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Modelling the Effects of Processing Factors on the Changes in Colour Parameters of Cooked Meatballs Using Response Surface Methodology

Cemalettin Saricoban and Mustafa Tahsin Yilmaz

Department of Food Engineering, Faculty of Agriculture, Selcuk University, Konya, 42049, Turkey

Abstract: A three-factor Box-Behnken design was adopted for studying the simultaneous effects of processing variables such as fat (10-30%), wheat bran (5-15%) and NaCl (0-2%) on the colour changes (L^*, a^*, b^*, whiteness index, saturation index, hue-angle, total colour difference and browning index) of cooked beef meatballs. In addition, the ridge analysis was conducted to find the values of processing variables that maximize and minimize the colour parameters. Experimental design allowed for evaluation of potential interactive and quadratic effects between these variables. The results showed that the processing variables had a significant effect on the colour parameters. L^* and whiteness index values of meatballs were decreased by the wheat bran addition. b^* and saturation index values were increased by fat addition. ΔE value was decreased by the wheat bran addition. Increase in the fat content increased the browning index values; however, salt addition showed an inverse effect.

Key words: Meatball . wheat bran . fat . salt . colour . response surface methodology

INTRODUCTION

Ingredients used in the processing of food products are among the most important factors having great influence on the final quality. However, during processing, the food materials may be exposed to some treatments providing temperatures that have an adverse effect on quality and make these materials more susceptible to colour deterioration [1, 2], which can be also triggered by the ingredients used. Cooking is among these treatments. The ingredients used in the food formulations may show different effects along with the cooking process.

At the point of sale, the first quality judgement of consumer on a food is its visual appearance. Appearance evaluation of foods such as colour, taste, odour and texture is used in the maintenance of food quality throughout and end of the processing. Colour is one of the most important appearance characteristic because it affects directly consumer preference for the food material [3].

It has been reported that the ingredients can influence many reactions causing colour change during thermal processing of comminuted meat products and their derivatives. Among them, the most common are pigment denaturation, especially myoglobin and browning reactions such as Maillard condensation of hexoses and amino components [4]. Other factors influencing product colour include pH, meat source, packaging conditions, freezing history and preservation treatments. These factors change the ratio of different forms of myoglobin; the main pigments responsible for the ultimate colour of meat [5, 6]. Most of researches on cooked meat colour have focused on comminuted meats, particularly ground beef products.

There is an increasing trend for consumers to favour meat products lower in fat, such as beef patties prepared with lean meat. Some publications have showed that fat content does not affect the cooked meat colour in any readily distinguishable way [5, 7, 8]. It was also reported that although the fat content may influence the cooked colour of meat, it is probably not as influental as other factors that alter cooked colour, particularly high pH and freezing history [9, 10]. On the other hand, other studies suggested that the fat content of meat may have some effect on the final cooked colour, with higher fat meatballs appearing less pink [5]. In spite of much studies on the indirect effect of fat on the comminuted meat products, very limited study have appeared to cite the effect of fat concentration alone or in combination with other ingredients on the browning of meatballs. Apart from fat, other ingredients may be added to meat prior to cooking. This is more common for comminuted meats, where ingredients may include extenders such as soy protein, non-fat dried milk or cereals such as bread crumbs, rusk as well as salt and spices [11]. Some of these ingredients have been shown to influence the colour of

Correspoding Author: Dr. Cemalettin Saricoban, Selcuk University, Agriculture Faculty, Food Engineering Department, Konya, 42049, Turkey

cooked meat. Fibre addition in meat products has also been increased because of its technological advantages and benefits to human health [12]. However, the addition of dietary fibres (sugar beet, oat or pea) were reported not to affect the internal colour of beef patties cooked to internal temperature of 71 or 77 ºC [13].

Although, the effects of fat, several fibre sources and salt on the colour properties of meatballs were extensively studied [10, 14-18], these studies were only on the L^*, a^* and b^* values, not on overall colour parameters such as whiteness index, browning index and total colour difference measuring the colour change and deterioration in the meatballs as a result of processing factors. In addition, it was only focused on the effect of individual processing factors with a one-at-a-time approach not on statistical analysis. Therefore, information on total effects and cross factor interactions of the major processing factors as well as colour properties (especially browning index and total colour difference) of the products remained unclear. In order to minimise the colour deterioration, suitable statistical designs are needed to find the optimum levels of the processing variables. Response Surface Methodology (RSM) is an effective tool to find these optimum levels of the processing variables for the parameters studied [19]. Accordingly, there are some recent studies where some effects of processing variables on the parameters studied using response surface methodology [20]. However, no study has appeared to study the levels of the processing variables that optimise (maximise and minimise) the colour parameters. Therefore, the objective of this research was to study the effect of processing variables such as fat (10-30%), wheat bran (5-15%) and NaCl (0-2%) on the change in the colour properties of cooked beef meatballs and to find the levels of processing variables optimising these colour parameters.

