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Physical Properties and Microstructure of Butter Cake Added with *Persea americana* Puree

(Sifat Fizikal dan Mikrostruktur Kek Mentega yang Ditambah dengan Puri *Persea americana*)

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ABSTRACT

The effect of addition of avocado (Persea americana) *puree on the physical and microstructure of butter cake was studied. Butter cakes were made by replacing butter with 10, 30 and 50% of avocado puree. Physical properties including batter specific gravity, volume, colour and image analysis of cellular structure of the crumb were analyzed. Texture profile analysis was determined using texture analyzer. The results showed that with the increased amount of avocado puree, the batter specific gravity increased while volume of the cakes reduced. The texture profile analysis showed that the cakes became harder as the amount of avocado puree increased, while cohesiveness was not affected. The cellular structure of the crumb exhibited a decrease in the number of air cells while the average cell size increased with addition of avocado puree. The colour analysis showed that the cake crumb became darker as the aavocado puree was increased.*

Keywords: Avocado; butter cake; physical; scanning electron microscopy; texture

ABSTRAK

*Kesan penambahan puri avokado (*Persea americana*) ke atas ciri fizikal dan mikrostruktur kek mentega telah dikaji. Kek mentega telah dihasilkan dengan menggantikan mentega dengan puri avokado pada kadar 10, 30 dan 50%. Ciri fizikal termasuk graviti tentu bater, isi padu, warna dan analisis imej struktur selular kek telah dianalisis. Analisis profil tekstur telah ditentukan menggunakan penganalisis tekstur. Keputusan kajian menunjukkan bahawa dengan peningkatan puri avokado, graviti tentu bater meningkat manakala isi padu kek menurun. Analisis profil tekstur menunjukkan kek menjadi semakin keras apabila jumlah puri avokado meningkat manakala nilai kelekatan tidak terjejas. Struktur selular kek menunjukkan penurunan pada bilangan sel udara manakala purata saiz sel udara meningkat dengan penambahan puri avokado. Analisis warna menunjukkan kek menjadi semakin gelap apabila kandungan puri avokado meningkat.*

Kata kunci: Avokado; kek mentega; fizikal; mikroskop imbasan elektron; tekstur

INTRODUCTION

Fat is an important food component that contributes to sensory characteristics of food such as flavour, mouth feel and odour. However, high fat diet may lead to several health problems such as obesity, overweight and cardiovascular disease. Much evidence has shown that increases in obesity and overweight were related to increase in fat and calorie intake (Hayek & Ibrahim 2013). The present dietary guidelines suggested limiting the total fat intake to less than thirty percent of calories (Wylie-Rosett 2002). The increases in concern over diet and health among consumers have also created a demand for healthier products. The challenge arise for food industry to produce tasty and convenient foods that provide added nutritional and health benefits. Due to that, researchers have focused on reducing the amount of fat in food products as a means to increase the public health status.

Over the years, there has been tremendous research in replacing dietary fat with fat replacers to modify the food products to helps consumers lower their fat intake. Some of the fats replacer used were polydextrose, maltodextrin, oligofructose and inulin (Armbrister & Setser 1994; Psimouli & Oreopoulou 2013; Zahn et al. 2010). Apart from that, there were also natural fat replacers that have been used such as oatbran, oatrim, mungbean and fruit puree such as paw-paw, apple and avocado in various baked products (Adair et al. 2001; Dadkhah et al. 2012; Swanson & Munsayac 1999; Wekwete & Navder 2008; Wiese & Duffrin 2003).

High consumption of fruits and vegetables is correlated with lower incidence of some types of cancer and cardiovascular disease (Wang et al. 2012). Avocado (*Persea americana)* is one of the fruits that provide various health benefits. It is rich in monounsaturated fatty acid and contains high level of antioxidants such as polyphenols, tocopherols and carotenoids (Carvajal-Zarrabal et al. 2014). Thus, incorporating avocado in baked products can greatly enhanced the nutritional value as well as improving the functional value of the baked products.

