Use of Response Surface Methodology to Optimize the Quality of Reduced-Fat Biscuits Containing Banana Puree as a Fat Replacer

Abd-El-Khalek, M.H.
Food Technology Research Institute, Agricultural Research Center, Giza, Cairo, Egypt.

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ABSTRACT

Response surface methodology was applied to optimize the quality of reduced-fat biscuits in which banana puree (BP) was used as a fat replacer and sodium stearoyl lactylate (SSL) as an emulsifier. The results showed that the replacement of fat with BP resulted in biscuits with lower values for width and spread ratio, but higher in thickness, volume and specific volume. Sensory analysis declared that the replacement of fat led to production of biscuits with lower scores for appearance, texture, taste, odour and overall acceptability. The incorporation of SSL had an improving effect on most sensory characteristics of the biscuits. When the optimization process was implemented, it was found that biscuits with fat replaced by 64.5% BP and 0.5 g of SSL exhibited comparable physical properties to the control biscuits. Optimized biscuits exhibited lower organoleptic scores, but were still highly scored by the panelists.

Keywords: Biscuits, fat replacement, response surface methodology, banana puree, sodium stearoyl lactylate, optimization.

INTRODUCTION

Fat is a key nutrient for the human body and is one of the principal ingredients in our daily diet (Vaclavic & Christian, 2008). Although the nutritional benefits of fats are well known, the excessive consumption of fats, especially saturated types, was found to be associated with some health problems like obesity, cardiovascular and coronary heart diseases (FAO, 2008). Fats impart many functional and sensory properties in food products. Fat interact with other ingredients to develop texture, mouthfeel, structure, and lubricity of foods. It also acts as a flavour carrier and enhances the perception of taste (Conforti & Archilla, 2001). In the baking industry, fats are very important because they comprise from 10 to 50% of most baked products. Shortenings impart shortness, or richness and tenderness to improve flavour and eating characteristics and they enhance aeration for leavening (O'Brien, 2004)

Fat replacers provide one alternative to reduce fat content in the baked goods (Swanson & Munsayac, 1999). Different types of fat replacers have been used in the baking industry, and most of them can be categorized under three main groups, carohydrate-, lipid-, or protien-based fat replacers (Jonnalagadda & Jones, 2005).

Fruit purees have been known to replace fats in some foods. Studies showed that fruit purees can work as a good partial or total replacer of fats in the production of several bakery items such as the use of prune, apricot and apple purees in the production of chocolate cake and spice cookie recipe (Landis & Altman, 1996), semi-moist fruit puree in the formulation of gingersnap cookies (Mitzel *et al.*, 1996), applesauce and prune puree in producing butter, chocolate-chips and oatmeal cookies (Swanson & Munsayac, 1999), Pawpaw fruit puree for use in both muffins (Duffrin *et al.*, 2001) and in plain shortened cake (Wiese & Duffrin, 2003), and the use of prune puree to replace fat in chocolate cupcakes (Ackroyd *et al.*, 2010).

Emulsifiers have a big improving role in the baking process and have been applied to the baking industry for a long period of time (Miyamoto *et al.,* 2005). Sanchez *et al.* (1995) reported some improvements in the quality of reduced-fat shortbread cookies associated with the use of emulsifiers.

The present study was carried out to apply the response surface methodology to investigate the physical and sensory quality characteristics of reduced-fat biscuits prepared by using banana puree (BP) as a fat replacer and sodium stearoyl lactylate (SSL) as an emulsifier. An optimized biscuit formulation was developed to contain both BP and SSL and was compared with the control biscuits.

MATERIALS AND METHODS

Materials:

Raw materials for biscuit preparation (i.e. wheat flour, powdered sugar, fat, dextrose syrup and nonfat dry milk) were purchased from the local market. Chemicals and food additives used in the biscuit formulation (i.e. sodium chloride, sodium bicarbonate, ammonium bicarbonate, sodium stearoyl lactylate SSL) were provided by Food Technology Research Institute (FTRI), Giza, Egypt.

