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Optimization of Low-Fat Pork Burgers Made with Konjac/Gellan Blend and Added Water

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Abstract: Low-fat pork burgers prepared with two independent variables, konjac/gellan blend (3:1) and added water as fat replacement, were examined for quality by sensory evaluation. Experiments were carried out using a central composite rotatable design (CCRD) and sensory attributes as response variables. Response surface analysis indicated that sensory texture, flavor and overall liking scores of low-fat pork burgers varied from 5.05 to 6.45, 5.25 to 6.60 and 5.15 to 6.65, respectively. The result of analysis showed that all second-order polynomial models of these attributes were found to be fitted well (R^2>80%). The increase of konjac/gellan blend alone increased texture but decreased overall liking; however, as added water was incorporated with it, the burgers were rated in higher scores for texture, flavor and overall liking. The low-fat burger containing a minimum level of 0.84% konjac/gellan blend and 93.68% added water showed a minimum score of 6.6 for all sensory attributes. The optimized low-fat product was considered nutritious and provided the reduction of fat and total caloric content about 43.57 and 30.33% of the full-fat product, respectively.

Key words: Low-fat meat products · Konjac flour · Gellan gum · Response surface methodology

INTRODUCTION

Fat reduction in food products has been extensively investigated by the reason that fat, especially saturated fat, is proved as the cause of many health problems including coronary disease, obesity, high blood pressure and some cancers. Gums or hydrocolloids have been successfully used as fat replacement in various meat products [1, 2]. Konjac flour, an non-ionic polysaccharide comprising of mannose and glucose (3:2) units with β-(1, 4)–linkages, can be gelled by incorporating with secondary hydrocolloids including kappa-carrageenan, xanthan and gellan [3]. Konjac gel has been carried out to retain sensory and textural attributes through fat substitution by replacing fat with konjac gel in some meat products such as low-fat prerigor fresh pork sausages [4], low-fat bolognas [5], reduced-fat pork sausages [6], Thai traditional minced and preserved pork products (Moo Yo) [7] and low-fat/reduced salt sausages [8].

Pork burger, one of convenience foods served for present rush lifestyle and society in most Asian countries, is continuously consumed and tends to increase. The quality of pork burger depends on its ingredients, raw materials, heating process and so on [9]. Fat provides flavor and texture related to consumers acceptability. Although, there are many investigations on low-fat meat products, a few information on optimization of ingredients for fat replacement is available. Most observations varied one parameter while keeping the others at a constant level, thus it lacks of the interactive effects among two or more variables needed to depict the net effects of various parameters on low-fat meat production. Consequently, the response surface methodology (RSM) is an effective tool for optimizing the process conditions. It usually uses an experimental design such as a central composite rotatable design (CCRD) to fit a first- or second-order polynomial by a least significance technique. This design can describe how the test variables affect the response and to determine the interrelationship among the test variables in the response [10].

The objective of this study was to perform a systematic investigation on how different levels of konjac/gellan blend (3:1) and added water in the formulation of low-fat pork burgers influence on their sensory properties by using RSM as well as to determine an optimal condition for producing low-fat pork burgers. The nutritional evaluation of an optimized formulation was also investigated.

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MATERIALS AND METHODS

Materials: Fresh pork meat and fat were obtained from local processors. Konjac flour (Chengdu Qiteng Trading Co., Ltd) and gellan gum (KELCOGEL®, CP Kelco UK Ltd., UK) were used. Other ingredients including sugar, pepper, wheat flour, evaporated milk, white onion and salt were purchased from a local supermarket.

Experimental Design: A central composite rotatable design (CCRD) of the response surface methodology (RSM) for a two-variable, five level combinations coded -1.41, -1, 0, 1, 1.41 was used. Konjac/gellan blend and added water were designed as independent variables of the process. Experimental design matrix for low-fat pork burger formulations are presented in Table 1, showing the actual design of experiments which contain eight randomized experimental runs and three replicates as the center point for evaluating the experimental error and the suitability of the mathematical model.

The second-order response function for the experiments was predicted by the following model

$$Y = b_o+b_1x_1+b_2x_2+b_{11}x_1^2+b_{22}x_2^2+b_{12}x_1x_2 \quad (1)$$

Where Y is the response calculated by the model; x_1 and x_2 are the coded konjac/gellan blend and added water, respectively and b_1 and b_2 are linear, b_{11} and b_{12} are quadratic and b_{12} is interaction coefficient, respectively.

