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Effect of Konjac/Gellan Blend and Fat Content on Physical and Textural Properties of Low-fat Pork Burgers: A Response Surface Analysis

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Abstract: A central composite rotatable design was employed to investigate the effects of independent variables on physical and textural properties of low-fat pork burgers and to optimize the process condition of the product. The independent variables were konjac/gellan blend (0-1%) and pork fat content (0-100%). The analysis of variance and regression analysis showed that cooking yield (%), reduction in diameter (%), redness (a^*value), hardness (N), springiness (mm) and chewiness (mJ) ranged from 70.05 to 81.35, 9.56 to 16.62, 2.52 to 4.07, 4.06 to 6.16, 6.43 to 10.02 and 14.77 to 38.94, respectively. The coefficients of determination or R^2-values of the responses were within the range from 0.8509 to 0.9928. A second-order polynomial was used for predicting the responses. Response surface analysis revealed the relationship between independent variables and most physical and textural properties of low-fat burgers were strongly influenced by konjac/gellan blend. The optimum predicted condition for the production of the products was 1% konjac/gellan blend and 66.43% pork fat, which was confirmed by the agreement between the experimental and predicted values for physical and textural properties.

Key words: Low-fat meat products, konjac flour, gellan gum, response surface methodology

INTRODUCTION

Current consumer demand for low-fat/healthier food products which have a same mouthfeel of full-fat treatment is considerable importance to develop low-fat meat products. There is an increasing evidence that the consumption of less fat foods in place of full-fat products lowers blood cholesterol levels and may provide the cardiovascular benefits. The simple way to reduce fat and calories in processed meat products is to add water substituted for reduced-fat portion, which has been reported to increase cooking and purge losses and to affect the texture and juiciness of the products (Gregg *et al.*, 1993). Gums or hydrocolloids have been successfully used as fat replacement in various meat products, because they form gels at low concentrations, physically binding water to produce better quality of low-fat meat products (Yang, 2001). Konjac flour, an non-ionic polysaccharide comprising of D-mannose and D-glucose (3:2) units with b-(1, 4)–linkages, can be heat-induced gelled when it was incorporated with secondary hydrocolloids including kappa-carrageenan, xanthan and gellan gums (Thomas, 1997). 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 (Osburn and Keeton, 1994), low-fat bolognas (Chin *et al.*, 2000), Thai traditional minced and preserved pork products (Moo Yo) (Akesowan, 2002), light pork sausages with soy protein isolate (Akesowan, 2008) and low-fat/reduced salt sausages (Lee and Chin, 2009).

In recent years, the response surface methodology (RSM) has become one of the most popular optimization methods used for optimizing a process when the independent variables have an interaction effects on the desired response (Tang *et al.*, 2010). This can overcome the traditional production of low-fat meat products, which was achieved by the one-factor-at-a-time approach, causing the time-consuming and lack of interaction effects between variables to depict the net effects of various variables on low-fat meat products. An experimental design of the RSM, a central composite rotatable design (CCRD) is used 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 (Liu *et al.*, 2008).

In this study, the influence of different levels of konjac/gellan blend (3:1) and pork fat content (fat

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replacement with water) on physical and textural properties of low-fat pork burgers were analyzed using RSM. Also, the optimal condition for producing the low-fat burger was investigated.

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 pork fat content (fat replacement by using an amount of water replaced for reduced-pork fat portion) 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

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2 \quad (1)$$

where Y is the response calculated by the model; X_1 and X_2 are the coded konjac/gellan blend and pork fat content, 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 full-fat pork patties (% by 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 pork fat content was varied in the range from 0 to 100%. The burgers were processed by thoroughly mixing of ground lean 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 preheated (148°C) electric pan in 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 5 days for physical and textural properties.

Physical Analysis:

Cooking Yield:

The weight of each sample was measured before and after cooking to determine cooking yield, which was defined as the cooked weight divided by the uncooked weight then multiply by 100% (DAS *et al*. 2008).