Bananas (*Musa Cavendishii* L.) in the mature-green stage of ripening were procured from a fruit market in Cairo, Egypt.

Methods:

Preparation of banana puree

Banana puree (BP) was prepared according to the following method :

Banana fruits were washed in a 20 ppm chlorine solution, peeled by hand, and then blanched in boiling water for 7 min. The puree was prepared by homogenization in a Moulinex blender (Optiblend 2000, France) for 5 min, and immediately cooled to about 15°C in a water bath (Tsen & King ,2002).

Preparation of biscuits

Biscuits were prepared by using the method outlined by Leelavathi & Haridas Rao (1993). The formulation of the control biscuits along with reduced-fat biscuit formulations are shown in Table (1). For preparation the control biscuits, fat and powdered sugar were creamed using a Moulinex mixer (Supermix 150) at the lowest speed for 1 min, and continued creaming at the highest speed for 4 min. Dextrose syrup, milk powder, baking chemicals and sodium chloride were dissolved in the used amount of water (17 ml) and were transferred to the above cream and mixed at the lowest speed for 2 min, followed by a further mixing at the highest speed for additional 2 min to get a smooth cream. Wheat flour was added to the above cream and mixed manually for 2 min to get the biscuit dough. The dough was sheeted to a thickness of 4 mm and was cut using a dough round cutter of 4.6 cm diameter.

For reduced-fat biscuit formulations, BP was used to replace fat at levels of 14.64, 25, 50, 75, and 85.36% according to the central composite design combinations, and was added before the creaming step. The SSL, used as an emulsifier, was added at levels of 0.02, 0.1, 0.3, 0.5, and 0.58 g SSL/100 g flour for the central composite design combinations during the creaming step.

Design generation

Response surface methodology (RSM) was used to study the simultaneous effects of BP and SSL on the characteristics of the produced biscuits. The central composite design (CCD) with two affecting factors (i.e. BP and SSL) was prepared with five levels of each variable and included five replications in the center point with a total of thirteen combinations was used in response surface methodology. Model selection (mean = no model, linear, quadratic) for each response was made on the basis of the sequential model sum of squares (SMSS), lack-of-fit tests and the multiple correlation coefficient (R^2) by using Design-Expert7 Software (Stat-Ease Corporation, Minneapolis, MN) as described by McCarthy *et al.* (2005). The runs of the experiment within the central composite design along with actual and coded levels of BP and SSL are shown in Table (1).

Physical properties of biscuits

After cooling, biscuits were subjected to physical measurements (i.e. width and height) according to the method described by the A.A.C.C. (1983) as follows:

Biscuits were laid edge to edge and width was measured. They were rotated 90° and remeasured to obtain the average diameter (width, W). Then, they were stacked on top of one another and thickness (height) was measured, restacked in different order and remeasured to get the average thickness (T).

Spread ratio was calculated according to the following equation as described by Salama (2001):

Spread ratio = Width (W) / Thickness (T)

Average weight of five biscuits was measured in g. Volume of biscuits was measured in cc by rapeseed displacement. Specific volume was calculated by dividing the volume (in cc) by the weight (in g).

Sensory characteristics of biscuits

The biscuits were evaluated for appearance, texture, colour, taste, odour and overall acceptability on a 9-point hedonic scale by a panel of eight trained panelists according to the methods of Larmond, (1974), and Hooda & Jood (2005). The 9 choices on the hedonic scale were: like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely. The

Table 1: Ingredients for the treatments of central composite design (CCD) used for response surface methodology optimization experiments

