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OPTIMIZATION OF LIGHT PORK BURGERS FORMULATED WITH CANOLA OIL AND LINSEED/SUNFLOWER SEED/ALMOND (LSA) MIX

A. Akesowan

Department of Food Science and Technology, School of Science and Technology,

University of the Thai Chamber of Commerce, Bangkok 10400, Thailand.
Corresponding Author E-mail: adisak_ake@utcc.ac.th

ABSTRACT

The aim of this study was to make a healthier light pork burger containing konjac flour. Two independent variables included (1) the pork fat replacement with canola oil (20-80%, w/w) and (2) added linseed/sunflower seed/almond (LSA) mix (4-10% by pork meat weight) were determined for their effects on the physical properties (cooking yield, peak force, reduction in diameter, emulsion stability and color (L^* and a^*), as well as sensory quality (color, texture, flavor, taste and overall acceptability) of light pork burgers using response surface methodology (RSM). The optimal process conditions were also investigated. The results showed that the RSM was able to describe how canola oil and the LSA mix affected the physical and sensory properties of light pork burgers made with konjac flour. The development of physical properties such as cooking yield, peak force, reduction in diameter and emulsion stability were pronounced with increasing the amount of canola oil and the LSA mix. However, the product became darker and possessed a strong nutty flavor as a result of the LSA mix, consequently affecting the panelists' preference. The optimal conditions were to substitute 21.32% of the pork fat with canola oil incorporated with 4% LSA mix.

Key words: Low-fat meat products, fat replacement, nutritional fortification, konjac flour, response surface methodology.

INTRODUCTION

In the modern day, food products which are low in fat and sugar content but high in dietary fiber are being increasingly consumed, although most of these products are expensive. This is because of consumer awareness regarding preventing or avoiding the risks of fat and sugar-related diseases including cardiovascular disease, diabetes, obesity, hypertension and some cancers (Ozvural and Vural, 2008). Low-fat meat products have been investigated for reductions in some unhealthy ingredients such as animal fat, salt and phosphate (Mahmoud and Badr, 2011). Hydrocolloids such as carrageenan, konjac and xanthan gum have contributed as fat replacers because of their very low caloric content, inexpensive cost and versatile applications as they can be added directly or prepared as fat analogues. Konjac flour, a neutral polysaccharide from the yam tuber (*Amorphophallus konjac*), has been extensively used as a thickening and gelling agent in various food products (Thomas, 1997). Konjac gel, either prepared by deacetylation in mild alkali (calcium hydroxide) or by combining with secondary gums (κ-carrageenan, xanthan or gellan), has been used as a fat replacer in low-fat fresh pork sausages (Osburn and Keeton, 1994), low-fat bologna (Chin *et al.*, 1998), light pork burgers (Akesowan, 2010) and low-fat, low-salt frankfurters (Jiménez-Colmenero *et al.*, 2010). Apart from the above-mentioned properties, konjac is also famous for its potential health benefits including cholesterol reduction, relieving constipation and satiation (Takigami, 2000; Delgado-Pando *et al*., 2011). In recent work, a light pork burger was accomplished through 34% pork fat replacement by added water incorporated with a 1% konjac/gellan blend. The product was acceptable; however, its sensory texture was softer than the regular burger (Akesowan, 2011). Since fats in meat products are responsible for many functions such as emulsion stabilization, water holding capacity, structural properties and product palatability, fat reduction can affect meat product characteristics (i.e. toughness) and consumer acceptability (Mendoza *et al*., 2001). As a consequence, alterations to the type of fat and fatty acid composition is an approach that maintains the amount of fat needed for these functions in the light burger, but also provides more health benefits as these supplements contain no cholesterol and fewer saturated fatty acids (Singh *et al*., 2011). The pale golden oil, "canola oil", extracted from canola seeds has a light, neutral taste with high heat resistance (El-Gammal, 2010). It has been increasingly selected for various studies concerning fat replacement because it is beneficial for heart and brain function. This oil is low in saturated fat and high in monounsaturated fat and also contains the beneficial omega-3 and omega-6 fatty acids. However, there is a limitation for the usage of omega-3-rich sources such as olive oil, canola oil and linseed oil in processed meat products that contain a low or reduced fat composition (Singh *et al*., 2011).