Since the pulp of avocado has a buttery texture, it is highly potential to be used as natural fat replacer. Fat affects the structural properties of cake and facilitate the air incorporation in cake batter (Psimouli & Oreopoulou 2013). Previous study has shown that avocado has been successfully substituted for fat in cookies and has acceptable sensory properties. However, the analyses on the structural and physical effects of avocado puree in baked products were scarce. It is important to study how natural fat replacer such as avocado puree affects the batter and baking performance of baked product. Thus, the objectives of this study were to investigate the feasibility of using avocado fruit puree as fat replacer in butter cake and to study its effect on the structural and physical properties of the cake. For this purpose, four different formulations were examined which was the control cake (without avocado puree) and cake with fat replacement of 10, 30 and 50% w/w.

MATERIALS AND METHODS

CAKE PREPARATION

Ingredients used for making cake were purchased from the local market. Butter cake with 0, 10, 30 and 50% by weight replacement of butter for avocado puree were prepared and the formulas are listed in Table 1. All ingredients has been previously equilibrated to room temperature for 40 min before weighing according to the formulation. Then, fat was creamed with sugar using an electric mixer (Faber FBR-FM533) for 8 min. Next, the rest of wet ingredients were added followed by dry ingredients and mixed under constant mixing. All the cakes were baked at the same time in an electric oven (Zanussi ZCG 841W) at 180°C for 45 min. During baking, each pan was rotated twice by 180° to ensure even baking.

PHYSICAL MEASUREMENTS

Batter specific gravity The batter specific gravity was calculated by dividing the weight of a standard measure of the batter by the weight of an equal volume of water.

Moisture content The moisture content was determined by air-oven method according to AOAC (2000).

Cake volume The volume of the cake was determined by rapeseed displacement method according to Lin and Lin (2001). Specific volume was calculated by dividing the cake volume by weight.

Colour The colour of the cake crumb was measured using Minolta CN-508i spectrophotometer (Minolta Co Ltd, Japan) with standard illuminant D65. The results were expressed in CIE L*a*b* colour space.

Image analysis of cellular structure of the crumb Cakes were cut into 1.5 cm thickness and scanned using a scanner (Canon, PIXMA MP 287) with 200 dpi of resolution. The scanned images were then analysed using ImageJ software programme (ImageJ 1.47v, Wayne Rasband, National Institutes of Health, USA). The image of each slice was cropped into 1:1 ratio, before it was split in color channels. Next, the contrast was enhanced and then converted to binary image after applying grey-scale threshold (Rodriguez-Garcia et al. 2014a). The number of cells, mean cell size (mm^2) and total cell area within crumb (%) were determined using the software. The cell density (C/mm^2) was calculated using the formula according to Rodriguez-Garcia et al. (2012):

Cell density (C/mm^2) = Number of cells / Area of crumb analyzed.

Scanning electron microscopic (SEM) analysis SEM studies were carried out using Fei scanning electron microscope (Model Quanta FEG 450) according to the method of Sowmya et al. (2009). Butter cake samples (size 20 × 20 mm) were defatted with hexane, followed by freeze-drying using freeze dryer. The freeze dried samples were kept in desiccator until further used. The samples were separately placed on sample holder using double sided scotch tape before exposed to gold sputtering for 150 s (5×10^{-2} mbar). All samples were coated with 26.7 nm of gold. Finally, samples were transferred to the microscope where each of them was observed at 5.00 kV.

Texture profile analysis Cake samples were cut into 25 × 25 × 25 mm cubes before texture profile analysis measurement. Texture of the cake was determined using TA-XT2 texture analyzer (Stable Microsystems, Surrey, UK). A 25 mm diameter, cylindrical aluminum probe was used with double compression test, penetrating to 50% of the depth at a speed of 2 mm/s with a 30 s between the first and second compression.