Treatment	Run No.	Flour (g)	Sugar(g)	Fat(g)	BP [a] (g)	Dextrose(g)	Dry milk(g)	NaCl(g)	Sodium Bi-carbonate (g)	Ammonium bicarbonate (g)	Water (ml)	Actual values [a]		Coded Values [a]	
												BP (%)	SSL (g)	BP (%)	SSL (g)
Control	-	100	30	20	-	2	2	1	0.4	1.5	17	-	-	-	-
8	1	100	30	10	10	2	2	1	0.4	1.5	17	50.00	0.58	0.00	1.41
3	2	100	30	15	5	2	2	1	0.4	1.5	17	25.00	0.50	-1.00	1.00
13	3	100	30	10	10	2	2	1	0.4	1.5	17	50.00	0.30	0.00	0.00
1	4	100	30	15	5	2	2	1	0.4	1.5	17	25.00	0.10	-1.00	-1.00
11	5	100	30	10	10	2	2	1	0.4	1.5	17	50.00	0.30	0.00	0.00
9	6	100	30	10	10	2	2	1	0.4	1.5	17	50.00	0.30	0.00	0.00
10	7	100	30	10	10	2	2	1	0.4	1.5	17	50.00	0.30	0.00	0.00
4	8	100	30	5	15	2	2	1	0.4	1.5	17	75.00	0.50	1.00	1.00
7	9	100	30	10	10	2	2	1	0.4	1.5	17	50.00	0.02	0.00	-1.41
6	10	100	30	2.9	17.1	2	2	1	0.4	1.5	17	85.36	0.30	1.41	0.00
5	11	100	30	17.1	2.9	2	2	1	0.4	1.5	17	14.64	0.30	-1.41	0.00
2	12	100	30	5	15	2	2	1	0.4	1.5	17	75.00	0.10	1.00	-1.00
12	13	100	30	10	10	2	2	1	0.4	1.5	17	50.00	0.30	0.00	0.00

[a] BP = banana puree , SSL = sodium stearoyl lactylate

ratings obtained from the panelists were given numerical values ranging from 9 (for like extremely) to 1 (for dislike extremely).

RESULTS AND DISCUSSION

Influence of fat replacement with BP and the addition of SSL on the physical properties of biscuits:

Figure (1) shows the response surface graphs for the effects of BP and SSL on the physical properties of biscuits (i.e. width, thickness, spread factor, weight, volume, and specific volume). The model orders, coefficients (all linear terms for the linear model, all linear, squared terms and two-way interaction for the quadratic model), maximum and minimum values of physical properties of produced biscuits are shown in Table (2). Measurements of the physical properties of biscuits showed that the width of biscuits decreased as the percentage of BP increased. This trend was the opposite in the thickness as biscuits with higher fat replacement levels were found to be thicker. Spread factor decreased by its turn as a result of the decrease in biscuit width and the increase in thickness. In addition, models obtained from the response surface analysis for width, thickness and spread factor were all of linear type. The obtained results of width, thickness and spread factor agree with those obtained by Sudha *et al.*, (2007) who reported a decrease in both biscuit width and spread factor with an increase in the thickness associated with the reduction in fat content of biscuits. Furthermore, incorporation of fruit purees was found to reduce the cookie spread, indicating a restricted dough flow during baking (Swanson & Munsayac, 1999).

For biscuit weight, biscuits with medium fat replacement levels (around 50% replacement) had the highest weight and were found to follow a quadratic model. The range between the highest and the lowest weight values was 1.19 g (Table 2). Biscuits with higher fat replacement levels showed higher volumes when compared to the control ones or to those with lower fat replacement levels following a linear model. On the other hand, biscuit specific volume was found to be constant and showed no model response. Thus, the intercept of this model was used as the only value in the predictive equation (specific volume = mean). These aforementioned results regarding the volume and specific volume are in accordance with those obtained by Conforti *et al.* (1997) who found that biscuits pre-