The increasing trend for adding dietary fiber or fiber-rich ingredients in food products is associated with their positive effects such as preventing constipation and decreasing blood cholesterol and glucose levels (Daou and Zhang, 2011). Legumes, cereals and nuts are rich in dietary fibers, vitamins and minerals. The recommended consumption of dietary fiber ranges from 30 to 45 g/day to reduce the risk of cardiovascular diseases, diverticulosis, diabetes mellitus and colon cancer (Raghavendra *et al*., 2006; Kohajdová *et al*., 2011). Apart from its health benefits, in view of its functional properties, dietary fiber is incorporated into food products for many purposes such as a non-caloric bulking agent, enhancement of water and oil retention, emulsion stability improvement and water holding capacity (Elleuch *et al*., 2011). LSA mix, a mixture of ground linseeds, sunflower seeds and almonds (3:2:1), can be made at home or purchased in a supermarket. It contains extra dietary fiber, protein, omega-3 fatty acids and various vitamins and minerals like vitamin B1, B2, biotin, zinc, calcium and phosphorous (Cho, 2009). Because of its sweet and nutty tasting meal without gluten content, LSA mix can be sprinkled on breakfast cereals, desserts and salad or used as a dietary supplement in biscuits and other baked goods. So far, the information on LSA mix application in low- or reduced-fat meat products is scarce.

Animal fat replacement by vegetable oil incorporated with added dietary fiber in low-fat pork burger is feasible and can be accomplished by response surface methodology (RSM). A central composite rotatable design (CCRD) has been successfully used to describe the effects of independent variables and/or their interactions on responses as well as to optimize the process conditions (Anderson and Whitcomb, 2005; Liu *et al*., 2008). Therefore, this work aimed to investigate the effect of pork fat replacement by canola oil and added LSA mix on the physical and sensory properties of light pork burger using RSM. Also, the optimal conditions for the light pork burger with these two variables were determined.

MATERIALS AND METHODS

Materials: Konjac flour (Chengdu Qiteng Trading Co., Ltd), gellan gum (KELCOGEL®, CP Kelco UK Ltd., UK), LSA mix (ground linseeds, sunflower seeds and almonds in a ratio of 3:2:1, Nature First brand, Victoria, Australia) and canola oil (Pure Wessen brand, ConAgra Foods, Nebraska, USA) were used. Ingredients for burger processing included fresh pork meat and fat, evaporated milk, sugar, pepper, white onion, wheat flour and salt.

Experimental design: In this work, two independent variables, i.e. pork fat replacement by canola oil and LSA mix addition, were analyzed using CCRD. This design included five level combinations coded -1.41, -1, 0, 1, 1.41 and actual values, as presented in Table 1. Thirteen sets of randomized experiments were required for evaluating the response. The predictive model is described by the following equation:

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

Where Y is the observed response; X_1 and X_2 represent the coded pork fat replacement by canola oil and LSA mix addition, respectively, and b_1 and b_2 are linear, b_{11} and b_{12} are quadratic, and b_{12} is the interaction coefficient, respectively.

Processing of light pork burgers: Ground pork meat was prepared using 1.7 and 0.4 cm diameter grinder plates, respectively. The batch of light pork burgers (% by total weight) contained 62.22% pork meat, 16.70% pork fat, 8.44% added water, 6.30% whole egg, 2.07% evaporated milk, 1.25% sugar, 1% salt, 0.63% konjac/gellan (4:1) blend, 0.63% wheat flour, 0.38% pepper and 0.38% chopped white onion. Initially, a konjac/gellan blend in water (1:4) previously prepared for 30 min was thoroughly mixed with the ground pork meat, followed by the other ingredients using a food mixer for 5 min. Each 80 g uniform burger (9 cm diameter × 1 cm thickness) was formed using a plastic casing and kept in a freezer at -18°C for 1 h. The burgers were cooked on an electric pan (150°C) with a little palm oil for 6 min on one side, turned over, and further cooked for 5 min (internal temperature about 80±2°C).

Physical Analysis

Cooking yield: The uncooked burgers were weighed, cooked, cooled to room temperature (30±2°C) and weighed again as cooked burgers. Cooking yield was expressed the percentage of the cooked weight in relation to the uncooked weight (Das *et al*., 2008).

Peak force: The force needed to cut a cooked sample (4 cm diameter x 1 cm thickness) was determined using a Lloyd texture analyzer (Model LRX, Lloyd Instruments, Hampshire, UK). A shearing test cell with a crosshead speed of 250 mm s^{-1} was used. All analyses were performed in five replications and the peak force (N) was recorded.

Reduction in diameter: The diameter of the uncooked and cooked pork burgers was measured using a vernier caliper. The reduction in diameter was calculated as the percentage of diameter change between the uncooked and cooked samples divided by the uncooked diameter (Mansour and Khalil, 1999).