Processing of Low-Fat Pork Burgers: Pork meat was ground through 1.7 and 0.4–cm plates, respectively. Recipe for preparation of 1 batch of the full-fat pork patty, based on total weight, included: pork meat 62.85%, pork fat 25.14%, whole egg 6.30%, salt 1%, pepper 0.38%, sugar 1.25%, chopped white onion 0.38%, evaporated milk 2.07% and wheat flour 0.63%. In this study, experimental formulations were prepared by varying from 0 to 1% konjac/gellan blend based on pork meat weight whereas added water, which replaced equivalent amount of pork fat, was varied in the range of 0 to 100%. The burgers were processed by thoroughly mixing of ground pork meat, prehydrated konjac/gellan blend (1 part : 4 part of water for 30 min) and other ingredients by a food mixer for 5 min. The meat mixture was hand stuffed into a fiber casing to form the pork burger (80g weight, 9 cm diameter and 1 cm thickness) before freezing at -18°C. The patties were cooked in a preheated (148°C) electric frying pan with low layer of vegetable oil for 4 min on one side, turned over and cooked for 3 min (internal temperature was about 77±2°C measured by a thermocouple). The products were evaluated at an interval of 3 days for sensory properties.

Sensory Evaluation: Sensory evaluation was conducted by semi-trained, twenty four panelists who have experienced and some knowledge of food evaluation. They were familiar with the sensory attributes-texture, flavor, overall liking, of burgers. Sensory texture, flavor and overall liking were evaluated by using a 9-point hedonic scale test (1 = extremely dislike, 9 = extremely like). All testing sessions were held in a sensory evaluation laboratory with partitioned booth. Unsalted cracker, apple juice and distilled water were provided to rinse the palate between samples [11].

Table 1: Independent variables and their coded and actual values used for analysis

	Konjac/gellan blend [1)] (%)		Added water [2)] (%)	
Experimental Number	Coded value	Actual value	Coded value	Actual value
1	-1	0.15	-1	85
2	-1	0.15	+1	15
3	+1	0.85	-1	85
4	+1	0.85	+1	15
5	-1.41	0	0	50
6	+1.41	1	0	50
7	0	0.5	-1.41	100
8	0	0.5	+1.41	0
9	0	0.5	+1.41	50
10	0	0.5	0	50
11	0	0.5	0	50

1) Konjac/gellan blend is based on pork meat weight

2) Added water, which replaced equivalent amount of pork fat, is based on pork fat weight

Chemical Composition and Caloric Content: Moisture, protein, fat, ash, fiber and carbohydrate were determined according to AOAC [12] procedures for full-fat and optimized low-fat pork burgers. The total caloric value was calculated from the results obtained in the chemical analysis for the energy component: fat (9 Kcal/g), protein (4 Kcal/g) and carbohydrate (4 Kcal/g), based on a 100g serving basis.

Statistical Analysis: The production of low-fat pork burgers was carried out in triplicate. The observed responses were regressed against konjac/gellan blend and added water levels using the SPSS for Window version 14.0. The fitted equations were expressed as contour plots by using the STATISTICA software version 7.0 (Stasoft Inc., Tolsa, OK, USA) in order to visualize the relationship between the response and experimental levels of each factor and to deduce the optimum condition [10, 13].

RESULTS AND DISCUSSION

Statistical Analysis on Model Fitting: The independent and dependent variables were fitted to the quadratic model equation and examined for the goodness of fit. Regression analysis and ANOVA of the effect of the combination of konjac/gellan blend and added water to produce low-fat pork burgers were conducted for the model to examine the statistical significance of the model terms. The sensory results indicated that coefficient of determination or R^2 values of the model for texture, flavor and overall liking (R^2 = 0.929-0.993) were higher than 0.8 (Table 2), indicating that the models have satisfactory adequacy in fitting the experimental data and model significance. It has been suggested that the model with R^2 greater than 0.8 indicates a good fit [14]. At the same time, from Table 2, two models for texture and overall liking possessed no significant ($p > 0.05$) lack of fit, then these models were reliable. Whilst, the lack of fit for flavor ($p = 0.0140$) was significant ($p < 0.05$), then a more complicated or higher-order model was required to accommodate the data. The coefficients of variation of 0.90% for texture, 3.17% for flavor and 1.54% for overall liking were relatively low, as evidence in Table 2. This indicated that texture had better precision and reliability of experiments as compared with flavor and overall liking perception.