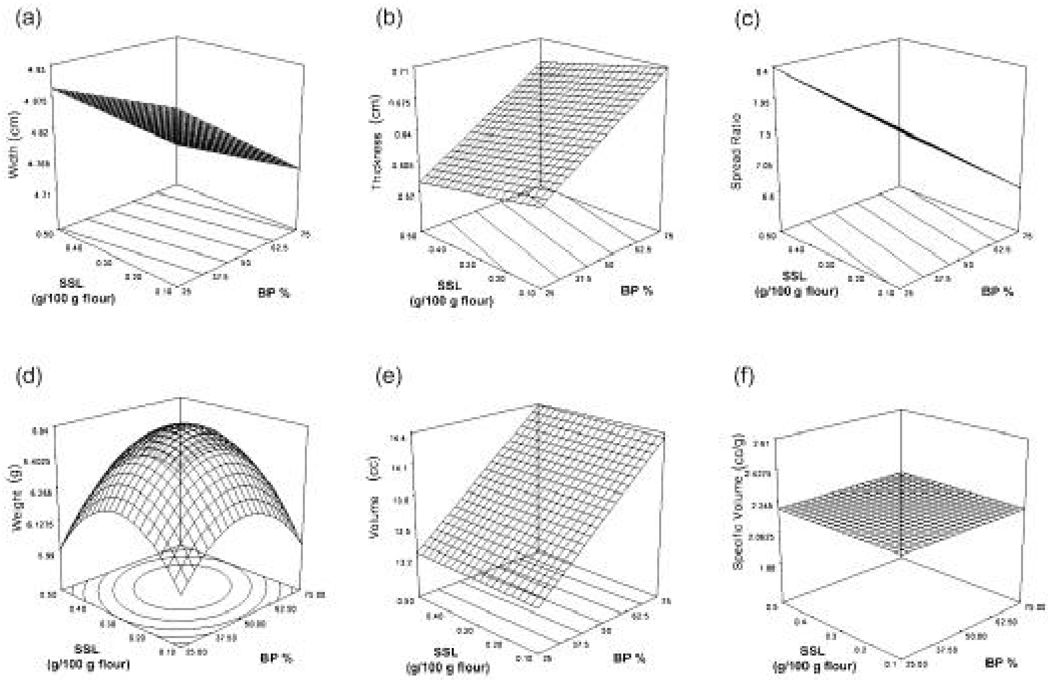

Fig. 1: Response surfaces for the effects of BP (%) and SSL (g/100 g flour) on width (a), thickness (b), spread ratio (c), weight (d), volume (e) and specific volume (f) of biscuits

Table 2: Model regression coefficients for the physical properties of biscuits containing BP and SSL using actual values

Physical properties	Model order	R^{2*}	Model coefficients [a]						Maximum value	Minimum value
			Intercept	BP	SSL	BP × SSL	BP^2	SSL^2		
Width (cm)	Linear	0.32	5.02	-3.45E-3	-0.08	-	-	-	5.05	4.61
Thickness (cm)	Linear	0.61	0.57	1.99E-3	-0.07	-	-	-	0.72	0.55
Spread ratio	Linear	0.62	8.70	-0.03	0.80	-	-	-	8.75	6.40
Weight (g)	Quadratic	0.40	5.07	0.03	3.48	9E-4	- 3.59E-4	-6.30	6.95	5.76
Volume (cc)	Linear	0.17	12.64	0.02	0.07	-	-	-	15.00	11.33
Specific volume (cc/g)	None (mean)	-	2.21	-	-	-	-	-	2.60	1.88

[a] BP = BP = banana puree (%), SSL= sodium stearoyl lactylate (g).

pared with carbohydrate-based fat replacers (i.e. Splendid, Kel-LiteBK, or TrimChoice) at replacement levels of 33, 66, and 100%, were higher in volume than the control cookies. This was previously supported by Orthoefer & McCaskill (1992) who had concluded that the control biscuit may not have expanded as high due to the weakening or tenderizing effect of the fat on the gluten-protein-structure.