Emulsion stability: Ten grams of the raw batter were wrapped in filter paper and placed in a centrifuge tube. The sample was heated at 75±2°C in a water bath for 30 min, and then centrifuged at 1000×g for 10 min. The weight of the pelleted sample was recorded. The emulsion stability (%) was calculated as follows: [(weight of raw batter - weight of pelleted sample)/weight of raw batter], and then multiplied by 100%.

Color: The inner color of the cooked samples was measured using a Hunter Lab colorimeter (Model ColorFlex, Hunter Associates Laboratory, Reston, VA). Lightness (L^*) (0 = black, 100 = white), red/green (a^*) (+ = red, − = green) and yellow/blue (b^*) (+ = yellow, − = blue) were recorded. Five replications were made per treatment.

Sensory Evaluation: Twenty-four panelists who are familiar with burgers were drawn from the Department of Food Science and Technology, University of the Thai Chamber of Commerce. A 9-point hedonic scale test (1 = extremely dislike, 9 = extremely like) was used for sensory evaluation in terms of color, texture, flavor, taste and overall acceptability. Panelists were invited to sit in a partitioned sensory booth, clean and rinse the palate between samples by unsalted cracker, grape juice, and distilled water (Lawless and Heymann, 1998).

Statistical Analysis: All analyses were carried out in triplicate unless otherwise indicated. The analysis of variance (ANOVA) and multiple regression were analyzed using the Design-Expert® Trial version 8.0.2 software (State-Ease Inc., Minneapolis, MN) (Anderson and Whitcomb, 2005).

RESULTS AND DISCUSSION

Physical Analysis

Statistical analysis of model fitting: The effects of canola oil and LSA mix on the physical properties of light pork burgers are shown in Table 2. Light burgers with canola oil and LSA mix exhibited coefficients of determination (R^2) of cooking yield, peak force, reduction in diameter, emulsion stability, lightness and redness of 0.8780, 0.9361, 0.9507, 0.9315, 0.9054 and 0.9187, respectively. These values, which are greater than 0.8, indicated that the models can explain the process conditions well (Sin *et al*., 2006), with exception of yellowness (R^2 = 0.5946) which is not mentioned hereafter. Among the listed R^2 values, the model showed the strongest relationship between the experimental results and predicted values was the reduction in diameter. At the same time, the adjusted R^2 values of all models were high (over 0.8) to advocate their adequacy. The lack of fit was not significant ($p<0.05$) in all fitted models and the p-values were significant ($p<0.05$), suggesting that these predictive models were suitable and reliable. In addition, the statistical analysis (Table 2) revealed that the adequate precision of all models (12.834-19.120) was greater than 4.0, thus suggesting the suitability of the responses to navigate the design. The model for cooking yield was the most precise and reliable because of its lowest coefficient variation (CV).

Effect on physical properties: Table 2 shows the effects of canola oil and LSA mix on the physical properties of the light pork burgers. The results indicate that both independent variables significantly affected cooking yield, peak force, reduction in diameter, emulsion stability and lightness, whilst the variation in redness (a^*) was influenced by the LSA mix alone. There was no interaction effect of canola oil and the LSA mix on these responses. The fitted models with significant terms were described by the following equations. In order to aid visualization, all models are illustrated as response surface graphs in Fig. 1a-f.

$$\text{Cooking yield} = 77.94+0.04\,X_1^{**}+0.81\,X_2^{***} \quad (2)$$

$$\text{Peak force} = 30.91-0.21X_1^{**}+0.32X_2^{*}+1.67\text{E-}003X_1^{2***} \quad (3)$$

$$\text{Reduction in diameter} = 22.90-0.37X_1^{**}-0.79X_2^{**}+2.96\text{E-}003X_1^{2***} \quad (4)$$

$$\text{Emulsion stability} = 4.62-0.02X_1^{*}-0.09\,X_2^{***}+2.97\text{E-}004X_1^{2***} \quad (5)$$

$$\text{Lightness} = 67.78+0.04\,X_1^{**}-1.04\,X_2^{***} \quad (6)$$

$$\text{Redness} = -1.31+0.94\,X_2^{***}-0.04\,X_2^{2*} \quad (7)$$

where:
X_1 = canola oil (%) and X_2 = LSA mix (%).
*Significant at the 0.05 level, **Significant at the 0.01 level, ***Significant at the 0.001 level.