MATERIALS AND METHODS

Meatball preparation: Beef as boneless rounds was obtained from a local market in Konya. All subcutaneous fat was removed from the muscles and used as a fat source in the meatball formulation. The beef and obtained fat were ground through a 3 mm of plate grinder. The spice mix (ground black pepper 0.1 %, red pepper 2% and cumin 0.4 %) and onion (1.5 %) were added to ground beef. The mix was kneaded for 15 min by hand and the meatball dough obtained was divided into 15 experimental batches. Relevant proportions of ground subcutaneous fat (10, 20 and 30%), wheat bran (5, 10 and 15 %) and NaCl (0, 1 and 2 %) were added into each batch as presented in Table 1. Wheat bran (moisture 14.1%, protein 13.2%, fat 4.9 %, dietary fibre 42.5%, carbohydrate 20.8 % and ash 4.5%) was provided from a local market in Konya. Each batch was mixed and kneaded for additional 15 min to obtain homogeneous dough batches. Meatball dough batches were shaped into 62.5 mm diameter and 11 mm thickness by using a metal shaper and then placed on plastic trays and wrapped with polyethylene film and frozen at -18 ºC until further analysis. For cooking procedure, meatballs were thawed at 4ºC overnight in a refrigerator and cooked in a preheated electric grill set at 170-190 º C for 4 min on one side, turned over and cooked for a further 3 min.

Determination of colour: Colour measurements (L^*, a^* and b^*values) were performed using a chroma meter CR-400 (Konica Minolta, Inc., Osaka, Japan) with illuminant D65, 2° observer, Diffuse/O mode, 8 mm aperture of the instrument for illumination and 8 mm for measurement. The instrument was calibrated with a white reference tile (L=97.10, a=-4.88, b=7.04) before the measurements. The L^*, a^* (+, red; - , green) and b^* (+, yellow; - , blue) colour coordinates were determined according to the CIELab coordinate colour space system. The colour measurements were performed on meatballs at room temperature (20 ±2 ºC) in triplicate. American meat science association guidelines for colour measurements were followed [21]. Whiteness index (WI; Eq. (1)), saturation index (SI; (Eq. (2)), hue angle (H; Eq. (3)), total colour difference (ΔE; (Eq. (4)) and browning index (BI; (Eq. (5)) and were calculated using measured L^*, a^* and b^* values [3, 22] as following and used to describe the colour change as compared to control meatball sample:

$$WI = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}} \quad (1)$$

$$SI = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$H = \arctan(b^*/a^*) \quad (3)$$

$$\Delta E = \sqrt{(L_0 - L^*)^2 + (a_0 - a^*)^2 + (b_0 - b^*)^2} \quad (4)$$

where subscript "$_o$" refers to the colour reading of control meatball sample used as the reference and a larger ΔE indicates greater colour change from the reference meatball sample.

$$BI = \frac{[100 \times (x - 0.31)]}{0.17}$$

where

$$x = \frac{(a^* + 1.75 \times L^*)}{(5.645 \times L^* + a^* - 3.012 \times b^*)} \quad (5)$$

Table 1: Second order design matrix used to evaluate the effects of process variables and experimental responses for *L*, *a* and *b* values of meatballs