With regard to the addition of SSL as an emulsifier to the biscuit formulations, the most important effect noticed was the increase in both width and spread factor of biscuits containing SSL at the different levels under investigation. The same results were obtained by Sudha *et al.* (2007) who reported a significant increase in biscuit spread factor as a result of the addition of SSL along with maltodextrin that was used as a fat replacer. A slight increment in biscuit volume was observed when SSL was added to the biscuit formulations. Kamel (1994) concluded that emulsifiers enhanced the incorporation of a great number of air bubbles and also aided in dispersing the fat in sufficiently small particles which led to the maximum number of nucleating sites. This conclusion could provide an explanation for the slight increase in biscuit volume as it can be attributed to the large number of air bubbles incorporated into biscuit dough during creaming and mixing steps as a result of the addition of SSL. It is worth pointing out that despite the relatively low values of multiple correlation coefficient (R^2) of the models of width, weight and volume, the linear (or quadratic) model was selected by Design-Expert 7 (Stat-Ease Corporation, Minneapolis, MN) depending on the combined overall selection procedure taking into consideration the other two model determinant factors (the sequential model sum of squares SMSS and lack-of-fits tests).

Influence of fat replacement with BP and addition of SSL on the sensory characteristics of biscuits:

The effect of replacing fat with BP and addition of SSL on the sensory characteristics of biscuits are shown in Table (3) and Fig. (2). Scores for the appearance of reduced-fat biscuits were rated by the panelists to be lower, at different extents, than those of their higher-fat counterparts. On the 9-point hedonic scale, appearance of reduced-fat biscuits was rated to range from like extremely to like slightly. For texture, a quadratic model was suggested to represent the effect of fat replacement with BP and the addition of SSL. In general, biscuits with higher fat replacement levels received lower sensory scores for texture. The panelists reported that biscuits with the higher fat replacement levels exhibited harder, more moisten and more chewable texture. These results are in agreement with those of Mitzel *et al.*, (1996) who reported the same observations in moistness and chewiness when semi-moist fruit puree was used to replace fat in gingersnap cookies. Scores for colour of biscuits obtained from the panelists didn't show any significant differences between reduced-fat biscuits and their higher-fat counterparts. Thus, no model was selected as there were no significant differences among the tested biscuits. Sudha *et al.* (2007) demonstrated that crust colour of the biscuits didn't alter much up to 60% fat reduction and became pale at 70% fat reduction level. For taste and odour, it was obvious that reduced-fat biscuits with higher fat replacement levels had lower ratings by the panelists. Three out of eight panelists reported a slight starchy taste and mouthfeel when evaluating biscuits with higher fat replacement levels. This might be attributed to the effect of replacing fat with a fat replacer containing a high amount of starch. On the other hand, two panelists observed a slight banana flavour in biscuits, especially at the very high fat replacement levels. However, no off-flavour was observed in all tested biscuits. Same observations were reported by Swanson & Munsayac (1999) as they found that flavour acceptability of peanut butter cookies was significantly reduced with the incorporation of applesauce in cookie formulation to replace fat. In all cases, fats were reported to not only provide flavour but also carry fat-soluble flavours and affect the flavour release profile (Stockwell, 1995). Overall acceptability of biscuits was evaluated and the results showed that, although all reduced-fat biscuits had lower scores for overall acceptability, they were all rated as acceptable and the preferences of panelists ranged from (like very much) to (neither like nor dislike) on the 9-point hedonic sensory scale.