TABLE 1. Formulation of butter cake with different fat replacement

Ingredients	Butter cake formulation (% of avocado puree inclusion)			
	Control (0%)	10%	30%	50%
All purpose flour (g)	110	110	110	110
Self-raising flour (g)	110	110	110	110
Sodium bicarbonate (g)	3	3	3	3
Butter (g)	150	135	105	60
Avocado paste (g)	0	15	45	90
Whole egg (g)	150	150	150	150
Sugar (g)	100	100	100	100
Milk (mL)	125	125	125	125

Statistical analysis All values presented were means of triplicate determination. Statistical analyses were carried out using One-way ANOVA using SPSS version 20.0. Significant differences were determined using Duncan's multiple range test with a 95% significant level.

RESULTS AND DISCUSSION

PHYSICAL CHARACTERISTICS

Table 2 shows the physical characteristics of butter cakes made with avocado puree as fat replacer. The batter specific gravity increased with the increased in percentage of avocado puree, with 50% fat-replaced cake had significantly ($p<0.05$) highest specific gravity. Specific gravity is a measurement of air incorporated into a cake batter during mixing. The increase in specific gravity could be attributed to the inferior ability of avocado puree to entrap air, which resulted in less incorporation of air bubbles in the cake batter. The same result has been observed by Lee et al. (2005) when shortening was replaced with Oatrim in the cake.

The increase in the specific gravity resulted in lower cake volume in the present study. The volume of the cake showed that the 50% fat-replaced cake was significantly ($p<0.05$) lowest in volume than the rest of the cakes. Volume decrease was also reported by Martinez-Cervera et al. (2013) when fat content in muffin was replaced by Nutriose, a carbohydrate based fat replacer. The specific volume shows constant decrease as the fat-replacement was increased. The specific volume of bake cake indicates the amount of air that can remain in the final product. The higher the specific volume shows higher gas retention and higher expansion of cake (Salama et al. 2013). The moisture content of the cakes increased as the percentage of avocado puree was increased; with 50% fat-replaced cake showing a significantly ($p<0.05$) highest moisture content. This might be contributed by the dietary fibre content in the avocado puree. High fibre content may retain water by preventing evaporation during baking (Lim & Wan Rosli 2013).

The colour analysis showed that as the amount of avocado puree increased, the cake crumbs became darker, as indicated by the lower value of L*. The decrease in L* value was also reported by Majzoobi et al. (2015) when commercial oat fibre was added in the sponge cake. The red colour (a*) also exhibited a decreasing trend, with 50% fat-replaced cake having significantly lowest ($p<0.05$) redness value. The yellowness (b*) of the cakes also became lower as the percentage of avocado was increased. The 50% fat-replaced had a significantly ($p<0.05$) lower yellowness than the control cake. The chlorophyll pigment in the avocado seemed to impart darker and greenish colour to the fat-replaced cakes.

TEXTURE PROFILE ANALYSIS

The texture profile analysis of butter cakes showed that the hardness of the cakes increased with increasing amount of avocado puree (Table 2). The cake without avocado puree formulation was significantly ($p<0.05$) softer than those cakes made with avocado puree. This might be due to the lower amount of fat in the fat-replaced samples which interfere with gluten development and thus making the fat-replaced cakes firmer than the control cake. Fat or butter lends softness to the baked product, thus the lower content of butter in the avocado cakes made them slightly harder (Psimouli & Oreopoulou 2013). Khalil (1998) also observed an increase in the hardness when lowfat cake was replaced with carbohydrate fat replacer. Dadkhah et al. (2012) also detected increase in hardness when shortening was replaced with oat bran in shortened cake.

The springiness of the cake crumbs increased to the maximum level in the 10% fat-replaced cake and then decreased. The decrease in the springiness value could be attributed to the decrease in the number of crumb cells, which is evident in the cellular structure of cake crumb

TABLE 2. Physical characteristics of butter cake with avocado puree as fat replacer