	Fat (%) X_1		Wheat bran (%) X_2		NaCl (%) X_3		Experimental responses			
Runs	Coded	Uncoded	Coded	Uncoded	Coded	Uncoded	L*	a*	b*	ΔE
Control	-1	0	-1	0	-1	0	35.86	9.32	9.36	0.00
1	0	20	-1	5	1	2	43.47	7.20	7.20	8.19
2	-1	10	0	10	-1	0	43.92	8.97	8.69	8.09
3	-1	10	-1	5	0	1	43.86	8.20	7.74	8.24
4	0	20	1	15	1	2	39.80	7.29	5.84	5.66
5	-1	10	1	15	0	1	39.94	8.12	5.76	5.57
6	-1	10	0	10	1	2	42.29	7.56	6.19	7.38
7	0	20	0	10	0	1	44.77	8.96	9.03	8.92
8	1	30	0	10	-1	0	45.26	8.99	9.28	9.41
9	0	20	0	10	0	1	43.88	9.15	8.73	8.05
10	1	30	-1	5	0	1	44.64	9.24	8.52	8.82
11	0	20	0	10	0	1	43.73	8.43	8.29	7.99
12	0	20	-1	5	-1	0	44.48	9.57	9.76	8.64
13	0	20	1	15	-1	0	38.25	8.95	6.97	3.40
14	1	30	0	10	1	2	42.89	8.44	8.78	7.11
15	1	30	1	15	0	1	38.03	9.47	6.22	3.82

Data analysis and modelling: A 3-factor-3-level Box-Behnken experimental design [23] with three replicates at the centre point was used to develop predictive models for colour ad colour change parameters. The levels of 3 factors (processing variables), experimental design in terms of coded and uncoded values and the experimental responses are presented in Table 1.

The following second-order polynomial equation of function X_i was fitted for each factor assessed:

$$Y = \beta_0 + \sum_{i=1}^{3}\beta_i X_i + \sum_{i=1}^{3}\beta_{ii} X_{ii}^2 + \sum_{\substack{i=1 \\ i<j}}^{3} \sum_{j=1}^{3} \beta_{ij} X_i X_j$$

where *Y* is the estimated response; B_0, B_i, B_{ii}, B_{ij} are constant coefficients. X_i, X_j, which are defined as the coded independent variables, are the concentrations of subcutaneous fat, wheat bran and NaCl. The analysis was performed using uncoded units. Majority of generated models adequately explained the variation of the responses with satisfactory R^2 values ($R^2 > 0.90$) and non-significant lack-of-fit, which indicated that most variations could be well explained by the quadratic models and can be considered adequate, because the probability of level of *F* was $P < 0.01$ [24].

The computational work, including the surface-contour graphical presentations of the response surface models, was performed using a Statistica for Windows software package (Statsoft, Version 5.0.1.a, SAS Institute. Inc. Tulsa, OK, USA). JMP statistical package software (Version 5.0.1.a, SAS Institute. Inc. Cary, NC, USA) was used to compute the estimated ridges of maximum and minimum response for increasing radii from the centre of the original design.

RESULTS AND DISCUSSION

General: The coded and uncoded levels of three variables and the experimental responses and ΔE are shown in Table 1. Control meatball results (mean of three replicates) are shown in first line. The magnitude of the effects denotes the sensitivity of the response to the processing variables and is calculated as the difference in the mean response as the processing variable changed from its low to higher level. Table 2 and 3 show the effects of added fat, wheat bran and NaCl levels on the changes in colour properties of cooked meatballs. Table 3 shows the estimated ridge analysis results predicting the critical levels of the processing variables that maximise and minimise the responses. In addition, Fig. 1-3, illustrate these effects as three-dimensional graphs where direction of the effects of the processing variables on the change in colour properties can been seen.

Changes in the CIELab L* and WI values: The lightness (L^*) value of the control meatball sample was 35.86; as expected, fat addition into meatball samples increased the L^* values (Table 1), which was probably due to dilution of the myoglobin because of fat

Table 2: Significance of the regression models (*F* values) and the effects of processing variables on the change in colour parameters

Sourcesof variance	DF	*L**	*a**	*b**	Whiteness index	Saturation index	Hue-angle	Δ*E*	Browning index
Linear									
b_1	1	1.204	0.050[c]	3.802[b]	0.905	0.745[a]	2.034	0.789	0.389[b]
b_2	1	10.665[a]	0.057	13.877[a]	8.687[a]	4.873[a]	5.687[a]	5.438[a]	1.135
b_3	1	0.166	0.612[a]	11.898[a]	0.013	6.697[a]	2.404	0.024	5.551[a]
Cross-product									
b_{12}	1	2.039	0.105	0.158	1.861	0.014	0.071	1.670	0.422
b_{13}	1	0.154	0.804	6.179[c]	0.325	4.485[c]	1.128	0.778	5.061[c]
b_{23}	1	1.847	0.548	3.159	1.239	2.548	0.159	2.259	0.459
Quadratic									
b_{11}	1	0.183	0.088	3.937	0.101	0.714	2.680	0.038	0.935
b_{22}	1	22.007[a]	0.429	33.290[a]	17.505[a]	13.674[b]	12.605[b]	11.869[b]	3.826
b_{33}	1	0.445	2.981	0.025	0.279	1.981	1.085	0.243	0.311
Total Error	5								
Lack of fit	3	4.012	2.085	1.280	5.890	0.768	9.464[c]	4.333	2.547
Pure Error	2								
Total Model	9	9.636[b]	3.379[c]	16.654[a]	7.816[b]	1.499[a]	4.845[b]	5.948[b]	5.942[b]