Effect on Texture: Results of sensory evaluation from 11 formulations with two variables by CCRD design listed in Table 3 show that maximum texture score (6.45) was found to be on experiment no.7, which was formulated by adding 0.5% konjac/gellan blend and 100% added water, while minimum texture score (5.05) recorded for experimental no.2 was at 0.15% konjac/gellan blend and 15% added water. This result revealed that the low-fat burger containing a higher amount of added water had a higher texture score, indicating that most panelists preferred more soft and elastic texture, which was because of increased added water substituted for pork fat in formulations. This was in agreement of my previous work and others who reported that low-fat meat products prepared with hydrocolloids or gums as fat replacement showed a higher moisture content than that of full-fat products, showing that the meat is perceived as more juicy [15-17].

Table 2: Regression coefficient estimates for sensory attributes of low-fat pork burgers

	Sensory attributes		
Factor	Texture	Flavor	Overall liking
Constant	4.933***	6.515***	6.184***
x_1	0.084	–4.229**	–1.645*
x_2	0.009**	–0.011	–0.006
$x_1 x_1$	0.603*	4.398***	0.237
$x_2 x_2$	6.631E–5*	0.0002*	9.371E–5
$x_1 x_2$	–0.005	–0.006	0.018*
R^2	0.993	0.929	0.963
P-value	0.000	0.007	0.001
Lack of fit	0.1819	0.0140	0.0620
Coefficient of variation (%)	0.90	3.17	1.54

*Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level

Independent variables: x_1 = konjac/gellan blend (%) and x_2 = added water (%)

Table 3: Sensory evaluation of pork burgers with different levels of konjac/gellan blend and

	Added water		
Experimental Number	Texture	Flavor	Overall liking
1	6.15	6.60	6.50
2	5.05	6.05	5.90
3	6.40	6.40	6.65
4	5.55	6.15	5.15
5	5.62	6.45	6.10
6	5.95	6.25	5.55
7	6.45	6.35	6.55
8	5.15	5.25	5.45
9	5.60	5.40	5.80
10	5.65	5.35	5.85
11	5.65	5.35	5.85

The total coefficient of determination (R^2) in Table 2 implies that 99.3% of the total variability in texture was attributed to konjac/gellan blend and added water levels. The estimated coefficients of analysis of data on texture in Table 2 produced a polynomial equation which after removing non-significant terms becomes:

$$\text{Texture} = 4.933 + 0.009x_2^{**} + 0.603x_1^{2*} + 6.631\text{E-}5x_2^{2*} \quad (2)$$

Where

x_1 = konjac/gellan blend (%) and x_2 = added water (%)

*Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level

From the model equation, the most variable affecting texture was positive linear term of added water, followed by positive quadratic terms of konjac/gellan blend and added water, which were significant at $p<0.05$. As a result, the increase in added water levels mainly resulted in increasing of texture perception of the products. There was no interaction effect between konjac/gellan blend and added water levels.

When considering the contour graph of texture (Figure 1a), it was clear that there was an increase in texture with increasing of konjac/gellan blend and added water. Maximum (6.6) and minimum (5.1) scores of texture were observed at konjac/gellan blend = 0.84-1% / added water = 93.68-100% and konjac/gellan blend = 0-0.47% / added water = 0-15.79%, respectively.

Effect on Flavor: Flavor score was significantly affected by the variables from which the low-fat pork burger was formulated. Maximum flavor score (6.60) presented in Table 3 occurred in experimental no.1 with 0.15% konjac/gellan blend and 85% added water whereas minimum flavor score (5.25) was recorded for experimental no.8 at 0.5% konjac/gellan blend and 0% added water (or total pork fat used). The statistical analysis of the data (Table 2) revealed R^2 of flavor is 0.929, indicating that 92.9% of the total variability in flavor was attributed to konjac/gellan blend and added water. The regression coefficients in Table 2 showed that both variables had effect on flavor of the products. Removing the non-significant terms and reomputing, the polynomial becomes:

$$\text{Flavor} = 6.515 - 4.229x_1^{**} + 4.398\, x_1^{2***} + 0.0002\, x_2^{2*} \quad (3)$$

Where

x_1 = konjac/gellan blend (%) and x_2 = added water (%)

*Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level.

The most significant variable affecting flavor was positive quadratic term of konjac/gellan blend, which was significant at $p<0.001$, followed by the negative linear term ($p<0.01$) of konjac/gellan blend, while the positive quadratic term ($p<0.05$) of added water was the last. The negative sign indicated that the ingredient had a reciprocal effect on the response. No interactive effect between konjac/gellan blend and added water was observed for flavor evaluation.