Reduction in Diameter:

The reduction in pork burger diameter was determined with a ruler using the following equation: (Uncooked diameter – cooked diameter) / Uncooked diameter, and then multiply by 100% (Mansour and Khalil, 1999).

Color Measurement:

A Hunter Lab digital colorimeter (Model ColoeFlex, Hunter Associates Laboratory, Reston, VA) was used to measure redness (a*-value) of samples.

Texture Profile Analysis:

The Lloyd texture analyser (Model LRX, Lloyd Instruments, Hampshire, UK) with 1000 N load cell was used for determining texture profiles of cooked samples (40 mm diameter x 1 cm thickness). Textural characteristics including hardness, springiness and chewiness of samples were determined with a test cell (50 mm width × 50 mm length) at 2 mms^{-1} crosshead speed.

Statistical Analysis:
The production of low-fat pork burgers was carried out in triplicate. The observed response was subjected to analyze for analysis of variance (ANOVA) and multiple regression using the Design-Expert ® Trial version 8.0.2.0 software (State-Ease Inc., Minneapolis, MN) in order to visualize the relationship between the response and experimental levels of each factor and to deduce the optimum condition (Anderson and Whitcomb, 2005).

RESULTS AND DISCUSSION

Statistical Analysis on Model Fitting:
Low-fat pork burgers obtained from the combination of different levels of konjac/gellan blend and pork fat content subjected to physical and textural analysis and their results are presented in Table 2. The data were conducted on regression and ANOVA analysis, showing that dependent and independent variables were fitted to quadratic equations The following second-order polynomial equations without non-significant terms were found to be represented the fitted models for physical and textural properties of low-fat pork burgers as presented in equation 2-7.

Physical Analysis:

$$\text{Cooking yield} = 73.61 + 10.26\ X_1 - 0.12\ X_2 + 9.92\text{E-004}\,x_2^2 \quad (2)$$

$$\text{Reduction in diameter} = 18.46 - 7.85\ X_1 - 0.08\ X_2 + 3.70\,x_1^2 + 3.13\text{E-004}\ x_2^2 \quad (3)$$

$$\text{Redness} = 2.49 + 2.95\ X_1 - 1.01\ x_1^2 + 8.67\text{E-005}\,x_2^2 - 9.39\text{E-003}\ X_1\ X_2 \quad (4)$$

Texture Profile Analysis:

$$\text{Hardness} = 4.50 - 2.21\ X_1 + 4.73\text{E-003}\ X_2 + 2.22\,x_1^2 + 2.08\text{E-004}\,x_2^2 \quad (5)$$

$$\text{Springiness} = 7.17 - 0.14\ X_1 - 0.02\ X_2 + 3.99\,x_1^2 + 1.49\text{E-004}\ x_2^2 \quad (6)$$

$$\text{Chewiness} = 36.60 - 47.54\ X_1 + 36.61\,x_1^2 + 0.45\ X_1\ X_2 \quad (7)$$

Where X_1 = konjac/gellan blend (%) and X_2 = pork fat content (%).

The models for physical properties (cooking yield, reduction in diameter and redness (a*-value)) and textural properties (hardness, springiness and chewiness) on equation 2-7 were highly adequate with their satisfactory levels of coefficient of determination or R^2 (0.9689-0.9928) and (0.8509-0.9927), respectively and all models were significant at $p<0.05$ (Table 3-4). It has been suggested that the model with R^2 greater than 0.8 indicates a good fit (Joglekar and May, 1987). The closer the values of R^2 to 1, the better correlation between the experimental and predicted values. As a result, the R^2 –value of 0.9928 for rednees indicates the most closed agreement between experimental results and theoretical values predicted by the model equation. However, a large value of R^2 does not always imply that the regression model is a good one. Adding a variable to the model will always increase R^2, regardless of whether the additional variable is statistically significant or not. Thus, it is preferred to use an adj–R^2 to evaluate the model adequacy and should be over 0.9 (Koocheki *et al.*, 2010). As seen in Table 3-4, adj–R^2 values of all responses, except for chewiness, were also high to advocate for a high significance of the model. Pred–R^2 measures the amount of variation in new data explained by the model. Generally, a number closer to 1 is preferred. Here, pred–R^2 values of all responses, except for chewiness were in reasonable agreement with their adj–R^2 values, while a negative pred–R^2 of chewiness implied that the overall mean is a better preditor of the response than the current model. When considering adeq precision, which measures the signal to noise ratio, a ratio greater than 4 is desirable. In this work the ratio of each response is found to be > 7, which indicates an adequate signal, demonstrating that the model can be used to navigate design space. The coefficient of variation (CV) indicates the degree of precision with which the treatments were compared. In general, the high value of CV implies that variation in the mean values is high and reliability of experiment is low. Here, a lower CV value of 1.20 for cooking

