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Effect of Extrusion Conditions on Hunter Colour (*L*a*b**) Parameters of Kodo (*Paspalum scrobiculatum L.*) Based Snacks Using Response Surface Methodology

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ABSTRACT

Response surface methodology was used to investigate the effects of extrusion conditions including the moisture content of feed (8-16%), die head temperature (160-240 ^{0}C), barrel temperature (120-200 ^{0}C), screw speed (80-160 rpm) and change in feed composition on the Hunter colour (*L*a*b**) characteristics of the ready-to-eat snack food developed from Kodo millet flour (70%) in combination with defatted soy flour (5-25%) and water chestnut flour (5-25%). Models developed for the colour parameters gave R^2 values 0.79 for *L**, 0.86 for *a** and 0.80 for *b**. The results indicated that the L* values of extrudates varied between 49.25 and 57.24 with a mean of 52.64, a* values ranged from 5.09 to 6.7 with a mean of 5.84 and b* values varied from 17.81 to 22.72 with a mean of 20.58.

Keywords: *Extrusion cooking, Hunter colour (L*a*b*), Kodo millet and Response surface methodology*

Food extrusion is a technology that is extensively used for the development of new products using starch-based raw materials. It is a high temperature-short time process; the feed material is conveyed, mixed, dried and cooked at the same time to obtain expanded products, changing some physical and chemical properties of the feed material (Harper, 1989). In this process, important processing parameters for product quality include moisture content of feed material, blend ratio, screw speed, die head and barrel temperature (Gogoi and Yam, 1994). Food extruder works like a pump, a heat exchanger and a continuous high temperature-high pressure reactor which have many advantages i.e. versatility and flexibility which save time, energy and cost (Huber and Rokey, 1990).

Colour is an important quality parameter of food products. In extrusion process, there are many chemical reactions that take place which affect the colour of product. Ilo and Berghofer (1999) stated that the most common chemical reactions that take place i.e. nonenzymatic browning reactions (maillard reaction, sugar caramelisation, etc.) and pigment degradation. The processing conditions used in extrusion cooking (high temperature and low water content) are known to favour the maillard condensation of amino groups with reducing sugars, which leads to the formation of colour compounds and a reduction in available lysine (Berset, 1989). Non-enzymatic browning is associated with a flavour development. If browning is too intensive, undesirable colours and flavours may appear. Also, the changes of colour in extrusion cooking may be a visual indicator to assess the process intensity concerning chemical changes or nutritional loss in food. Kodo is one among the six other minor millets. It is a rich source of dietary fibre and micro-nutrients (Ahmed *et al*. 2013). Defatted soy flour is a processed product made from finely ground defatted soy meal and contains less than 1.5% oil and minimum 50% protein by weight (Gandhi, 2009). It is widely used in food products due to its functional properties (Liu, 1997; Riaz, 2006). Water chestnut flour is a good source of dietary fibre, vitamin E and B group vitamins (Sacchetti *et al*. 2004). Response surface methodology (RSM) is a collection of statistical and mathematical techniques that has been successfully used to determine the effects of several variables and optimize processes which was originally described by Box and Wilson (1951).

The objective of the present study is to determine the effect of parameters such as Moisture content of feed (MC_F), Blend ratio (BR), Die head temperature (DHT), Barrel temperature (BT) and Screw speed (SS)) on the instrumental colour (Hunter *L*, a** and *b** colour values) of the extruded products obtained by single-screw extrusion of Kodo millet flour (KMF), defatted soy flour (DSF) and water chestnut flour (WCF) blend.

MATERIAL AND METHODS

The experiment was conducted in the Food Extrusion Lab of the Department of Post-Harvest Process and Food Engineering, College of Agricultural Engineering, J.N.K.V.V., Jabalpur (MP).

Raw materials

The KMF, DSF and WCF were taken as raw materials for the present study. The Kodo millet (JK-155) was procured from Tamia (block), Chhindwara (MP). DSF was procured from Ruchi Soya Industries Ltd., Indore (MP). WCF was procured from the local market of Jabalpur, manufactured by Dhanhar Exim Pvt. Ltd. Dhanhar House, Bhajiwali Pole, Bhagal, Surat (Gujarat).

