Development of chicken meat caruncles on the basis of sensory attributes: process optimization using response surface methodology

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Abstract A three factor Box-Behnken design of response surface methodology was employed to optimize spent hen meat level (600–700 g kg⁻¹), oil level (25–75 g kg⁻¹) and cooking time (3–5 min) for development of ready-to-eat chicken meat caruncles on the basis of sensory attributes - colour/appearance, flavour, crispiness, after-taste, meat flavour intensity and overall acceptability. The analysis of variance showed that meat and cooking time interaction showed significant effect ($p < 0.01$; $p < 0.05$; $p < 0.1$) on colour/appearance and crispiness of chicken meat caruncles. Quadratically meat level showed significantly higher effect ($p < 0.01$; $p < 0.05$; $p < 0.1$) on crispiness; and oil level and cooking time ($p < 0.05$; $p < 0.1$) on after-taste of chicken meat caruncles. Linearly meat level showed significantly higher ($p < 0.05$; $p < 0.1$) effect on colour/appearance, after-taste, meat flavour intensity and overall acceptability of chicken meat caruncles. The optimized conditions were: 650 g kg⁻¹ meat level, 50 g kg⁻¹ oil level and cooking time as 4 min. Among all sensory parameters, crispiness is one of the most important sensory parameters for meat snacks, which was highest (6.68) at the optimized conditions in the final product. The other sensory parameters ranged from 6.33 to 6.68 on an

eight point scale. Box-Behnken design of RSM performed well in the optimization process of development of chicken meat caruncles to produce product with very high degree of acceptability. 650 g kg⁻¹ of spent hen meat level produced the most acceptable product in terms of sensory profile.

Keywords Chicken meat caruncles · Sensory attributes · Box-Behnken design · Response surface methodology · Spent hen meat

Introduction

Meat and meat products have provided a valuable contribution to our diets since the time of hunter-gatherer societies. The importance of meat is reflected not only in terms of a concentrated source of proteins with high nutritional value but also due to containment of almost all essential amino acids, vitamins, minerals, fatty acids etc. Processing of meat into value added products is increasing day by day due to consumer demands. However, traditional meat products have limited role in our life due to their poor shelf-life at room temperature and bulkiness. So now a days, there is a growing need for convenient, shelf-stable meat products such as snacks and dehydrated meat products.

Snack foods are a part of fast food industry which is one of the largest food industries of world. Calling for a slice of meat between two slices of bread by John Montagu (fourth Earl of Sandwich, 1718–1792) is considered to be the origin of modern meat based snacks (Booth 1990). In broadest sense, snack is categorized as a “titbit” which is a small meal between two or more major meals. In general, snacking could be defined as problem free consumption of convenient, small amounts of hot or cold products in solid, semisolid or liquid form, which are intended to satisfy the short-term hunger (Macrae et al. 1993). Snack meats continue to be a growing trend, offering

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great taste and a lot more variety than in times past. Moreover, these foods are less perishable, more durable, more appealing and shelf-stable in nature. In 2004–05, the value of total market of world snack foods was Rs 82.9 billion including semi-processed/cooked and ready to eat foods, and is increasing with a growth rate of 20 % (FICCI 2006). But according to Global Industry Analysts, the market of world snack foods is predicted to reach almost US\$ 335 billion by 2015 (Anonymous 2012). According to Parmar (2011) the present value of Indian snacks market is worth around US\$ 3 billion, having half of the market share from organized sector with an annual growth rate of 15–20 % whereas unorganised snack market is valued at US\$ 1.56 billion with an annual growth rate of 7–8 %.

Food extrusion is a technique which is used to form snacks of different shapes by forcing the raw food material through a special die which is designed to form and/or puff dry extrudates (Rhee et al. 1999). Now a wide variety of snacks such as pastas, multigrain snacks, jelly beans, breakfast cereals, cookies, pretzels, French Fries, Idiappam, corn chips, tortilla chips, snack nuts, extruded snacks, meat snacks etc. are being prepared by the use of single screw, multiple and twin screw extruders.