Table 1: Experimental design matrix for low-fat pork burger formulations.

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

1) Konjac/gellan blend is based on pork meat weight.
2) Pork fat content, which replaced equivalent amount of reduced pork fat portion with water (w/w).

Table 2: Data of physical and textural properties of pork burgers with different levels of konjac/gellan blend and pork fat content.

Experimental Number	Physical properties			Textural properties		
	Cooking yield (%)	Reduction in diameter (%)	Redness (a*)	Hardness	Springiness	Chewiness
1	73.50	16.62	2.82	4.20	7.11	25.53
2	71.25	13.04	3.17	5.92	6.76	14.77
3	80.75	13.51	4.07	4.15	9.66	27.83
4	76.80	9.56	3.96	5.48	8.97	38.94
5	70.05	15.35	2.52	5.36	6.43	26.43
6	81.35	11.05	3.98	4.93	10.02	30.25
7	79.55	15.07	3.75	4.06	7.99	20.37
8	75.85	11.05	3.67	6.16	7.23	23.73
9	74.35	12.35	3.51	4.55	7.35	19.63
10	75.02	12.05	3.50	4.45	7.30	19.97
11	74.75	12.56	3.52	4.52	7.40	20.87

Table 3: Analysis of variance for physical properties of low-fat pork burgers.

Source	df	F			P		
		Cooking yield (%)	Reduction in diameter (%)	Redness (a^*)	Cooking yield (%)	Reduction in diameter (%)	Redness (a^*)
Model	5	31.18	73.11	138.67	0.0009	0.0001	< 0.0001
X_1	1	125.05	168.73	615.29	<0.0001	<0.0001	<0.0001
X_2	1	19.73	183.53	0.59	0.0068	<0.0001	0.4779
X_1^2	1	0.32	9.75	25.26	0.5980	0.0262	0.0040
X_2^2	1	10.07	6.97	18.62	0.0247	0.0460	0.0076
$X_1 X_2$	1	0.87	0.29	15.45	0.3931	0.6147	0.0111
Lack-of-fit	3	11.48	2.35	56.38	0.0812	0.3124	0.0175
R^2		0.9689	0.9865	0.9928			
Adj–R^2		0.9378	0.9730	0.9857			
Pred–R^2		0.7873	0.9185	0.9496			
Adeq precision		17.171	25.407	36.285			
Coefficient variation (CV)		1.20	2.67	1.67			

df – degree of freedom; F – statistics test to determine significance ; P – probability value; X_1 = konjac/gellan blend and X_2 = pork fat content.

yield revealed a better precision and reliability of experiment as compared with other parameters. At the same time, from Table 3-4, four models for cooking yield, reduction in diameter, hardness and springiness possessed no significant (p>0.05) lack-of-fit, then these models were reliable. Whilst, the lack-of-fit for redness and chewiness were significant (p<0.05), then a more complicated or higher-order model was required to accommodate the data. Also, the F-test with a very low probability of selected responses confirmed that these models were highly statistically significant models.