Equation 2 and Fig. 1a represent the linearly positive effect of canola oil ($p<0.01$) and LSA mix ($p<0.001$) on cooking yield. The increase in cooking yield was greatly influenced by the LSA mix. This result is consistent with the work of Park *et al.* (2005) who showed that replacing the animal fat content by vegetable oils resulted in an increasing cooking yield of low-fat hamburger patties. Mahmoud and Badr (2011) showed that the addition of wheat bran increased the cooking yield of beef burgers, which was attributed to the wheat bran property of moisture retention and fat entrapment in a meat system. Sariçoban *et al.* (2009) showed that wheat bran addition increased the moisture and fat content of patties, consequently increasing the cooking yield. In a study by Cofrades *et al.* (1997) focusing on bologna sausage with added wheat bran, insoluble dietary fiber in wheat bran had the ability to bind water and fat in the meat matrix, causing an increased cooking yield of the product. Similar results were found with bologna sausages containing raw and cooked lemon albedo (Fernández-Ginés *et al*., 2004), low-fat beef burgers with added hazelnut pellicle (Turhan *et al*., 2005) and low-fat *Tteokgalbi* with rice bran fiber (Choi *et al*., 2008). The highest cooking yield was obtained when >50% canola oil and >8.6% LSA mix were used.

The major negative linear ($p<0.01$) effect of canola oil (equation 3) caused a rapid decrease in peak force with increasing canola oil up to 60% canola oil (Fig. 1b). As canola oil increased from 60 to 80%, a slightly curvilinear increase in peak force was observed because of the positive quadratic effect ($p<0.001$). This finding suggests that greater fat replacement by canola oil resulted in a softer burger texture. This may affect consumer perception; for example, the firmness score of low-fat frankfurters containing 1.5% salt (softer texture) was lower than that containing 2.5% salt (firmer texture) (Sariçoban *et al.*, 2009). However, the LSA mix displayed a linearly positive effect ($p<0.05$), in which the peak force increased with increasing LSA mix. This implied that LSA mix could be used to develop the textural characteristics of the burger. At a low level of canola oil (<25%), the addition of LSA mix (>6.0%) may be beneficial to obtain the highest peak force of the light burger.

The diameter reduction in pork burgers after cooking is considered to be a parameter of meat product quality, especially regarding textural characteristics. Based on equation 4 and Fig. 1c, canola oil was the greatest variable affecting the reduction in diameter in different directions, depending on how much was used. Initially, a reduction in the diameter of light burgers decreased linearly ($p<0.01$) with increasing canola oil until its minimum value (~60% canola oil). Afterwards, it increased with up to 80% canola oil usage as a result of the positive quadratic effect ($p<0.001$). This variation may be due to the interaction between pork fat, canola oil and protein, causing changes to the gel structure (Singh *et al*., 2011). At any fat replacement level, increasing the LSA mix linearly decreased ($p<0.01$) the shrinkage of the cooked burger. This may have been due to the influence of the LSA mix with its high water holding capacity; like other dietary fibers, LSA can hold or trap water in a mixture or meat matrix which allows the burger to maintain its spread or size after cooking. The lowest reduction in diameter was achieved when the canola oil ranged between 40-75% and at least 7.2% LSA mix was used.

From equation 5 and Fig. 1d, it can be inferred that, at a low level of LSA mix, the curvilinear increase ($p<0.001$) of released water was paralleled with increasing canola oil, whilst increasing the LSA mix decreased ($p<0.001$) the amount of released water. The reduction in released water reflects the ability of the meat mixture to emulsify and entrap fat droplets in the meat system, showing desirable product quality. This agrees with the work of Martín *et al*. (2008) who showed that the lower melting point of the increased unsaturated fatty acid content in a meat mixture may reduce the emulsion stability in relation to a mixture containing saturated fatty acids. The addition of the LSA mix increased the viscosity of the mixture, because of the ability of fiber to hold and bind water in the meat matrix. Several studies have demonstrated the role of dietary fiber and fiber-enrich ingredients in improving the emulsion stability of meat products (Akesowan, 2010; Kim *et al*., 2010; Yang *et al*., 2010). Higher amounts of the LSA mix (>8.7%) and canola oil (approximately 25-78%) provided the product with the lowest amount of released water.