The data in Table (3) showed the effects of addition of the emulsifier (SSL) on the sensory characteristics of biscuits. The SSL was found to exhibit a general slight, but improving effect on ap-

Table 3: Model regression coefficients for the sensory characteristics of biscuits containing BP and SSL using actual values

	Model order	R^{2*}	Model coefficients						Maximum value	Minimum value
			Intercept	BP	SSL	BP × SSL	BP^2	SSL^2		
Appearance	Linear	0.51	8.36	0.03	1.72	-	-	-	8.75	5.75
Texture	Quadratic	0.52	12.16	-0.06	-19.87	0.14	-2.63E-4	22.46	8.50	4.00
Colour	None (mean)	-	8.30	-	-	-	-	-	9.00	7.88
Taste	Linear	0.37	7.85	-0.02	1.66	-	-	-	8.50	6.25
Odour	Linear	0.41	9.21	-0.04	0.00	-	-	-	8.88	4.50
Overall acceptability	Linear	0.56	9.04	-0.04	0.26	-	-	-	8.25	5.13

[a] BP = banana puree (%), SSL= sodium stearoyl lactylate (g).

* R^2: Multiple Correlation Coefficient .

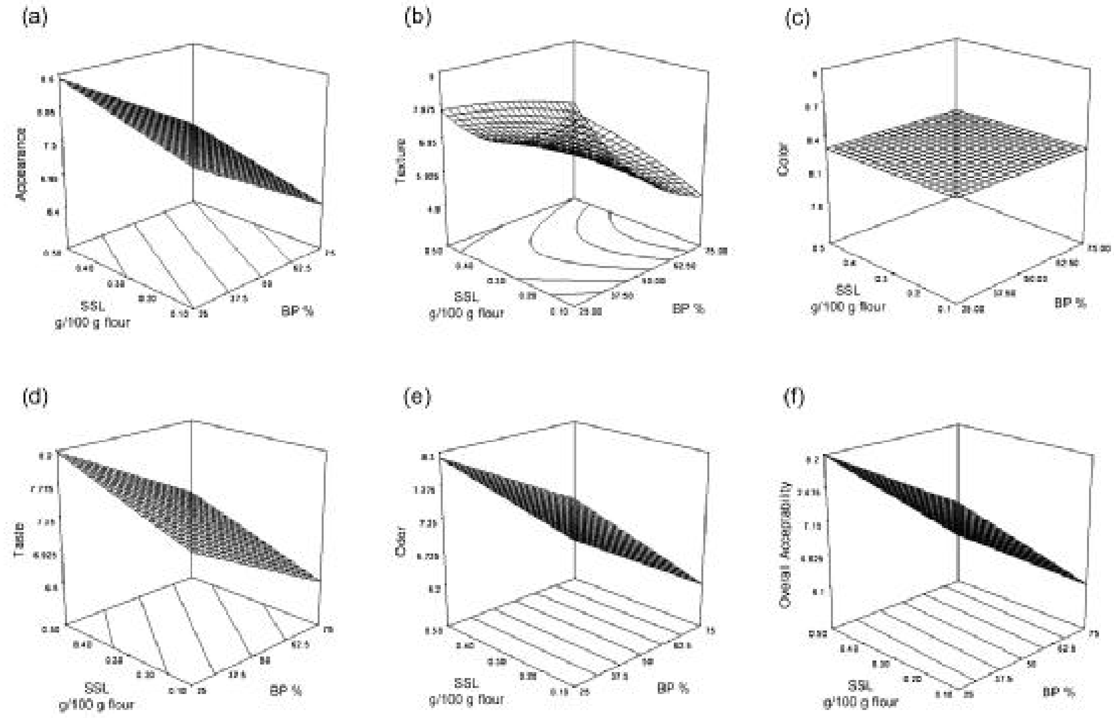

Fig. 2: Response surfaces for the effects of BP (%) and SSL (g/100 g flour) on appearance (a), texture (b), colour (c), taste (d), odour (e) and overall acceptability (f) of biscuits.

pearance and overall acceptability of reduced-fat biscuits. These results are in parallel with those obtained by Jacob & Leelavathi (2007) who reported an increase in cookie quality when SSL was incorporated at a level of 0.5%. In the current study, and despite the observation that SSL showed a positive relationship with the sensory characteristics of biscuits, the use of such an emulsifier was limited to the maximum addition level of 0.5 g/100 g flour. This was restricted by the Regulation (EC) No 95/2 of the European Parliament and of the Council of 20 February 1995 on food additives other than colours and sweeteners (p. 38) that limited the maximum use level of SSL in bakery goods to be 5g/kg flour.