Physical Analysis:
Effect on Cooking Yield:

Results of physical analysis from 11 conditions with two variables by CCRD design are listed in Table

2. Minimum cooking yield (70.05%) was found to be on experiment no. 5, which was formulated with 0% konjac/gellan blend and 50% pork fat, whereas maximum cooking yield (81.35%) recorded for experiment no. 6 was at 1% konjac/gellan blend and 50% pork fat. In this study, added water was used to replace for reduced-pork fat portion in the formulation on the basis of weight-by-weight; therefore, the amount of water content was raised in low-fat burger formulations with decreasing of pork fat content. According to the results, one can infer that the high level of konjac flour and gellan gum was associated with improving cooking yield of low-fat burgers. This may be attributed to the effect of water-holding capacity of konjac flour and gellan gum to immobilize excess water by the interaction of water-protein-gels, which caused water difficult to remove (Claus and Hunt, 1991; Gregg *et al*., 1993). This was also confirmed by the work of Yang *et al.* (2001), Andrès *et al.* (2006) and Cengiz and Gokoglu (2008). The low cooking yield was observed in low-fat pork burgers with no added konjac/gellan blend, probably because of water release during cooking.

According to Table 3, the fitted model in equation 2 represents that the variables affecting cooking yield were positive linear term ($p<0.001$) of konjac/gellan blend, followed by negative linear and positive quadratic terms of pork fat, which were significant at $p<0.01$ and $p<0.05$, respectively. There was no interaction effect between konjac/gellan blend and pork fat content. The negative sign indicates that the ingredients had reciprocal effect on the responses. The model exhibited $R^2 = 0.9689$ which suggested that 96.89% of the variation could be explained by the fitted model. The surface plot in Fig. 1a presents that the cooking yield was improved with increasing konjac/gellan blend incorporated with decreasing of pork fat, indicating that both konjac and gellan can bind excess water to form gel (Thomas, 1997). In addition, the contour plot shown in Fig. 1b presents that konjac/gellan blend was the greatest effect on cooking yield. On the other hand, the effect of konjac/gellan blend and pork fat content on cooking yield of the products was significant at very low level of konjac/gellan blend used.

Effect on Reduction in Diameter:

Reduction in diameter, which affects the spread factor of the pork burger, was influenced by the variables from which the pork burgers were formulated. Minimum reduction in diameter (9.56%) occurred in experimental no. 4 formulated with 0.85% konjac/gellan blend and 85% pork fat (Table 2), while maximum reduction in diameter (16.62%) was recorded for experimental no. 1 with 0.15% konjac/gellan blend and 15% pork fat. The total coefficient of determination ($R^2 = 0.9865$) recorded for the model (Table 3) suggested that 98.65% of the total variability in reduction of burger diameter was attributed to konjac/gellan blend and pork fat. It was also observed that these two variables were significant parameters with linearly negative effects on reduction in diameter, which was significant at $p<0.001$ (eq. 3 and Table 3), followed by the positive quadratic term ($p<0.05$) of konjac/gellan blend. However, no interaction effect between konjac/gellan blend and pork fat content was observed for reduction in diameter in this study. The surface plot in Fig. 1c represents that the low-fat pork burger containing a higher amount of konjac/gellan blend and pork fat content had a lower reduction in diameter. It was probably due to water-holding capacity of konjac and gellan gums to bind excess water in the product. As shown in Fig. 1d, the contour plot displayed a significant effect on reduction in diameter. The response was mostly influenced by konjac/gellan blend. The reduction in diameter of the products decreased as the amount of konjac/gellan blend and pork fat content increased.

Effect on Redness:

The result of redness expressed as a*-value in Table 2 shows that the formulation with a minimum redness (2.52) recorded for experimental no. 5 which contained 0% konjac/gellan blend and 50% pork fat, while maximum redness (4.07) observed for experimental no. 3 was recorded at 0.85% konjac/gellan blend and 15% pork fat. The fitted model for redness in equation 4 revealed that the addition of konjac/gellan blend had positive linear and negative quadratic terms affecting redness of the burgers, which were significant at $p<0.001$ and $p<0.01$, respectively (Table 3), whereas pork fat showed a positive quadratic term ($p<0.01$) on redness of burgers. There was an interaction effect ($p<0.05$) between konjac/gellan blend and pork fat on the redness. The total coefficient of determination ($R^2 = 0.9928$) in Table 3 for equation 4 shows that there was a 99.28% chance of the total variability in redness was affected by konjac/gellan blend and pork fat. The response surface plot (Fig. 1e) presents that at high amount of konjac/gellan blend and low amount of fat content, low-fat products became redder, probably because of the light brown color of konjac flour itself and reduction of white pork fat. In Fig. 1f it can be observed that the redness was strongly influenced by konjac/gellan blend. In fact, the increase of konjac/gellan blend promoted the redness of low-fat burgers while decreasing of pork fat only suppressed the decreased level of redness where the low content of konjac/gellan blend was used.

Table 4: Analysis of variance for textural properties of low-fat pork burgers.

Source	df	F Hardness	F Springiness	F Chewiness	P Hardness	P Springiness	P Chewiness
Model	5	66.53	135.27	5.71	0.0001	<0.0001	0.0394
X_1	1	9.42	582.50	9.97	0.0278	<0.0001	0.0252
X_2	1	283.07	26.92	0.26	<0.0001	0.0035	0.6347
X_1^2	1	26.04	65.13	8.92	0.0038	0.0005	0.0306
X_2^2	1	22.80	9.00	0.80	0.0050	0.0301	0.4132
X_1 X_2	1	2.38	1.39	9.39	0.1838	0.2912	0.0280
Lack-of-fit	3	9.46	13.18	51.03	0.0971	0.0714	0.0193
R^2		0.9852	0.9927	0.8509			
Adj–R^2		0.9704	0.9853	0.7018			
Pred–R^2		0.8994	0.9495	-0.0508			
Adeq precision		22.781	32.679	7.173			
Coefficient variation (CV)		2.59	1.84	14.63			

df – degree of freedom; F – statistics test to determine significance ; P – probability value; X_1 = konjac/gellan blend and X_2 = pork fat content.

Table 5: Criteria and outputs for numerical optimization of low-fat pork burgers.

Criteria	Goal	Limit	Output
Konjac/gellan blend (%)	In the range	0–1	1.00
Pork fat content (%)	In the range	0–100	66.43
Cooking yield (%)	maximize	70.05–81.35	79.54
Reduction in diameter (%)	In the range	9.56–16.62	10.24
Redness (a*)	In the range	2.52–4.07	3.94
Hardness (N)	In the range	4.06–6.16	5.20
Springiness (mm)	maximize	6.43–10.02	9.92
Chewiness (N × mm, mJ)	maximize	14.77–38.94	38.94
Desirability			0.936

Texture Profile Analysis:

Effect on Hardness:

The result of hardness presented in Table 2 shows that experimental no. 7 formulated with 0.5% konjac/gellan blend and 0% pork fat, was observed for the lowest hardness (4.06), whereas experimental no. 8 which contained 0.5% konjac/gellan blend and 100% pork fat was the highest (6.16). The total coefficient of determination (R^2 = 0.9852) in Table 4 for equation 5 demonstrated that the model contributed about 98.52% of the total variability in hardness of low-fat burgers.

Based on Table 4 and equation 5, the statistical model shows that hardness was affected by the negative linear term of konjac/gellan blend and positive linear term of pork fat, which was significant at $p<0.05$ and $p<0.001$, respectively, followed by positive quadratic terms for both variables at $p<0.01$. There was no interaction effect between konjac/gellan blend and pork fat. The representation of response surface given in Fig. 2a reveals that a decrease in pork fat content decreased hardness of low-fat products, which was expected as pork fat replacement by added water. Whereas, hardness was slightly changed subjecting to increasing of konjac/gellan blend. The contour graph of hardness in Fig. 2b shows that the pork fat content was the greatest effect on hardness, resulting in a decrease in hardness with decreasing of pork fat content.