[a]$p \leq 0.01$; [b]$p \leq 0.05$; [c]$p \leq 0.1$

Table 3: Estimated ridge of maximum and minimum values for responses of colour parameters

	Experimental factors				
Response	Minimum	Maximum	Fat (%7)	Wheat bran (%)	NaCl (%)
L*	10.38	15.00	0.00	38.91	
	30.00	5.75	0.00		45.93
a*	10.00	5.00	2.00	6.90	
	30.00	8.86	0.26		9.51
b*	10.00	15.00	2.00	4.52	
	20.75	7.17	0.00		9.90
Whiteness index	11.89	15.00	0.00	37.95	
	30.00	5.00	0.00		44.25
Saturation index	10.00	15.00	2.00	8.27	
	24.91	7.36	0.00		13.54
Hue-angle	30.00	15.00	0.57	0.61	
	19.06	7.45	0.00		0.83
ΔE	30.00	15.00	0.00	3.72	
	30.00	5.00	0.00		10.10
Browning index	10.00	15.00	2.00	24.54	
	19.24	7.55	0.00		39.16

addition. Fat is known to influence the colour properties of cooked meat products [14]. Lightness of meatballs, as measured by the CIELab *L** value and WI, calculated using Eq. (1), slightly increased by increasing fat level; however, this increase was not found significant (Table 2). Troutt *et al*. (1992) [7] have reported that when raw, the lower fat meatballs were distinctively darker red, but when cooked, the concentration of fat did not affect surface colour, or internal colour, which supports the results of our study.

Wheat bran addition decreased ($P < 0.01$) the *L** and product whiteness index values (Fig. 1 (a) and (b)). The quadratic effect of wheat bran was found significant ($P < 0.01$), which had a negative effect on the *L** and WI values. Decrease in the *L** value was thought to result from the cooking of the wheat bran, which resulted in darken colour of the meatballs. Similar result was obtained for the effect of rice bran on the colour properties of "Kung-wan", an emulsified pork meatball. Huang, Shiau, Liu, Chu and Hwang

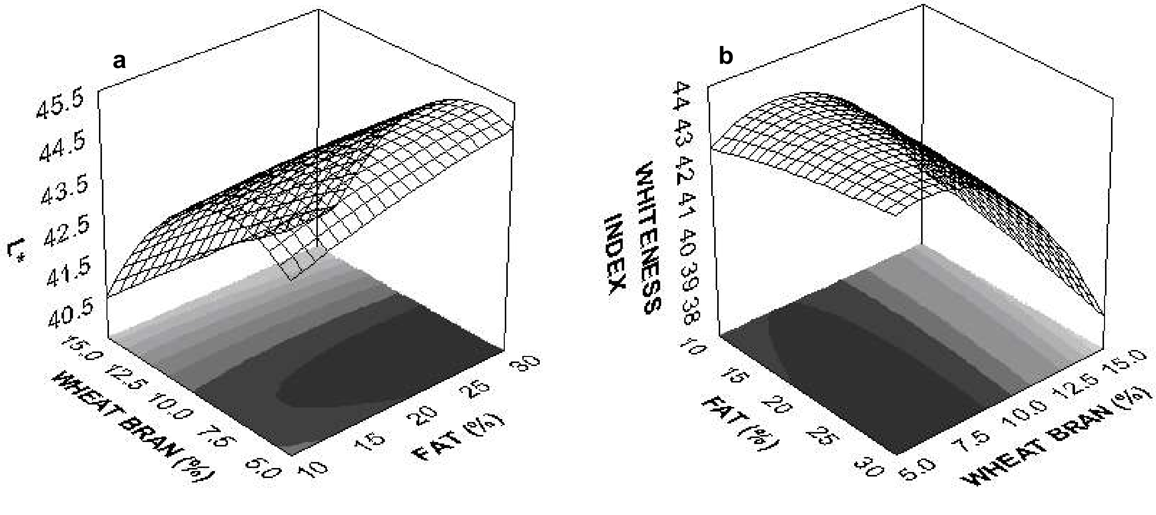

Fig. 1: Effect of wheat bran and fat on (a) L^* and (b) whiteness index values of meatballs