Traditional meat based snacks mainly include expanded pork rinds (bacon skins), jerky, chimni etc. (Matz 1976). Various scientific studies have documented the development of shelf-stable meat based snacks using different cooking methods viz. Processing technology and extension of shelf-life of shelf-stable chicken meat biscuits and noodles (Sahoo et al. 2011), chicken snacks using spent hen meat, rice flour and sodium caseinate (Singh et al. 2011), chicken snack sticks using spent hen meat, oat meal and ragi flour in different proportions (Kale et al. 2010), ready-to-eat chicken kebab mix using Box–Behnken design of response surface methodology (Modi et al. 2007), extruded blends of catfish flesh using a single-screw extruder (Rhee et al. 2004), cabrito snack stick using goat meat with different levels of soy protein concentrate (Cosenza et al. 2003), popped cereal snacks using different proportions of spent hen meat, corn starch and potato starch (Lee et al. 2003), chicken chips by deep fat frying (Sharma and Nanda 2002), meat papads using 50:50 rice flour and turkey meat (Berwal et al. 1996), highly nutritious jerky-type extruded products using potato flour with beef/chicken and chile powder (Ray et al. 1996), extruded beef blends using Response surface methodology (Park et al. 1993), snack dips using a combination of ham, bacon or pepperoni with added sour cream, unflavored yogurt and tofu (Defreitas and Molins 1988) etc.

Snack products, which are normally enriched with carbohydrates and fats, can be made with increased protein content and nutritional value by adding proteins from animal source such as fish, pork, beef and chicken (Suknark et al. 1999). Incorporation of spent hen meat into these snacks greatly enhances the nutritional value in terms of myofibrillar proteins (Lin and Chen 1989; Lee et al. 2003), omega-3 fatty acids and

less cholesterol especially in breast muscle (Ajuyah et al. 1992). Compared to broiler meat, excessive amount (Lee et al. 2003) and cross-linkages of collagen (Li 2006; Nowsad et al. 2000) in spent hen meat makes it quite heavy, tough and less juicy and is thus not much liked by the consumers. Use of spent hen meat in snack foods may revolutionize meat industry by the development of efficient and economic technology for processing such undervalued meat into value-added meat products that are palatable and reasonable in cost (Jin et al. 2009).

Materials and methods

Preparation of chicken meat caruncles

The white Leghorn layer spent hens (80–100 weeks old) were obtained from poultry farm of Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana and slaughtered as per standard procedure in the experimental slaughterhouse of Department of Livestock Products Technology, College of Veterinary Science, GADVASU, Ludhiana, Punjab. After manual deboning, the meat cubes were tenderized by dipping in a solution containing 2.5 g kg⁻¹ of papain (w/w) and 0.15 M calcium chloride (w/v) for about 36–40 h at refrigeration temperature (4±1 °C) as reported by Biswas et al. (2009). Thereafter, the meat chunks were taken out from the solution, washed thoroughly 2–3 times with running water; extra moisture was drained out, then packed in low density polyethylene (LDPE) bags and kept at -18±1 °C for subsequent use. Frozen tenderized meat sample was taken out as per requirement and cut into smaller cubes after partial thawing in a refrigerator (4±1 °C). The meat chunks were then double minced using 6 mm and 4 mm grinder plates (KL-32, Kalsi, Ludhiana, India) to get fine tenderized minced chicken meat (TMCM). Spice mix was prepared by grinding dried (45±2 °C for 2 h) ingredients viz. 150 g kg⁻¹ of coriander, 150 g kg⁻¹ of cumin seeds, 100 g kg⁻¹ of caraway seeds, 100 g kg⁻¹ of aniseed, 100 g kg⁻¹ of black pepper, 80 g kg⁻¹ of red chilli powder, 80 g kg⁻¹ of dry ginger powder, 50 g kg⁻¹ of cinnamon, 50 g kg⁻¹ of clove, 50 g kg⁻¹ of cardamom large, 50 g kg⁻¹ of mace, 20 g kg⁻¹ of nutmeg and 20 g kg⁻¹ of cardamom small to a fine ground powder using Inalsa mixer (Inalsa Maxie plus, 07120219, Inalsa Technologies, New Delhi, India) and sieved through a fine muslin cloth. The chicken meat emulsion was prepared by adding ingredients as per the formulation mentioned in Table 1. TMCM was blended with common salt (TATA salt, Tata chemicals Ltd. Mumbai) and sugar and mixed in Inalsa mixer for 1 min, followed by mixing of baking powder (Ajanta Baking powder, Ajanta Food Products Co., Solan, India; Code No. 288668), carboxymethyl cellulose (Sodium salt High Viscosity carboxymethyl, S d fine-CHEM Ltd., Mumbai, India;