Effect on Springiness:

As shown in Table 2, the formulation that showed the minimum springiness (6.43), recorded for experimental no. 5, contained 0% konjac/gellan blend and 50% pork fat, while maximum springiness (10.02) was occurred in experimental no. 6 with 1% konjac/gellan blend and 50% pork fat. From equation 6 and Table 4, the regression model (R^2 = 0.9927) explained 99.27% of the total variability in springiness of low-fat burgers. The affecting variables on springiness were negative linear terms of konjac/gellan blend and pork fat, which were significant at $p<0.001$ and $p<0.01$, respectively, followed by positive quadratic terms of konjac/gellan blend ($p<0.01$) and pork fat ($p<0.05$). No interaction effect between konjac/gellan blend and pork fat was observed. It was evident that konjac/gellan blend significantly displayed the largest effect on springiness of the low-fat products in the response and contour plots (Fig. 2c and 2d). A higher springiness was observed in a higher amount of konjac/gellan blend than in a lower one, probably because of the relatively higher protein-polysaccharide (konjac and/or gellan) interaction (Takigami, 2000).

Effect on Chewiness:

The experimental no. 2 shown in Table 2 demonstrates the minimum chewiness (14.77) as the low-fat burger was formulated with 0.15% konjac/gellan blend and 85% pork fat, whereas the maximum chewiness

