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Effects of Fat Replacers on the Physical, Chemical and Sensory Characteristics of Puff Pastry

Kamolchat Pimdit, Nantawan Therdthai* and Kamolwan Jangchud

ABSTRACT

Puff pastry is a bakery product containing a high fat content. To reduce the fat content in the puff pastry, fat replacer could be used to substitute for some or all of the functions of the fat. The aim of this study was to determine the physical, chemical and sensory characteristics of reduced-fat puff pastry containing different types of fat replacers including: carbohydrate– (maltodextrin gel and powdered cellulose); protein– (WPC-80%); and fat– (salatrim) based fat replacers. The results indicated that the reduced-fat puff pastries contained 12.88-15.86% fat and 318.73-348.80 Kcal/100g, which were less than those of the regular-fat puff pastry. However, the moisture content and water activity of the reduced-fat puff pastries were significantly higher than those of the regular-fat puff pastry ($p \leq 0.05$). The analysis of sensory characteristics indicated that the reduced-fat puff pastry containing salatrim had a rubbery aroma. The use of carbohydrate- and protein- based fat replacers led to a more dense texture, decreased puffiness and an increased aroma of wheat. Using a nine-point hedonic scale, liking scores indicated that the reduced-fat puff pastry with maltodextrin-gel had the highest score compared with other reduced-fat puff pastries.

Key words: bakery, puff pastry, reduced fat, fat replacer

INTRODUCTION

Thai people have been reported as tending to have an obesity problem (Nutrition Division, 2004). Obesity in humans is a condition where excessive natural energy is reserved and stored in fatty tissue. This can cause diseases such as; osteoarthritis, obstructive sleep apnea, diabetes and cardiovascular diseases. Obesity can be prevented by controlling diet and doing some exercise (Wikipedia, 2007). For diets containing high fat, a fat replacer could be used to reduce the amount of fat in the food.

Fat replacer is an ingredient that can be used to provide some or all of the functions of fat, but it has fewer calories than fat (Schwenk and Guthrie, 1997). There are three major categories of fat replacers: carbohydrate- based, protein-based and fat-based (White, 1993). Previous research has indicated that the fat replacers could be used in various baked goods such as; cake, cookies, brownies and bread. Zoulias *et al*. (2002) used carbohydrate–based fat replacers including polydextrose, maltodextrin, β-glucans and oligofructose, or protein–based fat replacer (Simples Dry 100) in cookies. The results indicated that by replacing up to 50% of the fat with the fat replacers, the cookies had a higher hardness than the low fat cookies without fat replacers. In the reduced-fat wheat bread, inulin gel could be used

Department of Product Development, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand.
* Corresponding author, e-mail: faginwt@ku.ac.th

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to produce the same loaf volume, yield and crumb hardness as in the regular-fat wheat bread. However, the reduced-fat wheat bread with inulin powder had a smaller volume, less yield and higher crumb hardness than the regular-fat wheat bread and the reduced-fat wheat bread with inulin gel. Similarly, the reduced-fat wheat bread with Simples Dry 100 (a protein-based fat replacer) had a smaller loaf volume and a lower yield than the regular-fat wheat bread (O'Brien *et al*., 2003). In a burger bun, polydextrose could be used to improve the color of the reduced-fat bun, by increasing the L, a and b values (Esteller *et al*., 2006).

Puff pastry is a bakery product containing a high fat content (Bakal, 1991), because the role of the fat in puff pastry is to produce product puffiness. Fat replacer should be used to produce a reduced-fat puff pastry containing at least 25% less fat than regular-fat puff pastry (Notification of the Ministry of Public Health No. 182/2541 (1998)). However, replacing fat with the fat replacer might affect the appearance, texture, structure and flavor of the reduced-fat puff pastry. Therefore, this research aimed to determine the physical, chemical and sensory characteristics of the reduced-fat puff pastry containing carbohydrate– (maltodextrin gel and powdered cellulose), protein– (WPC-80%) and fat– (salatrim) based fat replacers.