Table 1 Formulation used to prepare chicken meat caruncles

Ingredients	Quantity (g kg ⁻¹)
TCMC	X ₁ (600/650/700)
Refined wheat flour	350
Oil	X ₂ (25/50/75) ^a
Spice mix	20 ^a
Salt	10 ^a
Sugar	10 ^a
Carboxymethyl cellulose	7 ^a
Baking powder	5 ^a

^a Ingredients calculated on the basis of total quantity of TCMC and Refined wheat flour

X₁ is coded independent variable for meat level (TCMC), X₂ is coded independent variable for oil level, X₃ is coded independent variable for cooking time in minutes (3/4/5)

Code No. 56095) and spice mix, refined wheat flour and refined oil (FORTUNE Soyabean oil) up to 30 s in the mixer. The three levels of meat, oil and cooking time were selected on the basis of a previous study (Kale et al. 2010), where it was observed that 600–700 g kg⁻¹ of meat level, 25–75 g kg⁻¹ of oil level and 3–5 min cooking time gave acceptable product.

The prepared emulsion was extruded through a manually operated stainless steel extruder in the form of thin chips (Chicken meat caruncles, CMC) in a microwave plate. Cooking was done by putting this plate in a microwave oven (Inalsa microwave ovens, New Delhi, India) for required time (3–5 min). The cooked CMC were kept in Pearl Polyethylene Terephthalate (PET) jars and thereafter analyzed for different sensory attributes. A second order Box-Behnken design was used in which a total of 17 different trials were conducted with three different levels of each of meat, oil and cooking time as presented in Table 2.

Sensory evaluation

Samples of CMC were subjected to sensory evaluation by seven trained and experienced panelists from the staff at the Department of Livestock Products Technology, College of Veterinary Science, GADVASU, for different sensory attributes viz. Colour/Appearance (CA), Flavour (Flv), Crispiness (Csp), After-taste (AT), Meat flavour intensity (MFI) and Overall acceptability (OA), following 8- point hedonic scale (Keeton 1983 with slight modification) where 8=extremely desirable and 1=extremely undesirable. In all the trials, mean value of each sensory attribute ($n=7$) was taken as the value of response variable.

Data analysis and modelling

Response surface methodology or RSM is a collection of mathematical and statistical techniques useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response (Montgomery 2005). In the present study, a 3-factor-3-level Box-Behnken experimental design (Box and Behnken 1960) with five replicates at the centre point was used to develop predictive models for sensory score parameters. The combinations included a formulation having an intermediate level of the three variables, replicated five times, which was used to determine inherent variance in the technique. The design was randomized to increase the precision. In this design, X₁, X₂ and X₃ are the coded variables, which are related to uncoded variables in actual units linearly by the relation:

$$X_i = 2 \left(\xi_i - \bar{\xi}_i \right) / d_i$$

Where ξ_i is the variable value in actual units of the i^{th} observation, $\bar{\xi}_i$ is the mean of highest and lowest variable value of ξ_i and d_i is the difference between the highest and lowest variable value of ξ_i . The levels of 3 factors (processing variables), experimental design in terms of coded and uncoded values and the experimental responses are presented in Table 2. The data was analyzed employing multiple regression technique to develop a response surface model. After conducting the runs, a second order polynomial of the following form was fitted to each response using the “Design Expert” software (Version 8.0.4.1, Stat-Ease, Inc., Minneapolis, USA) statistical package.

$$Y = \beta_0 + \sum_{i=1}^3 \beta_i x_i + \sum_{i=1}^3 \beta_{ii} x_i^2 + \sum_{\substack{i=1 \\ i < j}}^3 \sum_{j=1}^3 \beta_{ij} x_i x_j + \varepsilon$$