(2005) [18] determined that Hunter-L value and the white index significantly decreased when the amount of rice bran became more than 5 %. In this study, L^* and WI were related to fat, wheat bran and salt concentrations by a multiple regression analysis. The following predictive equations involving these processing variables were developed using a second order response surface methodology:

$$L^* = 37.320 + 0.247X_1 + 0.147X_2 - 0.688X_3 - 0.013X_1{}^*X_2 - 0.019X_1{}^*X_3 + 0.128X_2{}^*X_3 - 0.021X_1{}^2 - 0.092X_2{}^2 - 0.327X_3{}^2 \quad (R^2 = 0.945) \tag{6}$$

$$WI = 36.455 + 0.217X_1 + 1.347X_2 - 0.197X_3 - 0.013X_1{}^*X_2 - 0.027X_1{}^*X_3 + 0.107X_2{}^*X_3 - 0.016X_1{}^2 - 0.083X_2{}^2 - 0.263X_3{}^2 \quad (R^2 = 0.934) \tag{7}$$

Changes in the CIELab a*, b* and SI values: Figure 2 (a) indicates that an increase in salt content decreased (P <0.01) the redness (a^*) of meatballs. Poligné, Collignan and Trystram (2002) [25] found that the a^* index of the cooked lean part of pork decreased from 11 to 3 during brining (salting) process. Fat showed a trend to increase the a^* values of the meatballs. Wheat bran did not affect the product redness. On the other hand, product yellowness (b^*) was affected (P <0.05; 0.01) by all the processing variables (Table 2). Fat increased; however, wheat bran and salt decreased the yellowness of meatballs (Fig. 2(b) and 2(c)). Increase in the b^* values could have been due to a decrease in the level of oxymyoglobin, which is the main pigment responsible for yellowness in meat products [26]. Berry and Bigner-George (2000) [10] concluded that higher fat patties displayed browner colour than low fat patties. The effect of fat to increase the product yellowness was thought to result from the oxidation of the surface fats of meatballs with air contact at 70ºC of internal temperature of product during the cooking process. Poligné, Collignan and Trystram [25] also assumed that lipid oxidation was mainly responsible for this yellowness in meat products.

The decrease in the b^* value indicates that colour of meatball turned to blue rather than yellow. Linear and quadratic effect of wheat bran and linear effect of salt were negative and decreased the b* values of meatballs. Bilgicli and Ibanoglu [27] found the same effect of wheat bran, which decreased the yellowness of tarhana, a wheat flour-yoghurt mixture. Decrease in the yellowness could have been due to the decrease in oxymyoglobin content. It was reported that b^* index, which is inversely proportional to the oxymyoglobin content, was found to decline at the beginning of salting process of meat products [28]. b^* values were closely (both linearly and quadratically) followed by the SI (chroma) values of meatballs, which were increased by the fat content; however, decreased by wheat bran and salt content (Fig. 2 (d) and (e)). The chroma value, calculated using Eq. (2), indicates the degree of saturation of colour and is proportional to the strength of the colour. The chroma values were changed by the processing variables, which indicated instability of yellow colour in meatballs due to processing variables. The equations involving the effect of processing variables on a^*, b^* and SI values were as followed:

$$a^* = 9.175 - 0.026X_1 + 0.055X_2 - 0.672X_3 - 0.002X_1{}^*X_2 - 0.022X_1{}^*X_3 + 0.036X_2{}^*X_3 + 0.001X_1{}^2 - 0.007X_2{}^2 - 0.431X_3{}^2 \quad (R^2 = 0.859) \tag{8}$$