MATERIALS AND METHODS

Preparation of the reduced-fat puff pastry

Hard wheat flour (White swan) and soft wheat flour (Red lotus) that were used in this research contained 13.50-13.80% and 8.0-8.3% protein, respectively. In this research, the fat replacers used were: maltodextrin gel (Paselli SA 2 supplied by Winner Group Enterprise LTD); powdered cellulose (VITACEL L600 supplied by Rama Production Co., LTD); whey protein (WPC-80% supplied by Vicchi Enterprise Co., LTD); and salatrim (Benefat® supplied by Danisco). Maltodextrin gel was prepared by dissolving maltodextrin powder in water with a 25 % w/w ratio. The gel was then stored at 4°C for 12 hours before use.

Dough was prepared by mixing all ingredients (Table 1), with the exception of the pastry margarine, in a small scale mixer (Variable Gear Mixer TS 207, Taiwan) at medium speed. The mixing times for the dough containing no fat replacer (control), maltodextrin gel, powdered

Table 1 Puff pastry formula containing various fat replacers.

Ingredients (Percentage of wheat flour)	Reduced-fat puff pastry containing				
	No fat replacer (control)	Maltodextrin gel	Powdered cellulose	Salatrim	WPC-80%
Hard wheat flour	50	50	50	50	50
Soft wheat flour	50	50	50	50	50
Cool water (4°C)	50	50	69.2	50	50
Salt	0.6	0.6	0.6	0.6	0.6
Egg	5	5	5	5	5
Baker's margarine	12	12	12	12	12
Pastry margarine	60	15	15	15	15
Maltodextrin gel	0	9.6	0	0	0
Powdered cellulose	0	0	9.6	0	0
Salatrim	0	0	0	9.6	0
WPC–80 %	0	0	0	0	2.0

cellulose, salatrim and WPC-80 % were 5, 5, 8, 5 and 7 minutes, respectively. The mixing times were varied depending on the water added to the dough for the different formulas. The higher the amount of water added to the dough, the longer the mixing time required. The amount of water added was dependent on the water-holding capacity of the fat replacers and the amount of fat replacer added. The dough was then proved in a chamber (0.5×0.5×0.8 m) under a controlled temperature of 4°C for 45 minutes. The folding process involved a first, second and last folding using 3, 4 and 3 folds, respectively. After the first and second folding, the dough was proved for 45 minutes. After the last folding, the proving lasted for 75 minutes. Finally, the dough was cut into blocks of 100 mm by130 mm and baked in a 0.8×0.8×1.0 m convective oven (King Machines, Bangkok, Thailand) at 200°C for 20 minutes.

The amount of each fat replacer used was based on the supplier's recommendations. For example, the recommended recipe range for WPC-80 % as a fat replacer was 1-5 %. Therefore, 2% WPC-80% was used in this study.

Chemical composition

The moisture and protein content of the puff pastry were determined using the standard methods described in AOAC (2000). The crude fat and total energy levels were determined using the ether-extraction method and a bomb calorimeter, respectively (Gallendamp, U.K.).

Physical properties

Water activity and crust color were measured using a water activity meter (AQUA LAB, CX3TE, USA) and chroma meter (Minota CR 200, Japan), respectively. The color of the reduced-fat puff pastry was evaluated at the edge and center of the crust. Color values were expressed as L*(lightness), a*(redness/ greenness) and b* (yellowness/ blueness) with a 10° observer and illuminant source-D65. Specific volume was measured using rapeseed replacement according to (Lee *et al*., 1982).

Sensory evaluation

For the descriptive analysis, 10 trained panelists were used to describe each product's attributes. Panelists were selected based on their ability to classify different samples using a triangle test and were then trained for the descriptive analysis with the development of terms to describe the product attributes. The panelists were trained to use a scale to define the product attributes and their intensity using a reference standard. The panelists were trained twice a week for eight weeks. The attributes were rated on a 15cm-line scale, with the lines anchored from "not" to "very" for each attribute. For sample evaluation, each trained panelist received three samples per evaluation. The descriptive analysis was conducted with two replications. At the time this study was conducted, salatrim was not allowed by law to be added to edible foodstuffs in Thailand, but it could be used in research projects. However, the information obtained from this study could be useful for product development of reduced-fat puff pastry for export to countries such as the USA, where salatrim could be used as a fat replacer .