The sensory data of flavor in CCRD (Fig. 1b) shows that the contour plot is elliptical and the minimum optimum point is attained at the centre as moving along the major and minor axis of ellipse. The graph implied that at 0% konjac/gellan blend used, flavor liking tended to increase with increasing added water substituted for pork fat in burgers. This was in agreement of the work of Gregg *et al.* [18] who demonstrated that the added water was allowed in low-fat meat products in order to compensate for loss of flavor resulting from fat reduction.

Table 4: Chemical composition and caloric content of cooked pork burgers

Composition (g/100 g sample)	Full-fat formulation	Low-fat formulation
Moisture	54.23	64.40
Fat	19.05	10.75
Protein	22.05	19.50
Ash	2.15	2.06
Fiber	0.10	0.07
Carbohydrate	2.42	3.22
Caloric value (Kcal/100g)	269.33	187.63

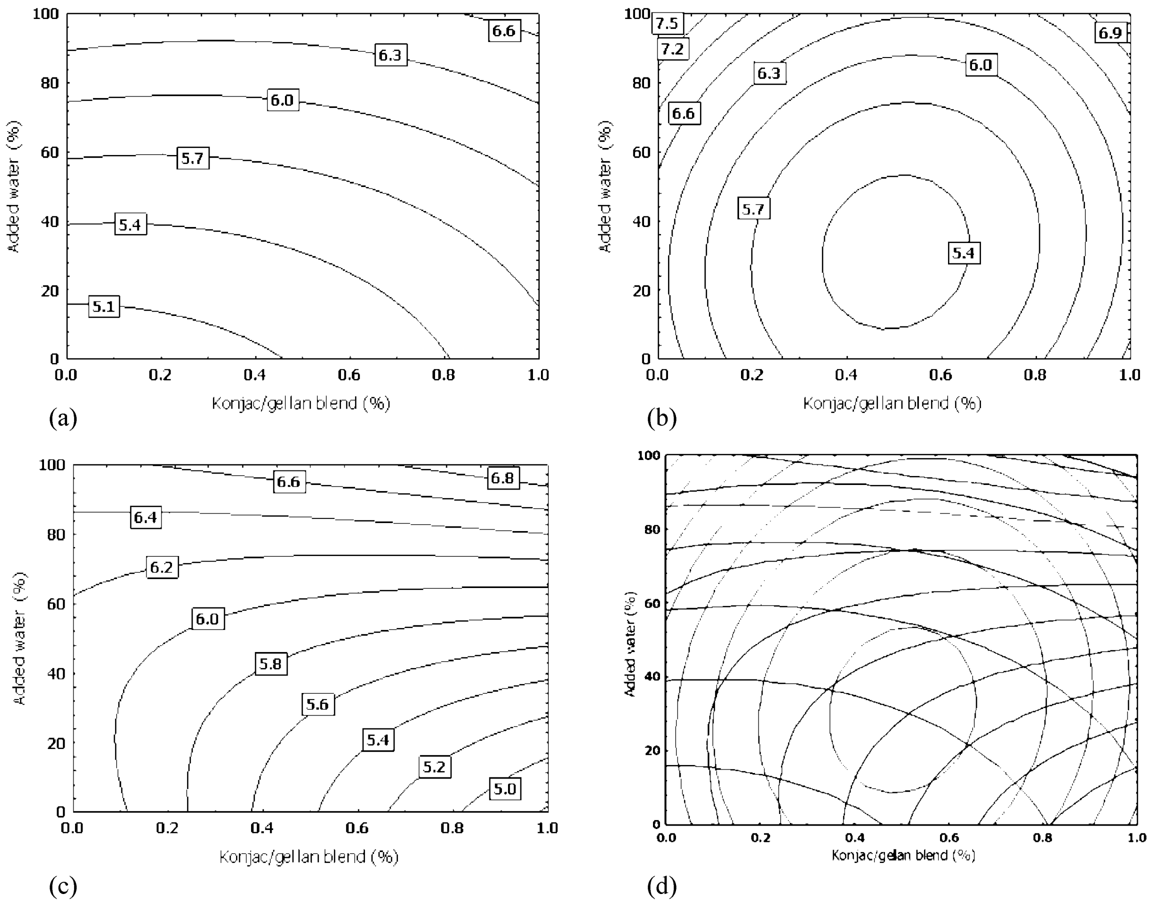

Fig. 1: The contour plot of sensory attributes of low-fat pork burgers as affected by konjac/gellan blend and added water: (a) texture; (b) flavor; (c) overall liking and (d) superimposed contour plot for significant responses