Optimization of biscuit quality:

For the optimization of the quality of biscuits, sensory characteristics were considered and the overall acceptability of the biscuits was used as the determinant factor for the quality. Other factors employed in the experiment were kept unchanged. In order to perform the optimization process, desired goal settings were set to be as follows: For the independent factors, BP was set to be maximized, as the general purpose of the production of reduced-fat biscuit was to reduce fat content. The SSL was set to be within the used range (0.1 – 0.5 g/100 g flour). For the dependent variable (overall acceptability), it was set to be maximized. The outcome from the optimization process was that the recommended levels of BP and SSL in the biscuit formulation to produce the optimized biscuit formulation with the highest overall acceptability were found to be 64.5% and 0.5g/100 g flour, respectively. The resultant biscuits were compared with the control (full-fat) ones with regard to their physical properties and sensory characteristics. Two-tailed unpaired t-test was used to compare means, and the results were outlined in Table (4). The results showed that the optimized biscuits had significantly ($P<0.05$) lower values for width (Fig.3) and spread ratio when compared to the control ones. On the opposite, thickness of the optimized biscuits was higher (but not significant, $P=0.080$) than that of the control ones. Moreover, the optimized biscuits were found to have significantly higher ($P<0.05$) values for volume and specific volume than the control biscuits.

For the sensory characteristics, the scores obtained from panelists indicated that the optimized biscuits had significantly lower scores ($P<0.05$) than the control ones for most sensory characteristics. Colour was the only sensory parameter that

Table 4: Physical properties and sensory characteristics of optimized biscuits as compared to control biscuits[a]

	Control	Optimized	
		Measured [b]	Predicted
Physical properties:			
Width (cm)	5.23 ± 0.06	4.66 ± 0.21*	4.76
Thickness (cm)	0.55 ± 0.01	0.65 ± 0.05	0.66
Spread ratio	9.46 ± 0.18	7.21 ± 0.68*	7.28
Weight (g)	5.80 ± 0.20	5.93 ± 0.12	6.28
Volume (cc)	11.77 ± 0.42	14.00 ± 0.60*	14.12
Specific volume (cc/g)	2.03 ± 0.05	2.36 ± 0.07*	2.21
Sensory characteristics:			
Appearance	8.37 ± 0.52	7.38 ± 0.74*	7.43
Texture	8.13 ± 0.99	6.63 ± 1.06*	7.23
Colour	8.63 ± 0.74	8.00 ± 0.76	8.30
Taste	8.13 ± 0.64	7.00 ± 0.76*	7.40
Odour	8.63 ± 0.52	7.38 ± 0.92*	6.63
Overall acceptability	8.00 ± 0.93	6.88 ± 1.13*	6.66

[a] values are expressed as means ± standard deviation.
[b] means of measured values followed by (*) are significantly (*P≤0.05*) different than those of the control biscuits.

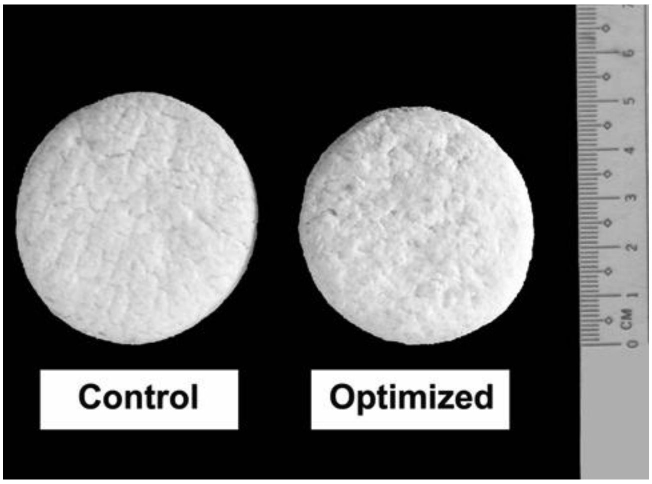

Fig. 3: Appearance of optimized reduced-fat biscuits (right) as compared to control (full-fat) biscuits (left)