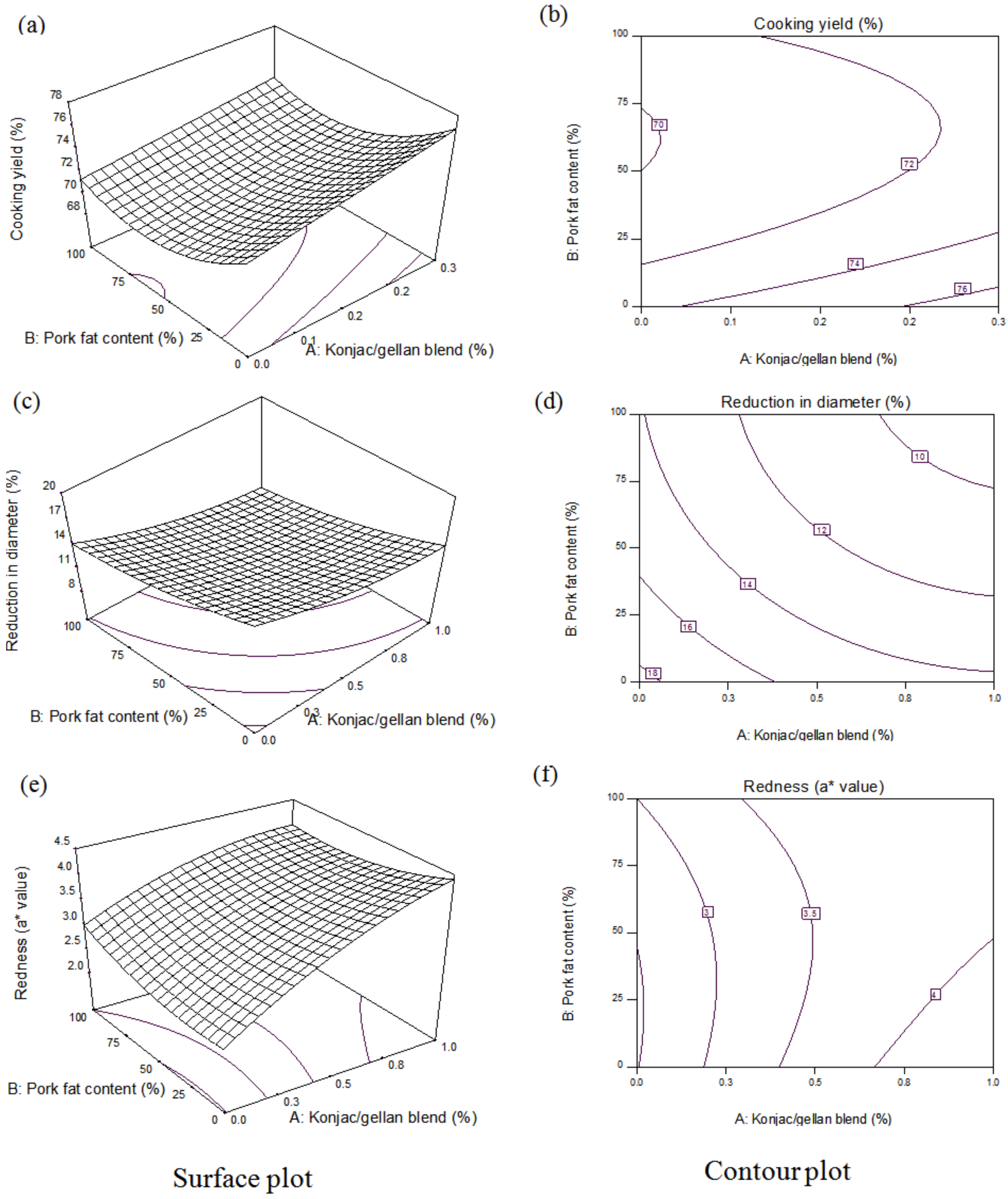

Fig 1: Surface and contour plots of physical properties of low-fat pork burgers: (a, b) cooking yield; (c, d) reduction in diameter and (e, f) redness (a*-value).

(38.94) was recorded for experimental no. 4 with 0.85% konjac/gellan blend and 85% pork fat. The total coefficient of determination (R^2 = 0.8509) (Table 4) on equation 7 explained 85.09% of the total variability in chewiness of low-fat burgers was attributed to konjac/gellan blend and pork fat. Also, the variables affecting chewiness were negative linear and positive quadratic terms of konjac/gellan blend, which were significant at $p<0.05$. There was an interaction effect ($p<0.05$) between konjac/gellan blend and pork fat which was significant at $p<0.01$ with a positive effect, indicating that the addition of konjac/gellan blend was dependent on pork fat content (fat substitution with water). When considering the surface plot of chewiness (Fig. 2e), it