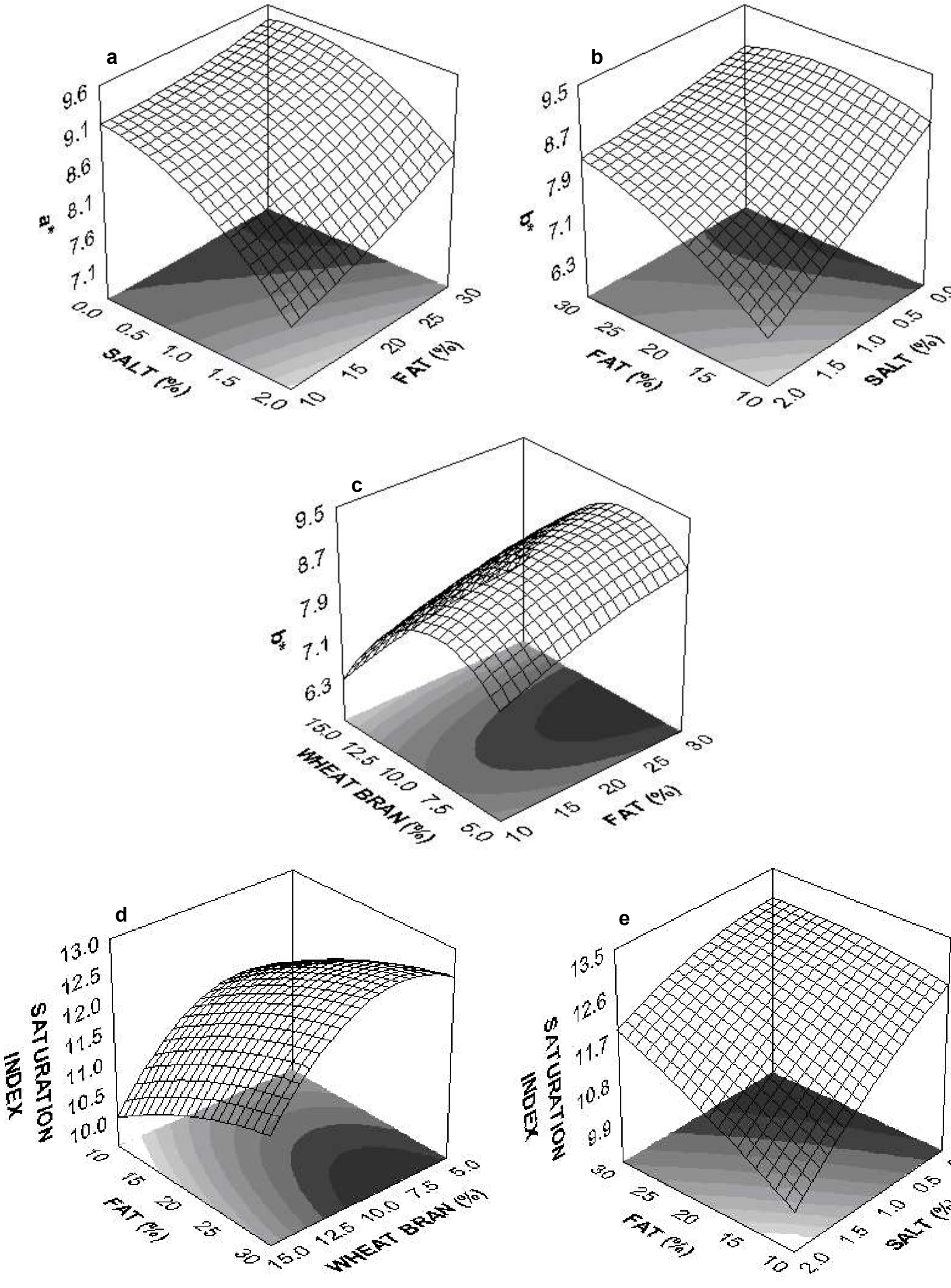

Fig. 2: Effect of (a) salt and fat on a^* values, (b) fat and salt on b^* values, (c) wheat bran and fat on b^* values, (d) fat and wheat bran on saturation index values and (e) fat and salt on saturation index values of meatballs

$$b^* = 5.391 + 0.187X_1 + 0.717X_2 - 2.485X_3 - 0.002X_1{}^*X_2 + 0.050X_1{}^*X_3 + 0.715X_2{}^*X_3 - 0.004X_1{}^2 - 0.048X_2{}^2 - 0.033X_3{}^2 \quad (R^2 = 0.968) \tag{9}$$

$$SI = 10.620 + 0.097X_1 + 0.496X_2 - 2.178X_3 + 0.001X_1{}^*X_2 - 0.050X_1{}^*X_3 + 0.075X_2{}^*X_3 - 0.002X_1{}^2 - 0.036X_2{}^2 - 0.344X_3{}^2 \quad (R^2 = 0.954) \tag{10}$$