Fifty untrained panelists were used to evaluate the acceptability of each product using a nine-point hedonic scale (1= extremely dislike, 9= liking extremely). The product attributes included: appearance, crispiness, puffiness, sweet, salty and overall liking.

Statistical analysis

The study was designed using a completely randomized design (CRD) with two replications of the five treatments; regular-fat puff pastry (control), reduced-fat puff pastry with maltodextrin gel, powdered cellulose, salatrim and WPC-80%. Data were analyzed using ANOVA(SPSS v.12.0). The difference between means was tested using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Chemical composition of the reduced fat puff pastries

Reduced-fat puff pastry was prepared using; carbohydrate- (maltodextrin gel and powdered cellulose), protein- (WPC-80%) and fat- (salatrim) based fat replacers. The chemical composition of the reduced-fat puff pastry is shown in Table 2. The control product contained 22.72% fat and total energy of 394.68 Kcal/100g. By using fat replacers as a substitute for some of the pastry margarine, the fat content was reduced by more than 25 %. Therefore, the puff pastry that had been made with maltodextrin gel, powdered cellulose, salatrium and WPC-80% could be claimed to be reduced-fat puff pastry (Table 1). In addition, the total energy of the puff pastry was decreased, though not by enough to allow a claim on the label of less than 25% energy. The reduced-fat puff pastry with powdered cellulose contained the highest moisture content compared with other the reduced-fat puff pastries, because the powdered cellulose contained a large amount of fiber, which had a high water-binding capacity. The puff pastry with WPC-80% contained the lowest fat content and the highest protein content compared with the other reduced-fat puff pastries, because WPC-80% was made from whey protein that had a high protein and a low fat content.

Physical quality of reduced fat puff pastries

Table 3 shows the water activity and specific volume of the different types of reduced-fat puff pastry and indicates that the water activity of both the reduced-fat puff pastries and the regular-fat puff pastry was higher than 0.9. The reduced-fat puff pastry tended to have a higher water activity ($p \leq 0.05$). This result was similar to Woods and Navder (2006) and Power *et al*. (2007). Woods and Navder (2006) used fiber (C–TRIM) as a fat replacer in chocolate chip cookies and Power *et al*. (2007) used pureed soy beans (tofu) as a fat replacer in short cake. Both studies indicated that the addition of fat replacers increased the moisture content and water activity

Table 2 Effect of fat replacers on the chemical composition of reduced-fat puff pastries.

Reduced-fat puff pastry type	Moisture (%)	Crude fat (%)	Protein (%)	% Total energy (Kcal / 100g)
Control	25.46±1.85^{d}	22.72±0.16^{a}	9.71±0.02^{b}	394.68
Maltodextrin gel	29.58±1.82^{b}	14.14±0.28^{bc}	8.17±0.22^{d}	318.73
Powdered cellulose	31.66±1.69^{a}	13.40±0.27^{bc}	8.52±0.17^{c}	328.39
Salatrim	27.90±1.33^{c}	15.86±0.36^{b}	7.70±0.29^{e}	347.03
WPC-80%	29.24±1.81^{b}	12.88±0.23^{c}	10.08±0.19^{a}	348.80

a-e : Means within the same column with different letters are significantly different ($p \leq 0.05$) and all values are means ± SD.

Table 3 Effect of fat replacers on the water activity and specific volume of the reduced-fat puff pastries.