Where Y is the estimated response; β_0 is the constant coefficient, β_i is the linear coefficient, β_{ii} the quadratic coefficient and β_{ij} the second order interaction coefficient. x_i , x_j are coded independent variables and ε is the error involved in estimating the coefficients β from the experimental data. After fitting the equation several targets of the responses were given through the software for achieving the best combination of variables which resulted in required product. Target values were given in the form of ranges of values of all the process variables and responses. All the models were tested for their adequacy using ANOVA technique. The F -values and R^2 values were computed for all the responses (Table 3). Surface plots and equations were developed which showed effect of interaction of two variables on each response. The full second order model of

Table 2 Second order design matrix used to evaluate the effects of process variables and values of experimental responses for sensory attributes of chicken meat caruncles

Runs	Meat level (g kg ⁻¹) X ₁		Oil level (g kg ⁻¹) X ₂		Cooking time (mins) X ₃		Responses					
	Coded	Uncoded	Coded	Uncoded	Coded	Uncoded	CA	Flv	Csp	AT	MFI	OA
1	1	700	-1	25	0	4	6.57	6.64	6.79	6.86	6.93	6.93
2	0	650	1	75	1	5	6.57	6.21	6.64	6.64	6.79	6.64
3	-1	600	0	50	-1	3	6.64	6.14	6.64	6.00	6.00	6.14
4	1	700	1	75	0	4	6.50	6.64	6.71	6.71	6.93	6.93
5	0	650	1	75	-1	3	6.57	6.57	6.57	6.64	6.64	6.93
6	-1	600	-1	25	0	4	6.29	6.36	6.79	6.50	6.14	6.21
7	-1	600	0	50	1	5	6.29	6.14	6.86	6.29	6.14	6.21
8	-1	600	1	75	0	4	6.57	6.07	6.71	6.64	6.14	6.07
9	0	650	-1	25	1	5	6.64	6.50	6.64	6.64	6.36	6.64
10	1	700	0	50	-1	3	6.50	7.00	6.87	6.57	6.64	6.36
11	0	650	-1	25	-1	3	6.50	6.14	6.57	6.29	6.79	6.64
12	1	700	0	50	1	5	7.00	6.29	6.64	6.36	7.00	6.64
13	0	650	0	50	0	4	6.64	6.36	6.64	6.57	6.50	6.64
14	0	650	0	50	0	4	6.50	6.21	6.79	6.86	7.00	6.29
15	0	650	0	50	0	4	6.36	6.07	6.71	6.50	6.36	6.36
16	0	650	0	50	0	4	6.64	6.36	6.64	6.64	6.64	6.64
17	0	650	0	50	0	4	6.43	6.00	6.64	6.50	6.36	6.36

CA colour/appearance, Flv flavour, Csp crispiness, AT after-taste, MFI meat flavour intensity and OA overall acceptability

Table 3 Significance of the regression models (*F* values) and the effects of processing variables on the sensory attributes of chicken meat caruncles

Source of variance	CA R ² =0.7141		Flv R ² =0.6965		Csp R ² =0.8279		AT R ² =0.8377		MFI R ² =0.6863		OA R ² =0.4972	
	DF	F value	DF	F value	DF	F value	DF	F value	DF	F value	DF	F value
Linear												
b ₁	1	6.16 ^{bc}	1	12.81 ^{abc}	1	3.685E-003	1	8.35 ^{bc}	1	28.07 ^{abc}	1	12.79 ^{abc}
b ₂	1	0.45	1	0.083	1	0.94	1	0.84	1	0.23	1	0.058
b ₃	1	0.85	1	1.87	1	0.62	1	1.35	1	0.14	1	9.256E-003
Cross-product												
b ₁₂	1	2.48	1	0.62	1	0.000	1	1.23	—	—	—	—
b ₁₃	1	14.63 ^{abc}	1	3.73 ^c	1	14.92 ^{abc}	1	3.65 ^c	—	—	—	—
b ₂₃	1	0.40	1	3.84 ^c	1	0.000	1	1.79	—	—	—	—
Quadratic												
b ₁₁	—	—	—	—	1	14.14 ^{abc}	1	2.08	—	—	—	—
b ₂₂	—	—	—	—	1	2.06	1	5.94 ^{bc}	—	—	—	—
b ₃₃	—	—	—	—	1	1.82	1	11.57 ^{bc}	—	—	—	—
Total error	10		10		7		7		13		13	
Lack of fit	6	0.63	6	1.41	3	0.45	3	0.46	9	0.42	9	2.03
Pure error	4		4		4		4		4		4	
Total model	6	4.16 ^{bc}	6	3.82 ^{bc}	9	3.74 ^{bc}	9	4.02 ^{bc}	3	9.48 ^{abc}	3	4.28 ^{bc}