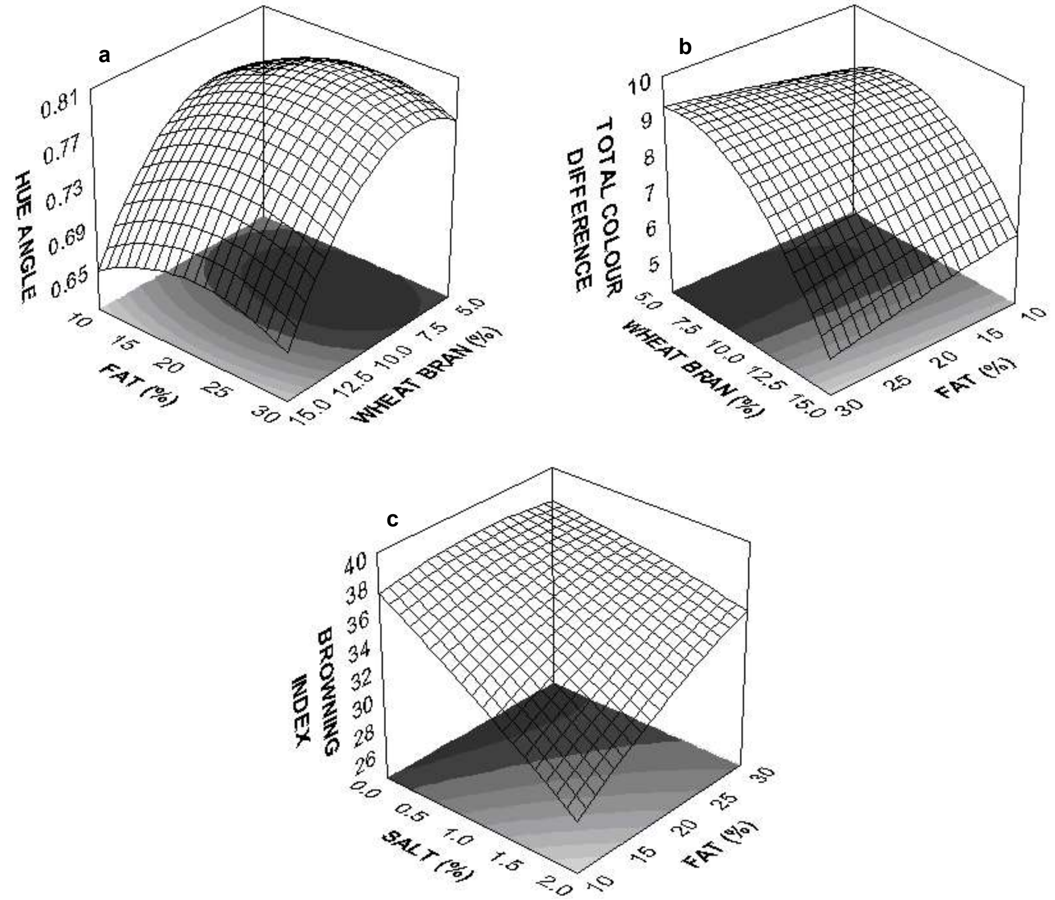

Fig. 3: Effect of (a) fat and wheat bran on hue angle values, (b) wheat bran and fat on ΔE values and (c) salt and fat on browning index values of meatballs

Changes in the H, ΔE and BI values: Wheat bran was the only processing variable having a significant linear (P <0.01) and quadratic (P <0.05) effect (Table 2) on the H and ΔE values, calculated using Eqs. (3) and (4), respectively. H values decreased with wheat bran addition (Fig. 3 (a)), which suggested reduction from a more green (when Hue > 90º) to an orange-red (when Hue < 90º) colour [29] of cooked meatballs. Total colour difference ΔE, which is a combination of parameters L^*, a^* and b^* values, is a colorimetric parameter extensively used to characterise the variation of colours depending on processing conditions [3]. In this study, ΔE values were calculated in relation to the control meatball (Table 1). A decrease in ΔE was observed (Fig. 3 (b)) with wheat bran addition. This decrement in ΔE showed that addition on wheat bran decreased the total change in the colour of meatball.

The last colour parameter is BI which was calculated using the Eq. (5). It indicates the purity of brown colour and is reported as an important parameter in processes where enzymatic and non-enzymatic browning takes place [30]. In this study, BI value was not changed by wheat bran addition; however, influenced by the fat (P<0.05) and salt (P <0.01) addition (Table 2). Fat increased and salt decreased the BI value of the meatballs (Fig. 3 (c)) as supported by the results for a^* values (Fig. 2(a) and 3 (c)). This conclusion is also supported by the result of Berry and Bigner-George [10] who found that one of the factors resulting in more brown colour in cooked patties were higher fat content.