Reduced-fat puff pastry type	Water activity	Specific volume (cm^3/g)
Control	0.930±0.012^{d}	1.540±0.350^{a}
Maltodextrin gel	0.968±0.005^{ab}	1.285±0.204^{ab}
Powdered cellulose	0.970±0.005^{a}	1.092±0.211^{b}
Salatrim	0.946±0.006^{c}	1.520±0.141^{a}
WPC-80%	0.960±0.007^{b}	1.425±0.225^{ab}

a-d : Means within the same column with different letters are significantly different ($p \leq 0.05$) and all values are means ± SD.

of the reduced-fat products. This was because fat replacers generally absorbed more water (Akoh, 1998).

Maltodextrin gel, salatrim and WPC–80% could be used in the reduced-fat puff pastry without any effect on the specific volume because they all had a specific volume not different from that of regular-fat puff pastry. However, the reduced-fat puff pastry with powdered cellulose had a lower specific volume than regular-fat puff pastry and reduced-fat puff pastry (Table 3).

Color measurements of the reduced-fat puff pastry were conducted at the edge and center of crust. Table 4 indicates that the center of the reduced-fat puff pastry containing WPC-80% had lower L* than the edge crust because it was puffed and burnt at center. The reduced-fat puff pastry containing salatrim had a lighter crust color than the other types. These results were similar to Esteller *et al*. (2006) that used polydextrose (LitesseIIs) and salatrim (Benefats) as fat replacers in a burger bun. The results showed that addition of salatrim increased the lightness value of the reduced-fat burger bun.

Sensory characteristics of the reduced-fat puff pastries

The sensory characteristics of the puff pastry were described by the 19 terms shown in Table 5. Using the 10 trained panelists, all attributes were evaluated as shown in Table 6. The appearance (yellow crust color, degree of burning, glossiness, color uniformity and puffiness) of the reduced-fat puff pastry types containing maltodextrin gel, powdered cellulose and salatrim was significantly different from that of the regular-fat puff pastry ($p \leq 0.05$).

The assessment of aroma (margarine, wheat and rubber) and flavor (margarine and oil) indicated that reduced-fat puff pastry containing maltodextrin gel and WPC-80% had the highest margarine aroma compared with the other reduced-fat puff pastries. The reduced-fat puff pastry containing maltodextrin gel had the highest flavor of margarine and oil compared with the other reduced-fat puff pastries. Maltodextrin gel, powdered cellulose and WPC-80% produced reduced-fat puff pastries containing a stronger wheat odor than the regular-fat puff pastry. The rubber aroma was found only when the fat-based (Salatrim) fat replacer was used.

The puff pastry with salatrim was the crispiest of the reduced-fat puff pastries, however, its crispiness was less than that of the regular fat puff pastry ($p \leq 0.05$). In contrast, the reduced-fat puff pastries containing maltodextrin gel, powdered cellulose, and WPC-80% were firmer than the reduced-fat puff pastry with salatrim and the regular-fat puff pastry. Using fat replacers tended to reduce the sweetness and saltiness compared with the regular-fat puff pastry. Taste and aftertaste (oily residue and mouth dryness) were reduced when fat replacers were used in the reduced-fat puff pastry. However, saltiness (aftertaste) in the reduced-fat puff pastry with maltodextrin gel and WPC-80% was not

Table 4 Effect of fat replacers on crust color of the reduced-fat puff pastries.

Reduced-fat puff pastry type	Edge crust of puff pastry			Center crust of puff pastry		
	L*	a*	b*	L*	a*	b*
Control	36.34±0.44^{c}	2.40±0.29^{b}	18.99±0.48^{b}	37.00±0.44^{bc}	2.05±0.24^{b}	14.77±0.43^{b}
Maltodextrin gel	37.28±0.67^{c}	1.66±0.34^{bc}	13.95±0.55^{c}	36.86±0.54^{bc}	0.38±0.26^{cd}	11.43±0.42^{c}
Powdered cellulose	36.87±0.56^{c}	0.73±0.34^{cd}	12.54±0.58^{c}	37.91±0.52^{b}	0.16±0.26^{d}	11.17±0.42^{c}
Salatrim	42.40±0.59^{a}	6.43±0.49^{a}	22.44±0.57^{a}	42.83±0.57^{a}	3.94±0.30^{a}	18.60±0.54^{a}
WPC–80%	39.03±0.59^{b}	1.77±0.34^{bc}	18.11±0.66^{b}	35.71±0.65^{c}	1.11±0.26^{c}	17.22±0.49^{b}

a-d : Means within the same column with different letters are significantly different ($p \leq 0.05$) and all values are means ± SD.