Extrusion

In the present study, a laboratory extruder model single screw (Brabender D47055 DUISBURG, Germany) was used for extrusion of different blends of KMF, DSF and WCF. The extruder consists of grooved barrel with heating elements and cooling jackets. The maximum temperature which can be achieved by each zone is 450 ^{0}C. A round die head assembly is fixed at the end of the barrel. In the present study a round die of 3 mm diameter was used. A 1.5 kW, 50 Hz and 1395 rpm electric motor is used to drive the extruder (make: Lenze Extertal, Germany). The L/D ratio of the screw used in Brabender food extruder is 20:1 and the compression ratio of the screw was 2:1.

Experimental design

Central composite rotatable design (CCRD) of Response Surface Methodology (RSM) was used to reduce the number of experimental runs without affecting the accuracy of results and determine interactive effect of variables on the response (Cocharan and Cox, 1957). In this study, CCRD with half replicate of five independent variables with five levels of each has been chosen in Table 1.

The CCRD can be fitted into a sequential programme starting with an exploratory 2k factorial to which a linear response surface is fitted (Cocharan and Cox, 1957). The experimental plan consisted of 32 treatment combinations of each independent variable chosen. The data obtained from the experiment outlined were processed using the Design Expert 9.0.0 (Statease, Minneapolis, USA). The adequacy of model was tested using F ratio and coefficient of determination R^2. The model was considered when the calculated F ratio was more than that of table value (Henika, 1982). The effect of variables at linear, quadratic and interactive level on the response was described using significance at 1, 5 and 10% level of confidence.

Blend preparation

WCF and DSF were procured from market and flour of kodo millet was prepared by grinding in the hammer mill (Make: Technowings, Gujrat). The moisture content of the flour at different blend ratios was measured by standard air oven method (AOAC, 2002). The moisture content of the samples was regulated in five different levels i.e. 8, 10, 12, 14 and 16% (wb). After getting the moisture content of KMF-DSF-WCF blends, additional water required to raise the moisture content to desired levels of blends i.e. 8, 10, 12, 14 and 16% (wb) was calculated. Then the calculated amount of water plus an additional amount of 10% of calculated water was added to supplement the evaporation losses during mixing and conditioning. The mixtures were then stored in plastic bags for 24 h in order to equilibrate (tempering of the samples) and then their moisture content was determined. If the determined moisture content was not desired, certain amounts of either distilled water or materials were added or dried for correction.

Preparation of extrudates

The conditioned samples were then feed to the Brabender single screw extruder under set operating conditions. The product after coming out of the extruder discharge end through round die, expanded due to sudden release of pressure. The extrudates were collected and packed in laminated polythene bags and properly labelled for further analysis.

Colour measurement by Hunter colour *Lab*

Hunter colour *Lab* value of extrudates was determined by Hunter Lab ColorFlex (A60-1010-615 Model Colorimeter, Hunter Lab, Reston, VA) (Fig 1) at 65% 10^0 with reading response variable of L^*, a^* & b^* where, L^* value gives a measure of the lightness of the product colour from 100 for perfect white to zero for black, as the eye would evaluate it, a^* is yellow to red and b^* is green to blue. It was analyzed by measuring the reflectance. The colorimeter was calibrated against standard white plate (L= 91.78, a = -0.28, b= 0.07) before the colour measurement of sample. Approximately 20g of extrudates was finely ground using a household-type mixer grinder (manufactured by Usha Lexus Company, India). A glass cylinder containing 5g aliquots is placed above the light source and covered with a lid. For each sample, four measurements were taken and averaged.

Fig.1 Hunter colour *Lab*

RESULTS AND DISCUSSION

The polynomial model in coded terms generated by multiple regression analysis using CCRD and fitting of second order degree polynomial equation for representative response surface of data between colour value (L^*, a^* & b^*) of extrudates versus different coded levels of MC_F (A), BR (B), BT (C), DHT (D) and SS (E), resulted the development of following model;

$$L = + 52.79 + 0.14 \times A + 0.19 \times B - 0.11 \times C - 0.023 \times D + 0.30 \times E - 0.29 \times AB - 0.096 \times AC + 1.46 \times AD - 0.071 \times AE + 0.31 \times BC + 0.20 \times BD + 0.18 \times BE + 0.096 \times CD + 0.11 \times CE + 0.073 \times DE - 0.67 \times A^2 + 0.13 \times B^2 - 0.34 \times C^2 + 0.79 \times D^2 - 0.11 \times E^2 \quad \ldots (1)$$