Physical characterists	Replacement level of butter for avocado puree (%)			
	0%	10%	30%	50%
Batter specific gravity	0.76 ± 0.00[c]	0.80 ± 0.00[b]	0.80 ± 0.01[b]	0.83 ± 0.01[a]
Volume (mL)	1051.33 ± 64.6[a]	1136.00 ± 50.4[a]	1089.33 ± 95.9[a]	854.67 ± 69.1[b]
Specific volume (mL/g)	1.71 ± 0.11[a]	1.75 ± 0.07[b]	1.67 ± 0.13[c]	1.26 ± 0.12[b]
Moisture (%)	2.04 ± 0.00[c]	2.06 ± 0.02[c]	2.13 ± 0.01[b]	2.27 ± 0.01[a]
Colour:				
L*	68.20 ± 0.40[a]	67.63 ± 0.34[a]	65.70 ± 0.17[b]	65.60 ± 0.23[b]
a*	-0.98 ± 0.04[d]	-1.80 ± 0.05[c]	-2.05 ± 0.15[b]	-2.55 ± 0.16[a]
b*	26.77 ± 0.23[a]	25.53 ± 1.91[ab]	24.97 ± 0.28[ab]	23.40 ± 1.09[b]
Texture profile analysis:				
Hardness (N)	1.69 ± 0.27[b]	2.23 ± 0.16[a]	2.38 ± 0.29[a]	2.34 ± 0.15[a]
Springiness (mm)	0.87 ± 0.01[b]	0.90 ± 0.01[a]	0.87 ± 0.01[b]	0.84 ± 0.01[c]
Cohesiveness	0.57 ± 0.05[a]	0.59 ± 0.01[a]	0.59 ± 0.03[a]	0.51 ± 0.07[a]
Chewiness (N)	0.84 ± 0.08[c]	1.21 ± 0.09[b]	1.57 ± 0.19[a]	1.12 ± 0.28[bc]

Mean in the same row with different letters are significantly different ($p< 0.05$)

analysis. This result is supported by Rodriguez-Garcia et al. (2014b), who reported a decrease in the springiness of cakes when fat was replaced with inulin. The cohesiveness of the cake was not affected by the avocado puree addition as shown by its insignificant values. The chewiness of the cake increased with the increase addition of avocado puree and reached maximum at 30% fat level. The avocado puree contains about 1.12 g/100 g of fibre (data not shown) and this factor could also contribute to slightly chewier crumb in the fat-replaced cakes.

CELLULAR STRUCTURE OF CAKE CRUMB

Figure 1 shows the greyscale and binarised images of butter cake crumbs. The size of air cells in the control cake crumb exhibited homogenous cell distributions compared to the fat-replaced butter cakes. The narrow bubble size distributions in small areas lead to a softer control cake. In contrast, more interconnected air cells were observed in the crumb structure of the fat-replaced cakes. This showed that coalescence has taken place, where two or more bubbles combined to form larger bubbles.

There were significant difference (p<0.05) between the maximum fat-replaced cake crumbs and the other formulations in term of number of cells, average cell sizes, and cell density of cake crumbs (Table 3). The decrease in the number of air cells and increase in the cell size of fat-replaced cakes resulted in harder cakes, which was reflected in the texture profile analysis. Fat replacement