The negative effect was seen only by addition of fat values because excessive BI values are not desired in the meatball product with respect to consumer preference. The equations involving the effect of processing variables on H, ΔE and BI values were as followed:

$$H = 0.547 + 0.013X_1 + 0.043X_2 - 0.105X_3 - 0.0001X_1{}^*X_2 + 0.002X_1{}^*X_3 + 0.002X_2{}^*X_3 + 0.0003X_1{}^2 - 0.003X_2{}^2 + 0.0204X_3{}^2 \quad (11)$$

$(R^2 = 0.897)$

$$\Delta E = 3.529 + 0.191X_1 + 1.004X_2 - 0.248X_3 - 0.012X_1{}^*X_2 - 0.040X_1{}^*X_3 + 0.136X_2{}^*X_3 - 0.001X_1{}^2 - 0.065X_2{}^2 - 0.231X_3{}^2 \quad (12)$$

$(R^2 = 0.915)$

$$\text{BI} = 33.083 + 0.261X_1 + 0.891X_2 - 7.389X_3 + 0.011X_1{}^*X_2 + 0.197X_1{}^*X_3 + 0.119X_2{}^*X_3 - 0.009X_1{}^2 - 0.071X_2{}^2 - 0.508X_3{}^2 \quad (13)$$

$(R^2 = 0.914)$

Product optimisation: Peaks in RSM three-dimensional plots along with contour plots were used to extrapolate the optimum level of the three processing variables (fat, wheat bran and salt). The levels of independent variables that minimise and maximise the L^* and WI values were determined by ridge analysis using the Eqs. 6 and 7, respectively. Results from ridge analysis (Table 3), which computes the estimated ridge of optimum response for increasing radii from the centre of the original design [31] indicated that maximum L^* value (45.93) would be at fat=30.00 %, wheat bran = 5.75 % and NaCl = 0.00 % w/w at the distance of coded radius 1.0. Similarly, maximum whiteness (44.25) would occur at fat=30.00 %, wheat bran = 5.00 % and NaCl = 0.00 % w/w.

Results from ridge analysis (Table 3) obtained using the Eqs. 8, 9 and 10, indicated that maximum a^* value (9.51) would be at fat=30.00 %, wheat bran = 8.86 % and NaCl = 0.26 % w/w at the distance of coded radius 1.0. Minimum b^* value (4.52) would occur at fat= 10.00 %, wheat bran = 15.00 % and NaCl = 2.00 % w/w. Likewise, minimum SI value (8.27) would occur at fat= 10.00 %, wheat bran = 15.00 % and NaCl = 2.00 % w/w.

Table 3 also shows the processing variables that maximise and minimise the H, ΔE and BI values. Ridge analysis using the Eq. (11) determined that maximum H value (0.83) would be at fat=19.06 %, wheat bran = 7.45 % and NaCl = 0.00 % w/w at the distance of coded radius 1.0. Excessive colour change in the meatballs may not be desired; therefore, the processing variables that maximise the ΔE values should be determined. Estimated ridge analysis using Eq. (12) indicated that maximum ΔE value (10.10) would be at fat=30.00 %, wheat bran = 5.00 % and NaCl = 0.00 % w/w. On the other hand, the levels of the processing values that minimise BI value should be determined because the meatball products having the lower BI values are preferred. Using the ridge analysis based on the Eq. (13), it was determined that the minimum BI value (24.54) would be achieved by the levels of fat = 10.00 %, wheat bran = 15.00 % and NaCl = 2.00 % w/w.

CONCLUSION

All colour parameters were influenced by the processing variables. Wheat bran addition decreased the lightness and whiteness of meatballs. On the other hand, total colour change of the meatballs was not influenced by fat and salt addition; even decreased by the addition of wheat bran. High level addition of fat increased the rate of colour deterioration. BI results showed that increased fat addition produced browner product. On the other hand, ridge analysis results indicated that the brownish colour of the product could be minimized by using the minimum level of fat (%10) and maximum level (2 %) of salt. The possibility of premature browning which occurred in the cooked meatballs as a result of processing factors studied in this study can provide further justification for using the proper levels of the processing factors to achieve more visual quality of products.

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