various shapes, flavors, textures and colours. The extrusion processing conditions (high temperature, pressure and low moisture content of the feed) often results in a coloured product or even a change in the colour of the raw feed even though the residence time is low (Bhattacharya *et al.,* 1997) . This change in colour is two ways, fading of the raw material colour due to heat induced degradation of raw material and darkening of the color due to non-enzymatic browning. Non-enzymatic browning is of two types, Maillard reaction and caramelization. The Maillard reaction (MR) occurs between the free amino group of lysine and/or other amino acids and the carbonyl groups of reducing sugars such as glucose and maltose (Camire *et al.,* 1990), whereas caramelisation depends on direct degradation of sugars (Ramírez-Jiménez *et al.,* 2001). These colour changes as a result of processing of foods may be desirable (bread crust) or may be undesirable (apple puri). In this context, the present study was undertaken to evaluate the effects of extrusion processing honey on the colour characteristics of resultant extrudates.

■ METHODOLOGY

Wheat (var. HD 2967), paddy (var. PR 121), maize (var. PMH 1) was supplied by Directorate Seeds, Punjab Agricultural University, Ludhiana, Punjab, India. Brown rice was obtained by dehulling the paddy in laboratory dehuller (Satake, Japan). Grains after cleaning were grinded in Torrento Flour Mill (Tech Electric Enterprise, Ahmedabad, India) to obtain the whole grain flours (250µ). Honey (sunflower cultivar) was supplied by Department of Entomology, Punjab Agricultural University, Ludhiana, India.

Experimental design :

The extrusion was carried out by varying the levels of three independent variables (feed moisture, extrusion temperature and honey level in the feed). The feed moisture was varied at two levels (14 and 17%), extrusion temperature was varied at 5 levels (100, 120, 140, 180 and 200^{0}C) while honey level was varied at 5 different levels (1, 5, 10, 15 and 20%). Three types of cereals (wheat, rice, maize) singly and in combination (3:4:3 proportion) were mixed with the honey and extruded at varying feed moisture and extrusion temperature.

Extrusion :

Extrusion of honey-cereals was performed with the help of twin screw co-rotating intermeshing extruder (BC 21, Clextral, Firminy, France) having a screw length of 400 mm and diameter 25 mm. The extruder was powered by an 8.5 kW motor with speeds variable from 0 to 682 rpm. However, over entire experiment, the screw speed of the extruder was kept constant (500 rpm). Raw materials were metered into the extruder with a single screw volumetric feeder (D S and M, Modena, Italy). The feed rate was kept at 10kg/hr rate for optimum fill in accordance with the screw speed. A variable speed die face cutter with four bladed knives was used to cut the extrudates. The die plate had one circular hole with 6 mm diameter.

Colour :

Colour of extruded snacks was measured by using Minolta Spectrophotometer in the hunter lab colour mode. In this system, the specimen surface is illuminated diffusely. The spectrophotometer utilizes a pulsed xenon arc lamp for illumination; light from the lamp is thoroughly diffused inside the integrating sphere to provide diffuse even lightening over the illuminated area of the specimen surface and the measurement appeared in the display.

The hunter scale (L*) measures brightness, from 100 for perfect white to 0 for black. The chromaticity dimensions (a* and b*) give understandable designations of colour *i.e.* the value a* measures redness when positive, grey when zero and green when negative. The value b* measures yellowness when positive, grey when zero and blueness when negative. The following guidelines indicate status of colour.

+L* = Sample lighter
-L* = Sample darker
+a* = Sample redder (less green)
-a* = Sample greener (less red)
+b* = Sample yellower (less blue)
-b* = Sample blue (less yellow)

Statistical analysis :

Values were mean of three replications, wherever not mentioned. The analysis of variance was performed with the help of Statistical Package for the Social Sciences (SPSS, [PASW version 18.0] Inc., USA). Tukey's test ($p<0.05$) was used to detect differences among treatment means.