significantly different from the regular-fat puff pastry ($p>0.05$). Based on the descriptive analysis, there was a noticeable change in the sensory characteristics of the pastry caused by the fat replacers. The change of quality due to fat replacers could also have affected the scores of all attributes, as shown in Table 7. There was a significant difference between the regular-fat puff pastries and the reduced-fat puff pastry. The reduced-fat puff pastries showed significantly lower liking scores for all attributes ($p\leq 0.05$). This could have been due to the impact of the fat replacers on the physical, chemical and sensory characteristics of the puff pastry. The reduced-fat puff pastry with 9.6% maltodextrin gel had the highest overall liking score compared with the other reduced-fat puff pastries. This was possibly because it contained more flavor of margarine and oiliness than the other reduced-fat puff pastries and so possibly had a better taste than the others.

CONCLUSIONS

Carbohydrate– (maltodextrin gel and powdered cellulose), protein– (WPC-80%) and fat– (salatrim) based fat replacers were used to achieve at least a 25% reduction in the fat content of puff pastry. The reduced-fat puff pastry products varied in quality. Among the fat replacers used in this study, fat-based (salatrim) fat replacers tended to have a better appearance, but had an unpleasant rubber odor. Protein- (WPC-80%) and

Table 5 Terms used in the descriptive analysis of the reduced-fat puff pastries.

Product attributes	Definition
Appearance	
1. Yellow crust color	Light yellow to dark yellow (under white light).
2. Degree of burning	Mark on the product showing over-baked product on edge crust.
3. Glossiness	Shine of the product crust.
4. Color uniformity	Uniformity of yellow color of the product crust.
5. Puffiness	Thickness of the product.
Aroma	
1. Margarine aroma	Odor of margarine in the product.
2. Wheat aroma	Odor of cooked-wheat flour in the product.
3. Rubber aroma	Odor of rubber in the product.
Texture	
1. Crispy	Force required to compress the product at the first bite by using incisors.
2. Firm	Force required to compress the product for three bites by using molars.
Flavor	
1. Margarine flavor	Intensity of margarine flavor in the mouth.
2. Oil	Intensity of oil flavor perceived in the mouth.
Taste	
1. Sweet	Taste on the tongue associated with sugars.
2. Salty	Taste on the tongue associated with salt.
Aftertaste	
1. Oily residue	Intensity of oil perceived in mouth after the product is swallowed.
2. Salty	Intensity of saltiness in mouth after the product is swallowed.
3. Tooth pack	Amount of product packed into crowns of the teeth after mastication.
4. Mouth dryness	Drying sensation on the palate.

carbohydrate- (maltodextrin gel and powdered cellulose) based fat replacers tended to have a denser texture and less puffiness than the regular-fat puff pastry. In the sensory evaluation, liking scores for the reduced-fat puff pastries were lower than those recorded for the regular-fat puff pastry. Maltodextrin gel was likely to produce a product with higher liking scores than WPC-80%.

Table 6 Descriptive analysis of puff pastries.