didn't exhibit any significant differences between the control and the optimized biscuits. However, the scores obtained for appearance (Fig.3), texture, taste, odour and overall acceptability were rated by the panelists to be liked moderately, ≈ 7. Four sensory characteristics of the control biscuits (i.e. appearance, texture, taste and overall acceptability) were evaluated as liked very much, ≈ 8. The odour of control biscuits was rated as liked very much, ≈ 9. Generally, when comparing the measured values with the predicted ones, it was clear that measured responses for all physical properties and sensory characteristics were compared favorably to the predicted values.

CONCLUSION

The simultaneous effect of two variables (i.e. BP as a fat replacer and SSL as an emulsifier) on the physical and sensory quality of biscuits showed that BP can be used as a good fat replacer in the biscuit formulation. Additionally, the incorporation of SSL into biscuit formulation was found to have an improving effect on the physical and sensory attributes of reduced-fat biscuits. Application of response surface methodology to study the different effects of such two variables, and to optimize the quality of reduced-fat biscuits led to the production of an optimized biscuit formulation which had 64.5% fat replacer (BP), and 0.5 g SSL was added to each 100 g flour. However, the resultant optimized biscuits were less scored by panelists, but were still comparable to the control biscuits. Further studies are needed to investigate the optimization of the quality of different reduced-fat bakery products by using response surface methodology. Use of various fruit purees and emulsifiers can be taken into consideration when performing such a methodology.

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استخدام طريقة سطح الإستجابة لتحسين جودة بسكويت منخفض الدهن يحتوى على بيوريه الموز كبديل للدهن

مختار حرب عبد الخالق

معهد بحوث تكنولوجيا الأغذية - مركز البحوث الزراعية - الجيزة - القاهرة - مصر

تم في هذه الدراسة تطبيق طريقة سطح الإستجابة لتحسين جودة البسكويت منخفض الدهن و الذى تم فيه إستخدام بيوريه الموز كبديل للدهن إضافة الى لاكتيلات ستيرويل الصوديوم كمادة مستحلبة . وقد أوضحت النتائج أن استبدال الدهن فى خلطات البسكويت باستخدام بيوريه الموز قد أدى إلى انخفاض كل من قطر و معدل فرد البسكويت، بينما على العكس من هذا فقد حدثت زيادة ملحوظة فى كل من الارتفاع و الحجم و الحجم النوعي للبسكويت الناتج. كما أوضحت نتائج التقييم الحسى أن استبدال الدهن قد أدى إلى إنتاج بسكويت أقل تقبلاً من حيث الشكل العام و القوام و الطعم والرائحة و درجة التقبل الكلى. كما بينت الدراسة أن إضافة المستحلب قد أدت إلى تحسن فى معظم الصفات الحسية للبسكويت.

و عند تطبيق طريقة سطح الاستجابة لتحسين جودة البسكويت، فقد وجد أن أفضل خلطة للبسكويت كانت تلك التى تم فيها استبدال ٦٤,٥٪ من الدهن المستخدم ببيوريه الموز مع استخدام ٠,٥ جم مستحلب ، و قد اتصف البسكويت الناتج من هذه الخلطة بصفات طبيعية مقاربة للعينة المرجعية ، أما من حيث التقييم الحسي، فعلى الرغم من حصول العينة المحسنة على تقبل أقل من العينة المرجعية ، إلا أنها كانت فى نفس الوقت ذات صفات جودة حسية مقبولة و حصلت على درجات تقبل عالية من المحكمين.