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Honey-wheat extrudates :

The colour values (L*, a* and b*) including hue angle of honey-wheat extrudates are presented in Table 1. Within 14 per cent feed moisture, the L* values of extrudates ranged from 58.35 to 68.35 while within 17 per cent feed moisture, the L* values of extrudates ranged from 56.55 to 69.15. It is apparent from the Table 1 that L* value (lightness) of extrudates declined with increase in extrusion temperature and honey level in the feed. Extrusion at lowest temperature (100^0C) produced extrudates with highest L* value while extrusion at highest temperature (200^0C) resulted extrudates with lowest L* value. a* value which indicates redness and greenness of the sample varied from 2.25 to 4.75 within 14 per cent feed moisture whereas within 17 per cent feed moisture, it ranged between 2.05-4.85. All the samples showed significant ($p<0.05$) variation in a* values. It was observed that the a* value of extruded samples increased as a function of extrusion temperature and honey level in the feed. This indicates that increased extrusion temperature and honey level in feed would result in more redness of the samples. The increase in darkness may be attributed to formation of dark brown colour compounds during extrusion. Such compounds are formed by the degradation of free sugar available in the sample. Honey, which is rich source of glucose and fructose, thus may contribute in darkening and decrease in L* value of the extruded samples. Production of brown colored compounds may have contributed in increasing redness (a* value) and yellowness (b* value). The hue angle which depicts all colour parameters of the sample ranged from 76.39 to 83.04^0. Increase in extrusion temperature resulted in reduced hue angle indicating more redness and darkness of the product. Increased honey in feed also had the similar effect on hue angle of the extrudates.

Honey-brown rice extrudates :

The colour characteristics of honey-brown rice extrudates are presented in Table 2. The maximum L* value was observed at 17 per cent feed moisture, 100^0C barrel temperature and 10 per cent honey level while minimum L* value was seen in extrudates prepared at 17 per cent moisture, 200^0C barrel temperature and 10 per cent honey level. It is evident from the Table 2 that the increase in extrusion temperature and honey level resulted in decreased L* value and hence increased darkness in the product. The lightness of the extrudates decreased gradually upon increase in barrel temperature and proportion of honey in the feed. Nevertheless, the extrudates prepared at 10 and 20 per cent honey at constant moisture (17%) and barrel temperature (150^0C) shown non-significant changes in L* value. The a* value which signifies redness of the product increased along with increase in barrel temperature and honey level in the feed. However, at 14 per cent moisture content, honey level have non-significant ($p>0.05$) effect on the a* value of extrudates. Moreover, at 17 per cent moisture honey level in feed, had significant effect on a* value only beyond 10 per cent honey addition. The a* value of the extrudates prepared at 1 and 10 per cent honey level was not influenced significantly.

The extrusion processing conditions influenced the b* value of extrudates much similar to the effect on a* value. Yellowness of the samples increased upon increase in barrel temperature and honey level in feed moisture. Though barrel temperature significantly ($p<0.05$) affected the b* value, effect of honey level was non-significant ($p>0.05$). Hue angle of the extruded samples ranged from 78.31 to 85.40^0. The high value of hue angle (85.40^0) at lower extrusion temperature could be due to the less gelatinization and degradation of sample as hue angle also followed the non-significant changes as a function of honey level in feed. The significant ($p<0.05$) effect of extrusion temperature on colour characteristics could be due to the reason that the sample underwent enough gelatinization and degradation to provide monomers for the browning reaction. The increase in redness or decrease in greenness may be due to the synthesis of brown coloured compounds at high temperature. Higher temperature facilitates degradation of free sugars which are converted into Maillard Reaction Products (MRPs) and other brown coloured compounds. Ahmed *et al*. (2007) found that as honey contains ample amount of free monosaccharides (glucose and fructose), its increased level could result in increase in a* and b* values as well as darkening of the colour sample.

Honey-maize extrudates :

Effect of extrusion processing variables on the colour of honey incorporated maize is depicted in Table

3. The various colour characteristics, L*, a*, b* values as well as the hue angle of extrudates varied very closely. These values differed significantly only for extrudates prepared at 100 and 200^{0}C extrusion temperature at 17 per cent feed moisture and 10 per cent honey level. Apart from this treatment all other treatments showed non-significant ($p>0.05$) variation in these colour characteristics. However, it can be seen from the Table 3 that L* value of extrudates decreased slightly by increasing the barrel temperature and honey level in feed.