The results of lightness (L*) observed in the light burgers with canola oil and LSA mix are presented in equation 6 and Fig. 1e. Product lightness linearly increased ($p<0.01$) with increasing canola oil, whilst the LSA mix had a greater negative linear effect ($p<0.001$) in terms of decreasing lightness with increased levels. When considering the redness (a*) results shown in equation 7 and Fig. 1f, only the LSA mix had positive linear ($p<0.001$) and negative quadratic ($p<0.05$) effects, showing a greater red color as the level of the LSA mix increased. This result indicates that the color of the LSA mix itself made the burger darker. Ngadi *et al*. (2007) demonstrated the relationship between redness and the degree of hydrogenation of vegetable oil. Increasing of the degree of hydrogenation (during cooking) improved the redness of chicken nuggets.

Sensory evaluation

Statistical analysis on model fitting: Sensory data were analyzed for regression and ANOVA and the results (Table 3) demonstrated that all models such as color, texture, flavor, taste and overall acceptability were highly reliable with R^2 values greater than 0.87 (Sin *et al*., 2006). They were also significant at $p<0.001$ and showed no significant lack-of-fit ($p>0.05$). In addition, other parameters including high adjusted R^2 and adequate precision greater than 4.0 were supportive of their reliability. Among the CV of sensory attributes, the flavor response (lowest CV) was the most precise and reliable in the experiment. Therefore, these models adequately represented the real relationship between the chosen parameters.

Effect on sensory attributes: Both independent variables, canola oil and LSA mix, had effects on all sensory attributes such as color, texture, flavor, taste and overall acceptability; however, only three attributes (texture, flavor and taste) were affected by their interactions, as shown in Table 3. The fitted sensory models were described by the following equations with significant terms, and they are illustrated as response surface graphs in Fig. 2a-e.

$$\text{Color} = 9.21 - 7.75\text{E-}003\ X_1^{*} - 0.55\ X_2^{***} + 0.03\ X_2^{2**} \quad (8)$$

$$\text{Texture} = 6.35 + 7.28\text{E-}004 X_1^{**} + 0.13 X_2^{***} - 9.42\text{E-}003\ X_2^{2*} - 1.39\text{E-}003\ X_1 X_2^{**} \quad (9)$$

$$\text{Flavor} = 8.70 - 0.02 X_1^{**} - 0.38 X_2^{***} + 1.12\text{E-}004\ X_1^{2**} + 0.02\ X_2^{2***} + 6.94\text{E-}004\ X_1 X_2^{*} \quad (10)$$

Taste = $7.73 - 0.02X_1^{***} - 0.16X_2^{***} + 1.97E\text{-}003X_1X_2^{**}$ (11)

Overall acceptability = $7.73 - 5.83E\text{-}003\ X_1^{**} - 0.12\ X_2^{***}$ (12)

where:

X_1 = canola oil (%) and X_2 = LSA mix (%).

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

Based on equations 8-12 and Fig. 2a-e, the results showed significant effects of canola oil and LSA mix on all the sensory attributes of light pork burgers. Most linear decreasing scores of color, flavor, taste and overall acceptability were evident with increasing these two variables, while a negative quadratic effect of the LSA mix was observed for texture. This indicated that the burger had a darker color, coarser texture, a strong nutty flavor and easily lost its structure after chewing when high levels of canola oil and LSA mix were applied. In comparison, the variation in LSA mix had a greater influence on sensorial quality. This may be due to the stronger effect of the dark color and nutty flavor of the LSA mix itself in relation to canola oil. The results of the interaction effect of canola oil and LSA mix showed a negative effect ($p<0.01$) on product texture, while positive effects were found on flavor ($p<0.05$) and taste ($p<0.01$). However, these effects were in contrast with their related linear effects, showing that the effects of these variables on sensory attributes were rather complex. Similar results were found in the study by Sariçoban *et al.* (2009), who suggested that the inverse effect between linear and interaction terms of the variables may be come from the reciprocal influence of other components in a mixed food system. Overall, an increase in canola oil and the LSA mix showed an interaction effect leading to lower texture, flavor and taste scores. As seen in Fig. 2a-e, the amount of canola oil and LSA mix needed to obtain high sensory scores included: color (canola oil <40% and LSA mix <4.4%), texture (canola oil 20-80% and LSA mix <8.3%), flavor (canola oil <40% and LSA mix <5%), taste (canola oil <28% and LSA mix <4.8%) and overall acceptability (canola oil <44% and LSA mix <5%).