Table1. Details of levels of process and operational parameters

Independent Variables	Levels				
	-2	-1	0	1	2
Moisture Content (% wb)	8	10	12	14	16
Blend Ratio (KMF:DSF:WCF)	70:05:25	70:10:20	70:15:15	70:20:10	70:25:05
Die Head Temperature(^oC)	160	180	200	220	240
Barrel Temperature (^oC)	120	140	160	180	200
Screw Speed (rpm)	80	100	120	140	160

Table 2. Analysis of variance (ANOVA) for colour value of extrudates

	*L** value				
Source	SS	DF	MSS	F	P
Regression	81.25	20	4.06	1.5	0.247
Residual	29.78	11	2.71		
Total	111.03	31			
	*a** value				
Source	SS	DF	MSS	F	P
Regression	4.91	20	0.25	1.21	0.382
Residual	2.23	11	0.2		
Total	7.14	31			
	*b** value				
Source	SS	DF	MSS	F	P
Regression	34.36	20	1.72	1.3	0.333
Residual	14.52	11	1.32		
Total	48.87	31			

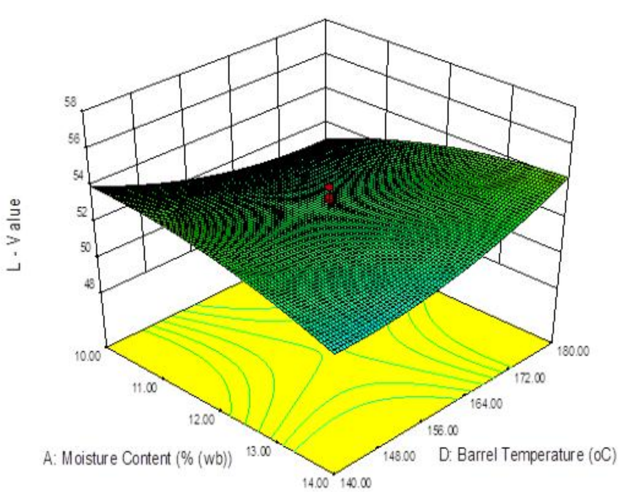

Fig 2. Effect of barrel temperature and moisture content on *L-value of extrudates**

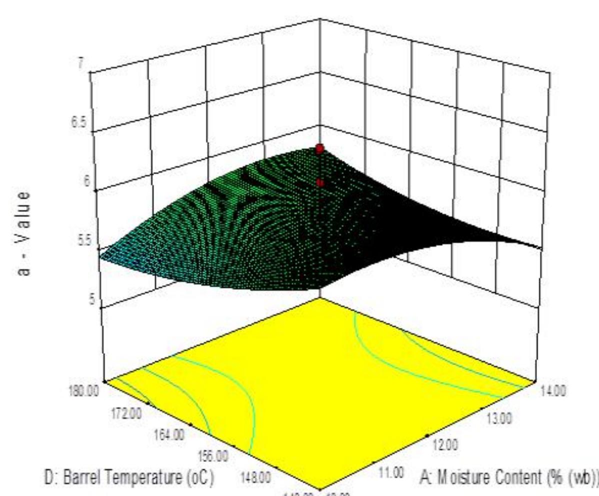

Fig 3. Effect of barrel temperature and moisture content on a*-value of extrudates