Highest L* value was observed at minimum temperature suggesting that the sample processed at this temperature was least dark. The most dark (low L* value) sample observed was that processed at higher temperature (180^{0}C) and higher honey level (15%). The a* and b* values were increased as a result of increase in extrusion temperature and honey level in the feed. This indicates that the samples processed at high temperature and high honey level turned more reddish and yellowish, respectively. Highest a* and b* values were observed at 14 per cent feed moisture, 180^{0}C barrel temperature and 15 per cent honey level in the feed. Contrary to a* and b* values, the hue angle of extruded samples declined steadily upon increase in barrel temperature and honey level. The decrease in hue angle portrays the more redness of extrudates. The positive effect of temperature on a* and b* values could be due to heat induced degradation of feed which may also have lowered the L* value of samples after extrusion. These colour changes in extruded samples could be used as in index of thermal processing as this study illustrated that intensive processing subtly affected the colour values of extrudates. The restrained changes in colour characteristics of honey-maize extrudates may be attributed to presence of pigmented compounds in maize which masked/lowered the browning effect during extrusion. These results are validated by the verdicts of Fratianni *et al.* (2005) and Lamberts *et al.* (2007).

Table 1 : Colour characteristics of honey-wheat extrudates

Treatments			Colour characteristics			
Moisture (%)	Temperature (^{0}C)	Honey (%)	L*	a*	b*	Hue angle (^{o})
14	120	5	68.35±0.25^a	2.25±0.10^d	16.85±0.05^c	82.39±0.31^a
	180	5	60.25±1.35^c	3.40±0.15^b	18.90±0.10^b	79.80±0.39^c
	120	15	65.85±1.10^b	2.95±0.35^c	17.85±0.15^c	80.62±1.02^b
	180	15	58.35±0.25^c	4.75±0.15^a	19.60±0.40^a	76.38±0.15^d
17	100	10	69.15±1.05^a	2.05±0.05^d	16.80±0.05^d	83.04±0.15^a
	200	10	56.55±1.25^c	4.85±0.25^a	21.25±0.25^a	77.15±0.49^c
	150	1	68.00±1.65^a	2.70±0.05^c	17.15±0.20^c	81.05±0.06^b
	150	20	62.05±1.35^b	3.65±0.05^b	19.30±0.05^b	79.29±0.12^b
	150	10	62.05±1.25^b	3.15±0.05^{bc}	18.15±0.25^c	80.15±0.02^b

L*-lightness, a* redness, b* yellowness

Means followed by different superscript letter in the column differ significantly ($p<0.05$) for a given feed moisture

Table 2 : Colour characteristics of honey-brown rice extrudates

Treatments			Colour characteristics			
Moisture (%)	Temperature (^{0}C)	Honey (%)	L*	a*	b*	Hue angle (^{o})
14	120	5	75.95±0.25^a	2.20±0.15^b	15.30±0.50^b	81.82±0.29^a
	180	5	66.65±1.35^c	3.40±0.20^a	17.45±0.40^a	78.98±0.39^c
	120	15	73.85±0.05^b	2.65±0.10^b	16.10±0.25^b	80.66±0.20^b
	180	15	62.85±0.50^d	3.65±0.05^a	18.55±0.75^a	78.86±0.29^c
17	100	10	77.05±0.05^a	0.95±0.05^c	11.80±0.05^d	85.40±0.22^a
	200	10	62.25±0.45^d	3.80±0.20^a	19.05±0.05^a	78.72±0.55^c
	150	1	74.75±0.25^b	2.50±0.05^b	15.55±0.45^b	80.87±0.08^b
	150	20	70.75±0.75^c	3.65±0.05^a	17.65±0.80^b	78.31±0.36^c
	150	10	71.20±0.65^c	2.75±0.05^b	17.10±0.70^{bc}	80.86±0.20^b

L*-lightness, a* redness, b* yellowness

Means followed by different superscript letter in the column differ significantly ($p<0.05$) for a given feed moisture.

Honey-cereals in combination extrudates :

Table 4 bespeaks the data pertaining to colour attributes of the extrudates prepared from whole grain cereals in combination (wheat, rice and maize) along with honey at various proportions by varying the processing conditions. Trivial changes were observed in the colour attributes of extrudates as affected by extrusion processing conditions. The effect of either solitary barrel temperature or honey level on the L* value of extrudates was non-significant ($p>0.05$). The cumulative effect of barrel temperature and honey level, however, produced the significant ($p<0.05$) effect on L* value. The L* value of extrudates varied scarcely from 64.10 to 69.30. The highest L* value was observed at 17 per cent feed moisture, 100^0C barrel temperature and 10 per cent honey level while lowest L* value was observed at the same feed moisture and honey level but maximum barrel temperature (200^0C).