Optimization and validation: The results showed a positive effect of increasing the physical properties of light burgers. However, the optimal level of canola oil and LSA mix is crucial since, at higher levels, undesirable effects causing lower scores on all sensory attributes were observed. In this study, the objective was also to find the optimum physical properties based on the most preferred sensory characteristics of the light burger. Consequently, main physical parameters such as cooking yield and emulsion stability and all sensory attributes were chosen for the numerical optimization. Each parameter goal is presented in Table 4. The optimal conditions were found to use 21.32% canola oil and 4% LSA mix, which led to a burger with high quality. The predictive values of cooking yield, emulsion stability (released water), color, texture, flavor, taste and overall acceptability were 82.02%, 4.50%, and scores of 7.00, 6.64, 7.15, 6.90 and 7.12, respectively.

The suitability of the recommended optimal conditions was validated by the experimental processing. The experimental values (n = 3) of cooking yield, emulsion stability, color, texture, flavor, taste and overall acceptability of the light burgers were found to be 83.35%, 4.64%, and scores of 6.95, 6.72, 7.25, 6.68 and 7.24, respectively. The relative error tested for each response was 1.60, 3.02, 0.72, 1.19, 1.38, 3.29 and 1.66, respectively, showing that the predicted models were accurate**.**

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

Independent variables	Unit	Symbol	Coded levels				
			-1.41	**-1**	**0**	**1**	**1.41**
Canola oil[1)]	%	X_1	7.7	20	50	80	92.3
LSA mix[2)]	%	X_2	2.8	4	7	10	11.2

[1)] Based on pork fat weight, which replaced equivalent amount of reduced pork fat portion with canola oil.
[2)] Based on pork meat weight, as an additional ingredient.

Table 2. Regression coefficients of physical properties of light pork burgers with canola oil and LSA mix

Factor	Cooking yield (%)	Peak force (N)	Reduction in diameter (%)	Emulsion stability (%)	Lightness (L^*)	Redness (a^*)	Yellowness (b^*)
Intercept	77.94	30.91	22.90	4.62	67.78	-1.31	25.095
Canola oil (X_1)	0.04**	-0.21**	-0.37**	-0.02*	0.04**	-0.01	-0.29
LSA mix (X_2)	0.81***	0.32*	-0.79**	-0.09***	-1.04***	0.94***	-1.43
X_1X_2		-2.50E-004	4.89E-003	-1.33E-003		0.00	0.03*
X_1^2		1.67E-003***	2.96E-003***	2.97E-004***		1.11E-004	
X_2^2		-6.10E-003	4.39E-003	-8.88E-003		-0.04*	
R^2	0.8780	0.9361	0.9507	0.9315	0.9054	0.9187	0.5946
Adj- R^2	0.8535	0.8904	0.9155	0.8826	0.8865	0.8606	0.4594
Adeq precision	16.712	015.305	17.351	15.516	19.120	12.834	7.735
Coefficient of variation	1.05	2.04	8.00	2.92	1.54	12.99	17.12
Probability (p-value)	<0.0001	0.0005	0.0002	0.0006	<0.0001	0.0011	0.0364
Lack-of-fit	0.1812	0.3757	0.1179	0.5574	0.3149	0.0821	0.0009

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

Table 3. Regression coefficients of sensory attributes of light pork burgers with canola oil and LSA mix

Factor	Color	Texture	Flavor	Taste	Overall acceptability
Intercept	9.21	6.35	8.70	7.73	7.73
Canola oil (X_1)	-7.75E-003*	7.28E-004**	-0.02**	-0.02***	-5.83E-003**
LSA mix (X_2)	-0.55***	0.13***	-0.38***	-0.16***	-0.12***
X_1X_2	1.39E-004	-1.39E-003**	6.94E-004*	1.97E-003**	
X_1^2	2.54E-005	5.03E-005	1.12E-004**		
X_2^2	0.03**	-9.42E-003*	0.02***		
R^2	0.9572	0.9474	0.9870	0.9010	0.8709
Adj- R^2	0.9266	0.9098	0.9777	0.8680	0.8451
Adeq precision	17.802	16.025	30.207	16.265	16.121
Coefficient of variation	1.89	1.07	0.76	1.32	2.12
Probability (p-value)	0.0001	0.0002	<0.0001	<0.0001	<0.0001
Lack-of-fit	0.1739	0.2355	0.2041	0.1250	0.1161

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

Table 4. **Criteria and output for numerical optimization of the light pork burger with canola oil and LSA mix**