When konjac/gellan blend was incorporated less than 0.35%, the low-fat burger showed a increased trend of flavor liking, but it was decreased as konjac/gellan blend was used in the range of 0.35-0.65%. When konjac/gellan blend was incorporated more than 0.65%, the low-fat burger showed a higher score for flavor. This may be attributed to the effect of differences in panelists' liking and specific flavor of konjac flour and pork fat. Panelists who like fat flavor may give higher scores for flavor evaluation at a low level of konjac/gellan blend used, which was the level that the intensity of fat flavor was dominant. On the other hand, at a higher level of konjac/gellan blend used, the konjac flavor may partially mask pork fat flavor, resulting in higher scores for flavor rated by panelists who dislike the flavor of pork fat. Thus, the center area implied indifferent liking of two groups of panelists, which was found to be at 0.35-0.65% konjac/gellan blend and 8.42-52.63% added water, with the lowest flavor score of 5.4.

Effect on Overall Liking: The result of overall liking shown in Table 3 presents that experimental no.3, which was formulated with 0.85% konjac/gellan blend and 85% added water, was observed for the highest overall liking score (6.65), while experimental no.4 with 0.85% konjac/gellan blend and 15% added water was the lowest (5.15). Overall liking would be influenced by texture and flavor attributes. The level of R^2 (0.963) in Table 2 demonstrated that the model contributed about 96.3% of total variation in overall liking of low-fat burgers. The model equation for overall liking without non-significant terms was presented as followed:

$$\text{Overall liking} = 6.184 - 1.645x_1^{*} + 0.018\, x_1x_2^{*} \quad (4)$$

Where

x_1 = konjac/gellan blend (%) and x_2 = added water (%)
*Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level.

From the model equation, it was clear that overall liking was affected by the negative linear term of konjac/gellan blend and an interaction effect between konjac/gellan blend and added water with a positive effect, which were significant at $p<0.05$. The interaction revealed that at a higher level of konjac/gellan blend but a lower level of added water, the overall liking was low. Nevertheless, an increase was noticed as the level of added water increased. The results indicated that overall liking of low-fat pork burgers was mostly influenced by their flavor and texture properties

As shown in Fig. 1c, the contour graph of overall liking revealed that maximum (6.8) and minimum (5.00) scores were observed at konjac/gellan blend = 0.68–1% / added water = 92.84–100% and konjac/gellan blend = 0.81–1% / added water = 0–15.52 %, respectively.

Optimization: The graphical optimization was carried out for the ingredients for the production of low-fat pork burgers. Overall optimization, conducted by overlaying the contour plots under investigations, was able to point out the optimal ranges of the independent variables within which the three responses were simultaneously optimized. The shade area in Fig.1d represents that the low-fat pork burger containing a minimum level of 0.84% konjac/gellan blend and 93.68% added water resulted in the high desirable product showing a minimum each of texture, flavor and overall liking score of 6.6 (moderately like), which were estimated from the superimposition of Fig.1a onto Fig.1b and 1c, respectively. For example, a point in shade area at 0.9% konjac/gellan blend and 100% added water was the optimum production condition to achieve a specific goal.

Chemical Composition and Nutritional Evaluation: When total pork fat content was replaced with water incorporated with a konjac/gelllan blend, the fat and energy content declined similar to the finding of Osburn and Keeton [4], Chin *et al.* [5] and Cengiz and Gokoglu [19]. In this study, the optimized low-fat pork burger made with 0.9% konjac/gellan blend and 100% added water was considered preferable because the intake of 100g would provide less than 43.57% of fat content and the total caloric value reduction was about 30.33% in relation to the full-fat pork burger.

CONCLUSION

The use of CCRD design was shown to be a good way to evaluate the responses of sensory attributes of low-fat pork burgers produced at different konjac/gellan blend and added water levels. Sensory scores of texture, flavor and overall liking were affected by these two variables. Increasing of konjac/gellan blend and added water showed a tendency for acceptable overall liking of the product. Information generated would help to producing of the low-fat burger for acceptable sensory attributes. The optimized formulation, contained 0.9% konjac/gellan blend and 100% added water, provided 43.57 and 30.33% reduction of fat content and total caloric value, respectively.

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