^a *p*<0.01; ^b *p*<0.05; ^c *p*<0.1; R² - Coefficient of determination, DF degrees of freedom, CA Colour/appearance, Flv flavour, Csp crispiness, AT after-taste, MFI meat flavour intensity and OA overall acceptability

Table 4 Values of regression coefficients estimated by multiple linear regression for response variables and their significance

Term	Regression coefficient	CA	Flv	Csp	AT	MFI	OA
Constant	β_0	6.54	6.34	6.68	6.61	6.55	6.51
Meat level(A)	β_1	0.097	0.23	1.250E-003	0.13	0.39	0.28
Oil level (B)	β_2	0.026	-0.019	-0.020	0.043	0.035	0.019
Cooking time (C)	β_3	0.036	-0.089	0.016	0.054	0.028	7.500E-003
Meat level*Meat level (A^2)	β_{11}	NS	NS	0.11	-0.092	NS	NS
Oil level*Oil level (B^2)	β_{22}	NS	NS	-0.041	0.16	NS	NS
Cooking time*Cooking time (C^2)	β_{33}	NS	NS	-0.038	-0.22	NS	NS
Meat level*Oil level (AB)	β_{12}	-0.087	0.072	0.000	-0.073	NS	NS
Meat level*Cooking time (AC)	β_{13}	0.21	-0.18	-0.11	-0.13	NS	NS
Oil level*Cooking time (BC)	β_{23}	-0.035	-0.18	0.000	-0.087	NS	NS

β_0 - Intercept, β_i - regression coefficients for linear terms, β_{ii} - regression coefficients for quadratic terms, β_{ij} - regression coefficients for interactive terms, Significant at $p < 0.05$, NS Non-significant, CA Colour/appearance, Flv flavour, Csp crispiness, AT after-taste, MFI meat flavour intensity and OA overall acceptability

the form was fitted to data and regression coefficients were computed the results of which are reported in Table 4.

Results and discussion

Perusal of Table 3 revealed that for all the responses, F -values for the 'model' were significant and that for 'lack of fit' was non-significant ($p < 0.05$, $p < 0.1$) thereby confirming the validity of the models. Also these models adequately explained the variation of the responses with satisfactory R^2 values, which indicated that most variations could be well explained by different models (Linear, 2FI or Quadratic) as suggested by the software.

Colour/Appearance

Colour/Appearance of a meat product depends on the quantity of myoglobin present, the type of myoglobin molecule and its chemical state; and the chemical and physical conditions of other components in the meat (Lawrie and Ledward 2006). Moreover, it is the primary factor on which our purchasing decision depends because it indicates stability or discoloration (spoilage), the two most important quality attributes in shelf-life (Renner and Labadie 1993). The following equation showed a relationship between the independent variables meat level (X_1), oil level (X_2) and cooking time (X_3) and the dependent variable CA.