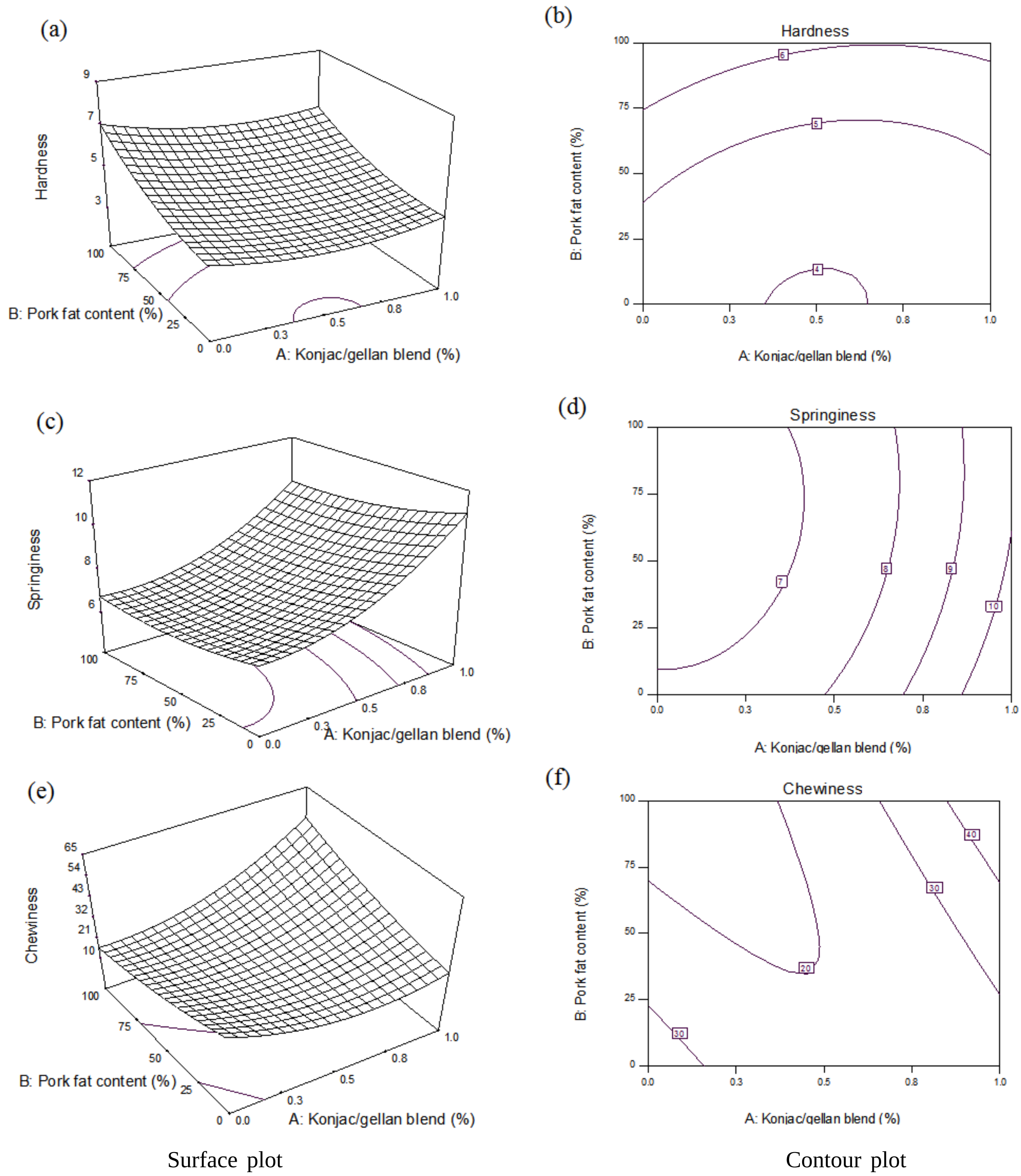

Fig. 2: Surface and contour plots of textural properties of low-fat pork burgers: (a, b) hardness; (c, d) springiness and (e, f) chewiness.

was observed that a combination of konjac/gellan blend and pork fat contributed to the improvement of chewiness of low-fat pork burgers. It was evident that the greatest effect on chewiness was konjac/gellan blend, as evidence in Fig. 2f. The contour plot also revealed that the konjac/gellan blend and fat content on chewiness was significant at a higher level of konjac/gellan blend used.

Optimization of the Experimental Conditions:

In order to arrive at the optimum condition for producing low-fat pork burgers made with of konjac/gellan blend and pork fat, Design-Expert[a] version 8.0.2.0 software was used while the desired goals for each variable and response were chosen as summarized in Table 5. Numerical optimization was carried out for this study.

Table 5 shows the software-generated optimum condition for independent variables with predicted values of responses, which were 1% konjac/gellan blend and 66.43% pork fat for achieving the highest values of cooking yield = 79.54%, reduction in diameter = 10.24%, redness, a^* = 3.94, hardness = 5.20 N, springiness = 9.92 mm and chewiness = 38.94 mJ, respectively.

Validation of the Model:

The suitability of the model equation for predicting the optimum response values were carried out by using the recommended optimum conditions. The results from the optimized operating condition (konjac/gellan blend = 1% and pork fat content = 66.43%) showed that the low-fat pork burger (n = 3) contained 80.85% of cooking yield, 10.25% of reduction in diameter, redness (a^* = 4.02), 4.88 N of hardness, 9.24 mm of springiness and 34.20 mJ of chewiness, which were close to the predicted values, indicating that the model is quite accurate in prediction.

Conclusion:

The statistical analysis by using CCRD showed how test variables, konjac/gellan blend and pork fat content, affected physical and textural properties of low-fat pork burgers. Results of modeling by RSM showed significant linear and quadratic terms of these two variables and the most important affecting variable was konjac/gellan blend. The optimal predicted physical and textural properties of low-fat pork burgers produced under the optimum condition of konjac/gellan blend and pork fat at 1 and 66.43%, respectively were found to be in agreement with the experimental production.

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