Criteria	Goal	Limit	Output
Canola oil (%)	In the range	20-80	21.32
LSA mix (%)	In the range	4-10	4
Cooking yield (%)	In the range	82.02-90.42	82.02
Emulsion stability (%)	Maximize	3.69-5.08	4.5
Color	Maximize	6.10-7.46	7.30
Texture	Maximize	5.93-6.80	6.64
Flavor	Maximize	6.19-7.23	7.15
Taste	Maximize	6.08-6.98	6.90
Overall acceptability	Maximize	6.10-7.40	7.12
Desirability			0.796

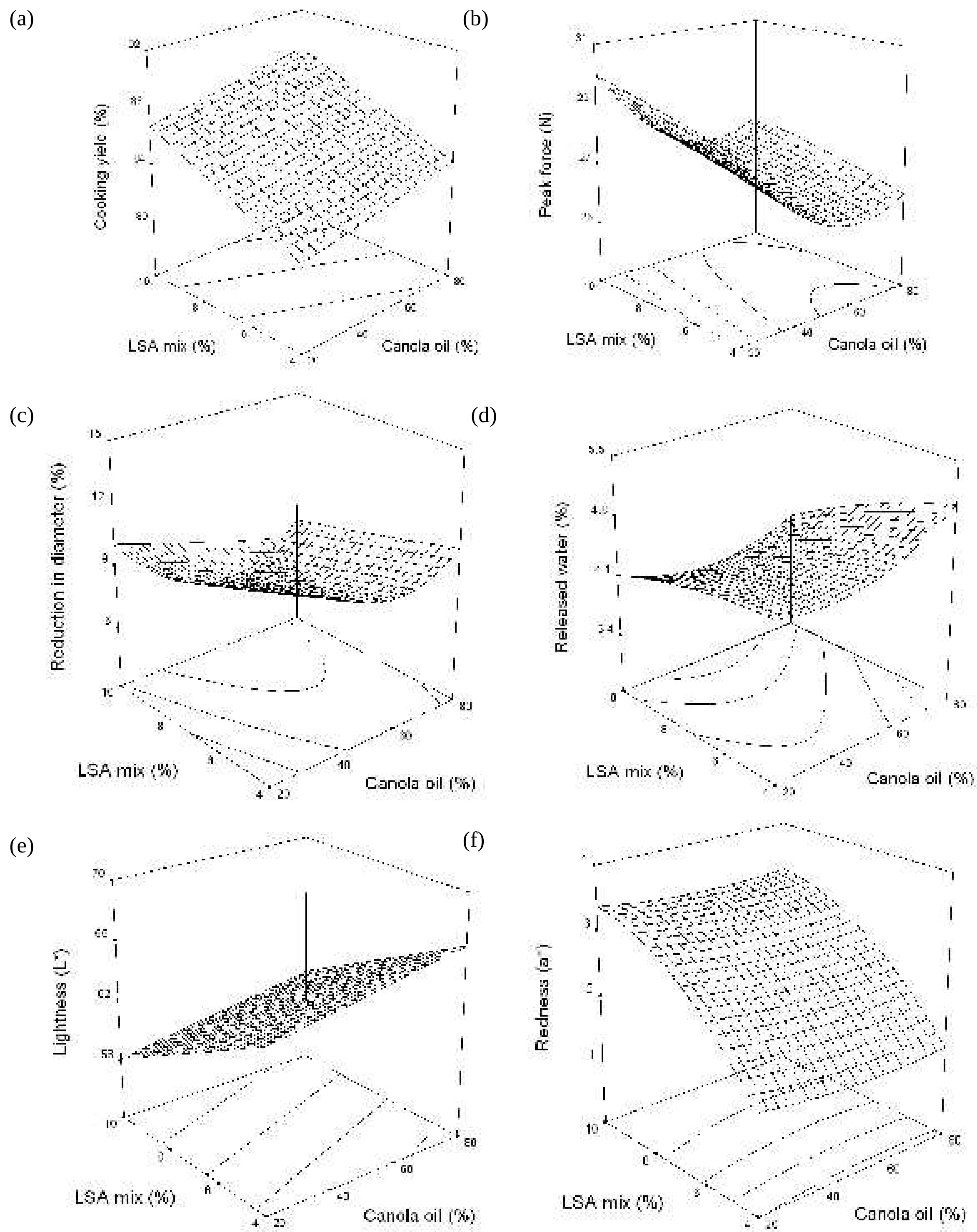

Fig. 1. Response surface plots for physical properties of light pork burgers with canola oil and LSA mix: (a) cooking yield, (b) peak force, (c) reduction in diameter, (d) emulsion stability, (e) lightness and (f) redness