$$CA = 6.54 + 0.097X_1 + 0.026X_2 + 0.036X_3 - 0.087X_1X_2 + 0.21X_1X_3 - 0.035X_2X_3$$

From the above equation, it was seen that the effect of meat level (X_1) and oil level (X_2) gave rise to linear terms only. The analysis of variance showed that meat and cooking time interaction showed significant effect ($p < 0.01$; $p < 0.05$; $p < 0.1$) on CA of CMC (Tables 3 and 4). However, linearly meat level showed significantly higher ($p < 0.05$; $p < 0.1$) effect on CA of CMC (Table 3). The goodness of fit of the model was checked by the determination coefficient (R^2). The R^2 value (0.7141) indicated that only 28.59 % of the total variation was not explained by the model whereas adjusted R^2 value (0.5425) showed the significance of the model. A low value of the coefficient of variation ($CV = 1.70$ %) indicated higher precision and reliability of the experiment. With increase in meat level and oil level, CA scores increased (Fig. 1a). This supports the study of Singh et al. (2011) who documented significantly increased ($p < 0.05$) sensory scores for CA of treated chicken snacks with increase in meat level as compared to control group. Cholan et al. (2011), also reported similar trends for CA of egg patties with increase in chicken meat level. At the same time, with increase in meat level, CA scores decreased during meat and cooking time interaction (Fig. 1b). However, with increase in cooking time, appearance improved (Fig. 1b and c). At 5 min cooking time, the sensory rating for appearance was 6.5. Similar trend of increase in appearance scores was found when oil level was increased (Fig. 1c). This finding is in accordance with the results of Muguerza et al. (2002), who documented that dry fermented pork sausages containing more fat were having higher values of CA scores.

Flavour

Flavour is a complex attribute of meat palatability which involves odour, taste, texture (feel), temperature and pH (Calkins

Fig. 1 Surface plot (3-D) for colour/appearance

Fig. 2 Surface plot (3-D) for flavour

Fig. 3 Surface plot (3-D) for crispiness

and Hodgen 2007; Lawrie and Ledward 2006). It is an important factor affecting consumer's meat purchasing habits and preferences when tenderness was held constant (Sitz et al.

2005). In the present study, it was found to fit with the three variables as per 2FI model and meat level was found to have significant effect ($p < 0.01$; $p < 0.05$; $p < 0.1$) on Flv of CMC as

Fig. 4 Surface plot (3-D) for after-taste

shown in Table 3. The best model equation for Flv was,

$$\text{Flv} = 6.34 + 0.23X_1 - 0.019X_2 - 0.089X_3 + 0.072X_1X_2 \\ - 0.18X_1X_3 - 0.18X_2X_3$$

This shows that interaction of meat and cooking time; and oil and cooking time, showed significant effect ($p < 0.1$) on Flv of CMC (Table 3). The Model F -value was significant and there was only a 3.03 % chance that it could occur due to noise. Adequate precision ratio (signal to noise ratio) was 6.975, which indicated adequate signal and was used to navigate the design space. With continued increase in meat level, Flv improved throughout the study (Fig. 2a and b). The observation strongly agrees with the report of Singh et al. (2011), who observed significantly increased ($p < 0.05$) sensory scores for Flv of treated chicken snacks with increase in meat level as compared to control group. Singh et al. (2002), also observed maximum Flv scores in chicken snacks with highest meat level. Similar trends in Flv scores were reported by Cholan et al. (2011), in egg patties with increase in chicken meat level. However with increase in oil level, Flv scores decreased during meat level and oil level interaction (Fig. 2a). At the same time, with increase in oil level, Flv scores increased during oil level and cooking time interaction (Fig. 2c). But with increased cooking time, Flv scores of CMC also increased (Fig. 2b and c). This might be due to prolonged cooking times which ultimately resulted into formation of a range of primary precursors, aroma volatiles and secondary intermediates such as aldehydes, diketones, hydrogen sulphide etc. The present finding is in agreement with statement of a study (Pearson and Gillett 1997), which documented that cooking always intensifies the flavour of meat.