The extruded samples became progressively darker upon increase in barrel temperature and honey level in the feed. The a* and b* values of extrudates were found in between 1.85-4.70 and 16.25-24.60, respectively. Considerable disparity was observed in the a* and b* values of extrudates. It is comprehensively understood from the Table 4 that the extrusion temperature as well as honey level in feed resulted in increase in a* and b* values of extrudates. Extrusion at 14 per cent feed moisture and 120^0C barrel temperature did not significantly influence the a* and b* values of extrudates when honey level was increased from 5-15 per cent. However, extrusion at 14 per cent feed moisture and 180^0C barrel temperature resulted in the significant difference in a* and b* values of extrudates when honey level was increased from 5-15 per cent. This indicates that the barrel temperature is deciding factor affecting the colour attributes of extrudates. Further, it was noticed that honey level had significantly ($p<0.05$) positive effect on a* and b* values of extrudates. Nonetheless, a* and b* values of extrudates at low barrel temperature and high honey level or *vice versa* were at par. This implies

Table 3 : Colour characteristics of honey-maize extrudates

Treatments			Colour characteristics			
Moisture (%)	Temperature (^{0}C)	Honey (%)	L*	a*	b*	Hue angle (^{o})
14	120	5	68.55 ± 0.30^{a}	3.95 ± 0.10^{c}	23.25 ± 0.05^{c}	80.36 ± 0.22^{a}
	180	5	65.85 ± 0.30^{bc}	4.65 ± 0.05^{b}	25.90 ± 0.05^{b}	79.82 ± 0.09^{ab}
	120	15	67.35 ± 0.40^{ab}	4.40 ± 0.05^{b}	24.15 ± 0.40^{c}	79.68 ± 0.52^{b}
	180	15	64.65 ± 1.15^{c}	5.20 ± 0.25^{a}	27.25 ± 0.10^{a}	79.20 ± 0.47^{b}
17	100	10	68.80 ± 0.85^{a}	3.20 ± 0.10^{c}	22.30 ± 0.05^{d}	81.83 ± 0.23^{a}
	200	10	58.30 ± 0.45^{c}	5.25 ± 0.05^{a}	29.15 ± 0.10^{a}	79.79 ± 0.06^{b}
	150	1	67.40 ± 0.10^{ab}	4.35 ± 0.25^{bc}	23.95 ± 0.95^{c}	79.71 ± 0.18^{ab}
	150	20	66.20 ± 0.10^{b}	5.20 ± 0.10^{a}	26.40 ± 0.05^{b}	78.86 ± 0.19^{c}
	150	10	67.20 ± 0.75^{b}	4.40 ± 0.30^{b}	24.25 ± 0.35^{c}	79.72 ± 0.03^{b}

L*-lightness, a* redness, b* yellowness
Means followed by different superscript letter in the column differ significantly ($p<0.05$) for a given feed moisture.

Table 4 : Colour characteristics of honey-cereals in combination extrudates

Treatments			Colour characteristics			
Moisture (%)	Temperature (^{0}C)	Honey (%)	L*	a*	b*	Hue angle (^{o})
14	120	5	68.35 ± 0.05^{a}	1.90 ± 0.35^{c}	17.15 ± 0.40^{c}	83.71 ± 0.81^{a}
	180	5	66.45 ± 0.20^{ab}	3.60 ± 0.05^{b}	19.30 ± 0.05^{b}	79.43 ± 0.12^{b}
	120	15	66.70 ± 0.70^{ab}	2.65 ± 0.10^{c}	17.50 ± 0.15^{c}	81.39 ± 0.25^{b}
	180	15	65.20 ± 1.50^{b}	4.65 ± 0.25^{a}	20.90 ± 0.10^{a}	77.46 ± 0.59^{c}
17	100	10	69.30 ± 2.50^{a}	1.85 ± 0.05^{d}	16.25 ± 0.15^{d}	83.51 ± 0.11^{a}
	200	10	64.10 ± 0.10^{b}	4.70 ± 0.30^{a}	24.60 ± 1.15^{a}	79.19 ± 0.18^{c}
	150	1	68.20 ± 0.05^{a}	2.05 ± 0.05^{c}	17.15 ± 0.95^{c}	83.18 ± 0.01^{a}
	150	20	66.60 ± 0.20^{ab}	4.40 ± 0.05^{a}	19.70 ± 0.55^{b}	77.41 ± 0.20^{d}
	150	10	66.95 ± 0.05^{ab}	3.15 ± 0.15^{b}	17.95 ± 0.10^{c}	80.05 ± 0.41^{b}

L*-lightness, a* redness, b* yellowness
Means followed by different superscript letter in the column differ significantly ($p<0.05$) for a given feed moisture.

that at 17 per cent feed moisture, the effect of barrel temperature and honey level on a* and b* values of extrudates was equally profound.