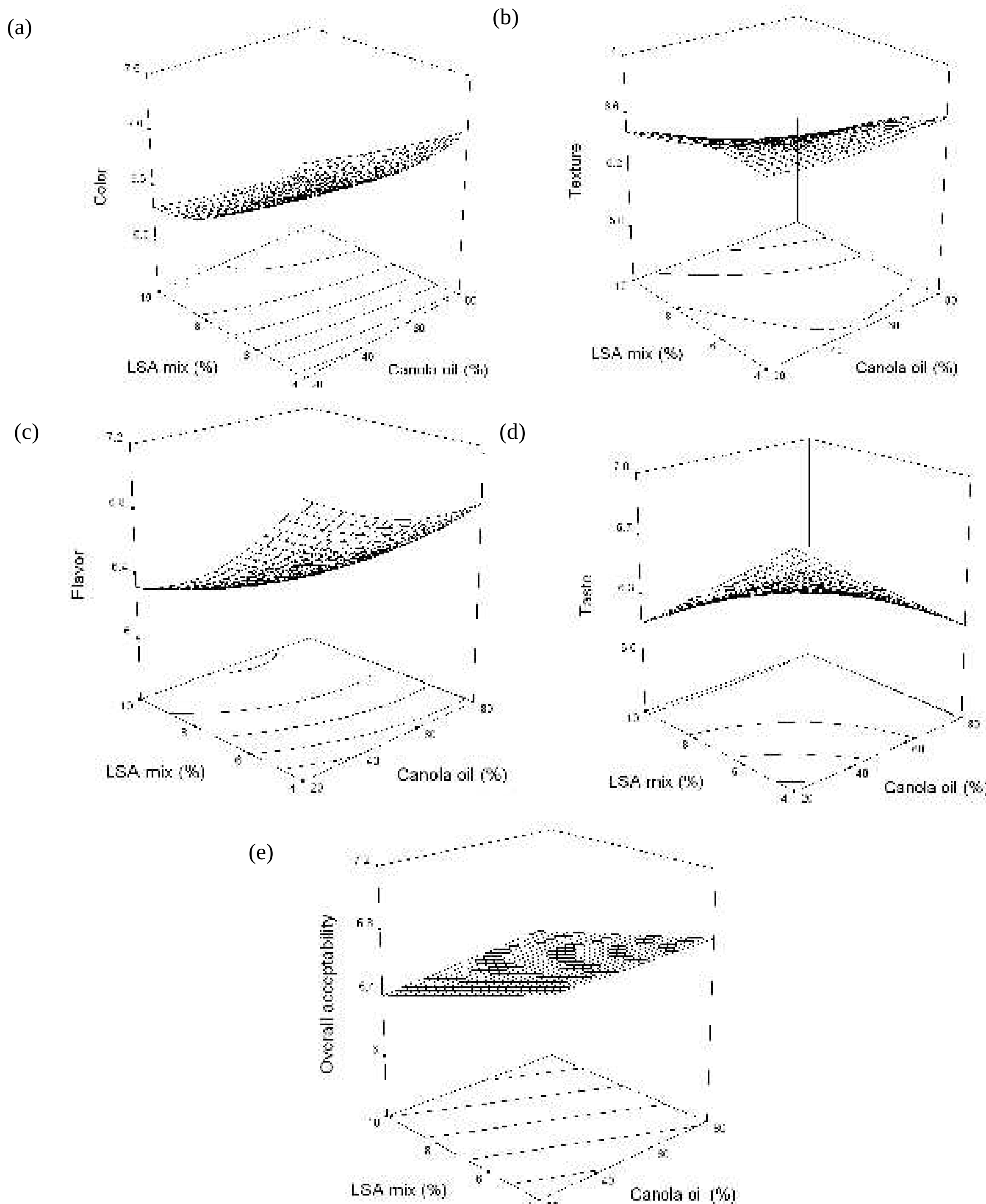

Fig. 2. Response surface plots for sensory attributes of light pork burgers with canola oil and LSA mix: (a) color, (b) texture, (c) flavor, (d) taste and (e) overall acceptability

Conclusion: The RSM was able to describe how canola oil and the LSA mix affected the physical and sensory properties of light pork burgers made with konjac flour. The development of physical properties such as cooking yield, peak force, reduction in diameter and emulsion stability were pronounced with increasing the amount of canola oil and the LSA mix. However, the product became darker and possessed a strong nutty flavor as a result of the LSA mix, consequently affecting the panelists' preference. The optimal conditions were to substitute 21.32% of the pork fat with canola oil incorporated with 4% LSA mix.

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