Crispiness

A crispy snack food is one which is usually firm and easily breaks or crumbles. Crispiness is a salient textural characteristic for most fresh dry cereal and starch-based snack food products. Csp of CMC was found to have quadratic relationship with the three process variables as per the following equation,

$$\text{Csp} = 6.68 + (1.250\text{E}-003)X_1 - 0.020X_2 + 0.016X_3 \\ - 0.000X_1X_2 - 0.11X_1X_3 + 0.000X_2X_3 + 0.11X_1^2 \\ - 0.041X_2^2 - 0.038X_3^2$$

The effect of meat level (quadratic) and meat level and cooking time interaction was found to be significant ($p < 0.01$; $p < 0.05$; $p < 0.1$) on Csp of CMC. The R^2 value (0.8279)

indicated that only 17.21 % of the total variation was not explained by the regression model (Table 3). The “Lack-of-fit F -value” of 0.45 implied that it was non-significant relative to the pure error. Furthermore, a very high degree of precision and a good deal of the reliability of the conducted experiment was indicated by a low value of the coefficient of variation ($CV = 0.87\%$). With increase in meat level, Csp of CMC first decreased and then increased (Fig. 3a and b). With increase in meat level, a decrease in Csp might be due to higher moisture content in it. The finding was similar to one reported by Sharma and Nanda (2002), which showed that crispiness was significantly higher in chicken chips with minimum level of meat. But with increase in oil level, Csp first increased and then decreased and a Csp value of 6.7 was observed at 75 g kg^{-1} of oil level (Fig. 3a and c). Increased cooking times always improved the Csp of CMC and it was highest at 5mins of cooking period (Fig. 3b). This might be due to higher moisture loss and thus surface firmness of CMC during prolonged cooking times (Pearson and Gillett 1997).

After-taste

After-taste is the taste intensity for a food which is perceived immediately after that food or meat product is removed from the mouth (Neely and Borg 1999). The following equation showed a quadratic relationship between the independent uncoded variables X_1 , X_2 and X_3 and the dependent variable AT.

$$\text{AT} = 6.61 + 0.13X_1 + 0.043X_2 + 0.054X_3 - 0.073X_1X_2 \\ - 0.13X_1X_3 - 0.087X_2X_3 - 0.092X_1^2 + 0.16X_2^2 - 0.22X_3^2$$

The above equation showed that meat level (linear), oil level (quadratic) and cooking time (quadratic) showed significant effect ($p < 0.05$; $p < 0.1$) on AT of CMC (Table 3). In this case, the value of determination coefficient ($R^2 = 0.8377$) indicated that only 16.23 % of the total variations were not explained by the regression model. The adjusted R^2 (0.6291) corrected the R^2 value for the sample size and the number of terms in the model. If there are many terms in the model and the sample size is not very large, the adjusted R^2 may be noticeably smaller than the R^2 . With increase in meat level AT also increased (Fig. 4a and b). The observation is in accordance with the study of Singh et al. (2002), who observed that in chicken snacks with highest meat level, after-taste scores were maximum. Singh et al. (2011), also reported significantly higher ($p < 0.05$) sensory scores for AT of treated chicken snacks with increase in meat level as compared to control group. With increase in oil level, AT of CMC first decreased and then increased (Fig. 4a and c). At 75 g kg^{-1} of oil level, AT of CMC was more than 6.6 (Fig. 4a). With

Fig. 5 Surface plot (3-D) for meat flavour intensity

increase in cooking time, it first increased and then decreased (Fig. 4b and c). At 5 min of cooking time, AT was more than 6.2 (Fig. 4b). This might be due to the fact that cooking generates taste and flavour compounds in the product.

Meat flavour intensity

Meat flavour intensity is an important sensory attribute which was found to have linear relationship with the three process

variables as described by the following equation,

$$\text{MFI} = 6.55 + 0.39X_1 + 0.035X_2 + 0.028X_3$$

The analysis of variance showed that meat level (linear) showed significant effect ($p < 0.01$; $p < 0.05$; $p < 0.1$) on MFI of CMC (Tables 3 and 4). In this case, the Predicted R^2 value (0.5004) was in reasonable agreement with the Adjusted R^2

Fig. 6 Surface plot (3-D) for overall acceptability

value (0.6139). However, the coefficient of variation being 3.14 %, indicated better precision of the experiment. Adequate precision value of 8.425, indicated model discrimination. MFI of CMC increased linearly, with increase in meat level (Fig. 5a and b). This might be due to more meat content of CMC. The finding supports the study of Singh et al. (2002), in which it was observed that in chicken snacks with highest meat level, MFI scores were maximum. Also with increase in oil level and cooking time, MFI of CMC slightly decreased in a linear fashion. At highest levels of meat (700 g kg⁻¹) and oil (75 g kg⁻¹), MFI was more than 6.8 and 6.0 respectively (Fig. 5a and b). Decrease in MFI due to increased oil level might be due to masking of flavour of CMC by refined oil.