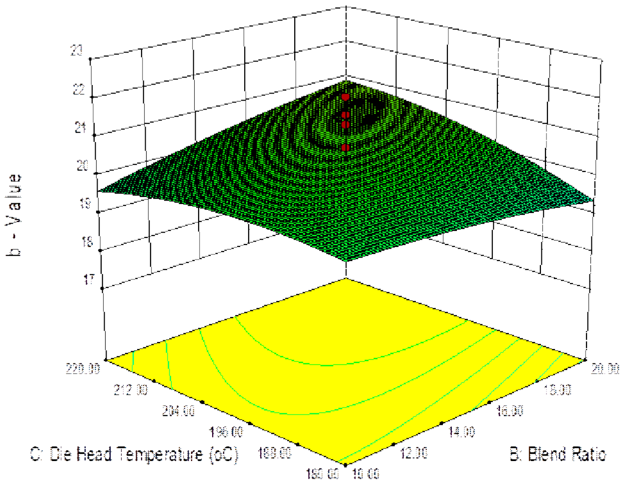

Fig 4. Effect of blend ratio and die head temperature on b*-value of extrudates

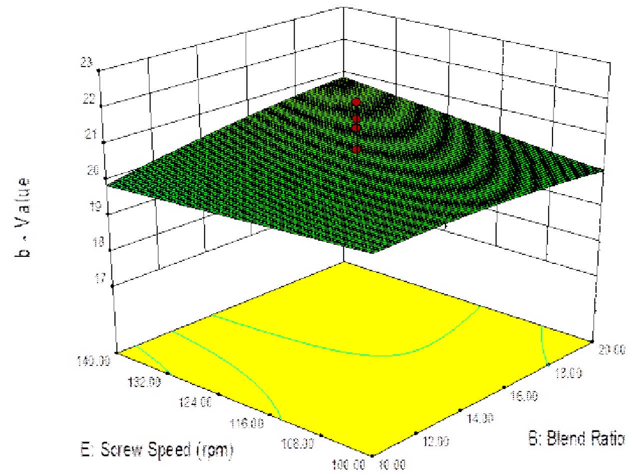

Fig 5. Effect of screw speed and blend ratio on b*-value of extrudates

$$a = +6.08 - 9.583E-003 \times A - 0.15 \times B + 0.10 \times C + 0.052 \times D + 0.021 \times E + 0.079 \times AB + 0.061 \times AC + 0.19 \times AD - 1.875E-003 \times AE - 0.071 \times BC + 0.029 \times BD + 0.13 \times BE - 0.10 \times CD + 0.068 \times CE - 0.19 \times DE - 0.18 \times A^2 - 0.16 \times B^2 - 0.069 \times C^2 + 0.10 \times D^2 - 0.024 \times E^2 \quad \ldots(2)$$

$$b = +21.08 - 0.16 \times A + 0.17 \times B + 0.30 \times C - 0.20 \times D + 0.096 \times E + 0.39 \times AB + 0.33 \times AC + 0.20 \times AD + 0.032 \times AE + 0.47 \times BC - 0.18 \times BD + 0.33 \times BE + 0.31 \times CD + 0.14 \times CE - 0.41 \times DE - 0.52 \times A^2 - 0.13 \times B^2 - 0.33 \times C^2 + 0.30 \times D^2 + 3.182E-003 \times E^2 \quad \ldots(3)$$

A strong association between the different variables under study was endorsed by fairly good value of R^2 i.e. 0.79 for '*L*', 0.86 for '*a*' and 0.80 for '*b*'. The second order model was adequate in describing the colour value (*L**, *a** & *b**) of extrudates. Brief information of results of analysis of variance (ANOVA) for model 1, 2 and 3 are presented in Table: 2.

The lightness (*L**) of extrudates decreased with increasing barrel temperature and increased with increasing feed moisture content (Fig. 2). In general, the higher extrusion temperature resulted in darker products, probably due to maillard reaction (non-enzymatic browning) favoured by high temperature (Pelembe, 2002). The redness (*a**) increased with increasing barrel temperature and die head temperature and decreased with increasing feed moisture content (Fig. 3), whereas screw speed was not significant effect on the *a** value. The change in yellowness (*b**) increased with increasing die head temperature (Fig. 4). It is also showed (Fig. 4 & 5), the value of *b** is increased with increasing DSF content. It is evident from the Fig. 5 higher screw speed reduced the yellowness (*b**) of extrudates. One explanation of the effect of screw speed on extrudates colour is that an increase in the screw speed reduced the residence time and, hence, reduced the extrudates browning. The results indicated that the *L** values of extrudates varied between 49.25 and 57.24 with a mean of 52.64, *a** values ranged from 5.09 to 6.7 with a mean of 5.84 and *b** values varied from 17.81 to 22.72 with a mean of 20.58.

CONCLUSION

In this study, the effect of extrusion conditions on colour (*L*a*b**) parameters of kodo based snacks were investigated using Hunter colour (*Lab*) and analysed with response surface methodology (with central composite rotatable design). The lightness of extrudates (*L**) and redness (*a**) were mostly dependent on barrel temperature and moisture content of feed. Die head temperature was also affected the redness (*a**). The yellowness parameters (*b**) was dependent on die head temperature and blend ratio. The value of *b** is increased with increasing DSF content. The colour of the product was light burly wood.

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