Product attributes	Score of puff pastries				
	Control	Maltodextrin gel	Powdered cellulose	Salatrim	WPC–80 %
Appearance					
1.Yellow crust color	9.35±0.16^{a}	4.20±0.16^{e}	4.63±0.16^{d}	7.77±0.18^{b}	6.48±0.16^{c}
2.Degree of burnt	3.38±0.17^{b}	0.82±0.18^{d}	1.78±0.18^{c}	5.65±0.19^{a}	1.68±0.15^{c}
3.Glossiness	9.38±0.17^{a}	7.22±0.18^{d}	7.62±0.19^{c}	8.07±0.20^{b}	7.50±0.13^{c}
4.Color uniformity	7.43±0.15^{d}	10.70±0.19^{a}	9.45±0.17^{b}	8.32±0.14^{c}	7.60±0.20^{d}
5.Puffiness	7.73±0.16^{a}	3.67±0.15^{d}	4.57±0.15^{c}	5.57±0.15^{b}	5.67±0.16^{b}
Aroma					
1.Margarine	10.7±0.15^{a}	8.65±0.16^{b}	6.77±0.18^{c}	5.75±0.19^{d}	8.75±0.19^{b}
2.Wheat	0±0	10.60±0.12^{a}	8.48±0.11^{c}	0±0	9.43±0.12^{b}
3.Rubber	0±0	0±0	0±0	4.28±0.17	0±0
Texture					
1.Crispy	10.85±0.11^{a}	6.60±0.11^{c}	2.63±0.16^{d}	8.63±0.15^{b}	2.57±0.12^{d}
2.Firm	2.22±0.19^{d}	8.25±0.21^{b}	8.40±0.14^{b}	3.62±0.12^{c}	10.30±0.15^{a}
Flavor					
1.Margarine	10.50±0.12^{a}	3.30±0.19^{b}	2.70±0.23^{c}	-	2.32±0.20^{d}
2.Oil	9.73±0.21^{a}	6.25±0.15^{b}	5.57±0.22^{c}	-	4.70±0.14^{d}
Taste					
1.Sweet	3.35±0.16^{a}	2.40±0.14^{b}	2.4±0.24^{b}	-	2.45±0.24^{b}
2.Salty	5.33±0.19^{a}	3.72±0.18^{b}	2.42±0.12^{d}	-	2.63±0.22^{c}
Aftertaste					
1.Oily residue	11.2±0.18^{a}	7.55±0.14^{b}	7.55±0.21^{b}	-	6.68±0.15^{c}
2.Salty	0.33±0.12^{ab}	0.23±0.158^{b}	0.43±0.16^{a}	-	0.28±0.15^{ab}
3.Tooth pack	6.65±0.14^{b}	4.37±0.20^{c}	3.52±0.13^{d}	-	7.25±0.23^{a}
4.Mouth dryness	5.37±0.12^{a}	3.97±0.20^{d}	5.18±0.18^{b}	-	4.55±0.14^{c}

a-d : Means within the same column with different letters are significantly different ($p \leq 0.05$) and all values are means ± SD.

Table 7 Effect of fat replacers on the liking scores of the reduced-fat puff pastries.

Treatment	Appearance	Color	Puffiness	Crispy	Sweet	Salty	Overall
Control	7.44±0.95^{a}	7.18±0.92^{a}	7.10±0.95^{a}	7.18±1.06^{a}	6.92±1.14^{a}	6.84±0.87^{a}	7.46±0.84^{a}
Maltodextrin gel ^{A}	5.76±1.91^{b}	5.66±2.04^{b}	5.36±1.99^{b}	5.16±2.19^{b}	5.56±1.24^{b}	5.62±1.29^{b}	5.78±1.92^{b}
Powdered cellulose ^{A}	5.04±1.23^{c}	4.28±1.50^{c}	3.94±1.67^{c}	4.18±1.32^{c}	4.24±1.13^{c}	4.52±1.25^{c}	3.78±1.37^{c}
Salatrim ^{B}	-	-	-	-	-	-	-
WPC–80 %^{C}	5.20±1.14^{c}	5.18±1.56^{b}	3.82±1.35^{c}	3.70±1.25^{d}	4.22±1.27^{c}	4.24±1.06^{c}	3.46±1.16^{c}

a-d : Means within the same column with different letters are significantly different ($p \leq 0.05$) and all values are means ± SD.

However, based on this study, no single type of fat replacer could produce the same quality as the regular fat puff pastry. Therefore, a combination of fat replacers (maltodextrin gel and WPC-80%) should be further studied as a means of improving the quality of reduced-fat puff pastry.

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