The hue angle of extrudates was found to be reduced with increase in barrel temperature and honey level, meaning that the redness of samples increased with increase in barrel temperature and honey level. The values of hue angle were found in the range of 77.41-83.71^0. At both feed moisture (14 and 17%), both barrel temperature and honey level had significant ($p<0.05$) effect on the hue angle of extrudates. The results of the present study are in agreement with the results of Singh-Sandhu *et al*. (2007).

Conclusion :

The results of the present study show that the extrusion processing parameters and level of honey in the feed significantly modified the colour characteristics of resultant extrudates prepared from various cereal flours. The changes in colour characteristics depend on the intensity of extrusion processing conditions. Increased extrusion temperature resulted in the darkening and reddening of the extrudates. Feed moisture at elevated temperature was found to non-significantly affect the colour characteristics of extrudates. Addition of incremental honey in the feed also found to increase the darkness, redness and yellowish-ness of the extrudates. Undesirable changes in the colour properties of extrudates are observed at extreme extrusion temperature (180 and 200^{0}C) combined with higher level of honey (15 and 20%) in feed. Results of this study indicate that acceptable extruded products in terms of colour can be processed when whole grain cereal flours are processed at temperature equal to or less than 150^{0}C and honey equal to or less than 10 per cent in feed.

Authors' affiliations:
SAVITA SHARMA, Department of Food Science and Technology, Punjab Agricultural University, LUDHIANA (PUNJAB) INDIA

REFERENCES

Ahmed, J., Prabhu, S.T., Raghavan, G.S.V. and Ngadi, M. (2007). Physico-chemical, rheological, calorimetric and dielectric behavior of selected Indian honey. *J. Food Engg.*, **79** : 1207-1213.

Bailey, L.N., Hauck, B.W., Sevatson, E.S. and Singer, R.E. (1991). Systems for manufacture of ready-to-eat breakfast cereals using twin-screw extrusion. *Cereal Foods World*, **36**: 863–869.

Bhattacharya, S., Sivakumar V. and Chakraborty, D. (1997). Changes in CIELab colour parameters due to extrusion of rice-greengram blend: a response surface approach. *J. Food Engg.*, **32**:125-131

Camire, M.E., Camire, A. and Krumbar, K. (1990). Chemical and nutritional changes in foods during extrusion. *Crit Rev. Food Sci. & Nutr.*, **29**: 35–57.

Fratianni, A., Irano, M., Panfili, G. and Acquistucci, R. (2005). Estimation of colour of durum wheat. Comparison of WSB, HPLC, and reflectance colorimeter measurements. *J. Agric. Food Chem.*, **53**:2373-2378.

Lamberts, L., Els, D.B., Greet, E.V., Wim, S.V., Veerle, D., Walter, D.M. and Jan, A.D. (2007). Effect of milling on colour and nutritional properties of rice. *Food Chem.*, **100**:1496-1503.

Mendes, E., Brojo Proenca, E., Ferreira, I.M. and Ferreira, M.A. (1998). Quality evaluation of Portuguese honey. *Carbohydrate Polym*, **37**: 219–223

Ramírez-Jiménez, A., García-Villanova, B. and Guerra-Hernández, E. (2001). Effect of toasting time on the browning of sliced bread. *J. Sci. Food & Agric.*, **81** : 513–518.

Singh-Sandhu K., Singh, N. and Singh-Malhi, N. (2007). Some properties of corn grains and their flours I: Physicochemical, functional and chapati-making properties of flours. *Food Chem.*, **101**:938-946.

Turhana, I., Tetika, N., Karhana, M., Gurelb, F. and Tavukcuoglu, R. (2008). Quality of honeys influenced by thermal treatment. *LWT.*, **41**: 1396-1399.