Overall acceptability

Overall acceptability of CMC was found to have linear relationship with the three independent variables as described by the following equation,

$$OA = 6.51 + 0.28X_1 + 0.019X_2 + (7.500E-003)X_3$$

As per this model only one variable i.e. meat level (X_1) was found to show significant effect ($p < 0.01$; $p < 0.05$; $p < 0.1$) on OA of CMC. The Model F -value (4.28) and “Lack-of-fit F -value” (2.03) implied that former one was significant but

the latter one was non-significant. With increase in meat level, OA of CMC always increased linearly (Fig. 6a and b). The finding strongly agrees with the report of Singh et al. (2011), which stated significantly higher ($p < 0.05$) sensory scores for OA of treated chicken snacks with increase in meat level as compared to control group. Similar results were documented by Cholan et al. (2011), for OA sensory scores in egg patties with increase in chicken meat level. Slight decrease in OA, due to increase in oil level and cooking time (Fig. 6a and b) might be due to decreased MFI. Crehan et al. (2000), also revealed decrease in OA scores of frankfurters with decrease in fat level. At highest levels of meat (700 g kg^{-1}) and oil (75 g kg^{-1}) overall acceptability was more than 6.7 and 6.2 respectively (Fig. 6a and b).

Desirability

In RSM, the most useful approach to optimization of multiple responses is to use the simultaneous optimization technique (Derringer and Suich 1980). Their procedure makes use of desirability functions. Essentially, the approach is to translate the functions to a common scale (0 and 1), combine them using the geometric mean and optimize the overall metric. By using this technique, instead of optimizing each outcome separately, settings for the predictor variables sought to satisfy all of the outcomes at once. Each response variable was assigned at low and high levels of the observed values for a desirability of 0 and 1, respectively to get the overall desirability. The desirability function to get optimum sensory scores was fitted by the least square method using the software. On the basis of ranges of these different responses, a total of 43 solutions were found out of which, the product with 650 g kg^{-1} of meat level, 50 g kg^{-1} of oil level and 4 mins cooking time was having desirability of 1.0 and it was

selected. Figure 7 shows contour plot for desirability (oil level vs meat level).

Optimization of process parameters

Responses were optimized individually in combination using Design expert software. In response surface analysis, the selected model was used to calculate the stationary point. A stationary point is a point at which the slope of the response surface is zeroed in all the directions. Since the optimum response for each variable were not all in exactly the same region in the space formed by the processing variables. So, constraints were set in the form of ranges (minimum and maximum values) for all the dependent and independent variables from Table 2, in such a way that the selected meat level (g kg^{-1}), oil level (g kg^{-1}) and cooking time (minutes) were optimum for most important attributes and close to optimum for the others. These constraints were met in the region where meat level was 650 g kg^{-1} , oil level was 50 g kg^{-1} and cooking time was 4 min. The optimized sensory scores for Colour/Appearance, Flavour, Crispiness, After-taste, Meat flavour intensity and Overall acceptability were 6.54, 6.33, 6.68, 6.61, 6.55 and 6.51 respectively.

Conclusions

Conventional processes of optimization are usually time consuming and expensive. Single factor optimization methods are not only monotonous but may also lead to misinterpretation of results because the interaction between different factors is usually overlooked. Response surface methodology is a powerful tool for optimization of a process involving several response variables. The results shown for process of

Fig. 7 Contour plot for desirability (oil level vs meat level)

development of chicken meat caruncles identified the optimum processing parameters which were 650 g kg⁻¹ of meat level, 50 g kg⁻¹ of oil level and 4 min as cooking time. The model equation for the response variables predicted values under the identified optimum conditions which were experimentally verified to be in general agreements with the model. The present study has provided comprehensive information, which could enable the meat industry to make progress in providing the quality of convenience chicken meat based snacks for the consumers.

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