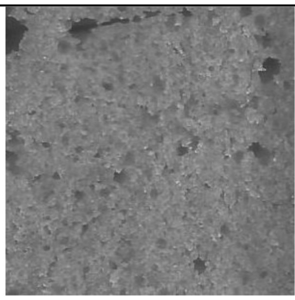
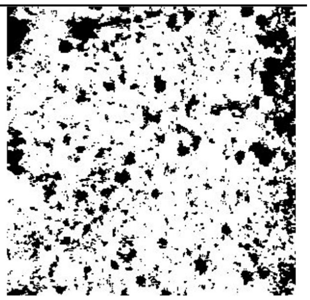
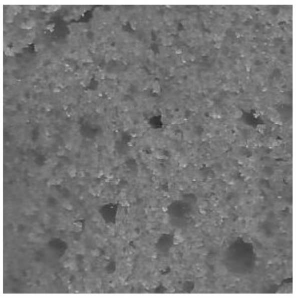
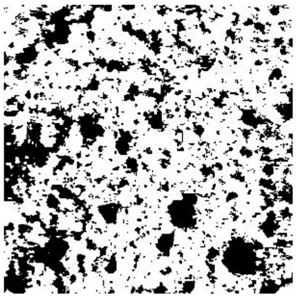
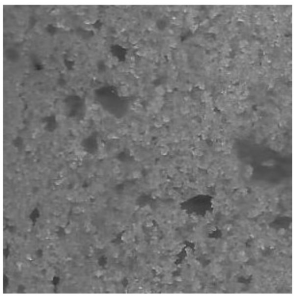
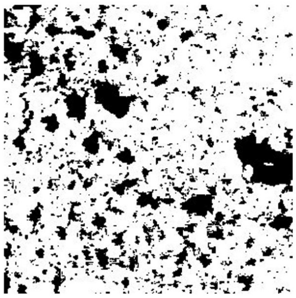
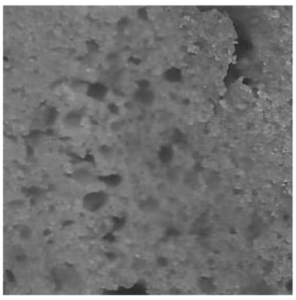
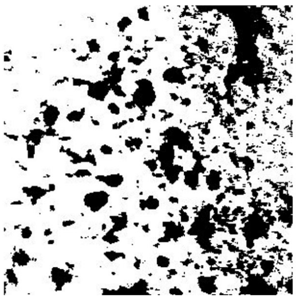
Cake sample	Grey-scale image	Binarized image
Control (0%)		
10% fat-substituted butter cake		
30% fat-substituted butter cake		
50% fat-substituted butter cake		

FIGURE 1. The grey scale and binarised image of cellular structure of butter cake crumbs in the presence of avocado puree

TABLE 3. Mean values of number of cells, average cell size, total area of cells within crumb, and the cell density of four formulations of butter cakes

Cake sample	Number of cells (C)	Average cell size (mm^2)	Total area of cells within crumb (%)	Cell density (C/mm^2)
Control	695 + 101.80^a	4.975 + 1.45^a	14.22 + 2.76^a	0.211 + 0.05^a
10% fat-replaced	828 + 71.06^a	4.694 + 0.62^a	16.21 + 0.75^a	0.216 + 0.03^a
30% fat-replaced	889 + 230.72^a	5.291 + 2.05^a	18.66 + 3.81^a	0.208 + 0.07^a
50% fat-replaced	359 + 89.77^b	10.991 + 1.27^b	16.35 + 3.29^a	0.092 + 0.01^b

Mean in the same column with different letters are significantly different ($p< 0.05$)

reduces batter stability, thereby producing bigger cells with lower cake heights. According to Sikorski and Sikorska-Wisnieska (2006), the presence of fats in bakery products produced shortening effects and surface-active properties. These factors showed that the functions of fats in baked goods are to disrupt gluten network, produced high volume final products with even-textured crumb grains, as well as to prevent loss of gas by stabilizing the gas bubbles in batter (Rodriguez-Garcia et al. 2014a). This explained the higher number of interconnected air cells and heterogeneous crumb structure in the higher fat-replaced butter cakes in the present study.

SCANNING ELECTRON MICROSCOPY (SEM)

Figure 2(a)-2(d) represent the micrograph of crumb of butter cakes with different percentages of avocado incorporated as fat replacer. Figure 2(a) shows the micrograph of control cake crumb. A few gelatinized starch granules were observed on the crumb with a few of them trapped in the protein matrix. Gelatinisation changed the original shape of starch granules in which they appeared shriveled, shrunken and distorted (Ashwini et al. 2009; Sowmya et al. 2009). The degree of starch gelatinization was among the factors affecting the crumb structure of baked products and the shelf life as well (Blaszczak et al. 2004). Figure 2(b) represents the micrograph of crumb of 10% fat-replaced butter cake. A few gelatinized starches can be seen embedded partially in the protein matrix.

Observation on the micrograph of butter cake crumb with 30% fat-replaced cake (Figure 2(c)) showed wrapped starch granules of different sizes in the crumb. The different size of starch granules differed in their shapes with larger lenticular shaped granules and the smaller round-shaped granules (Prabhasankar et al. 2003). The wrapped starch

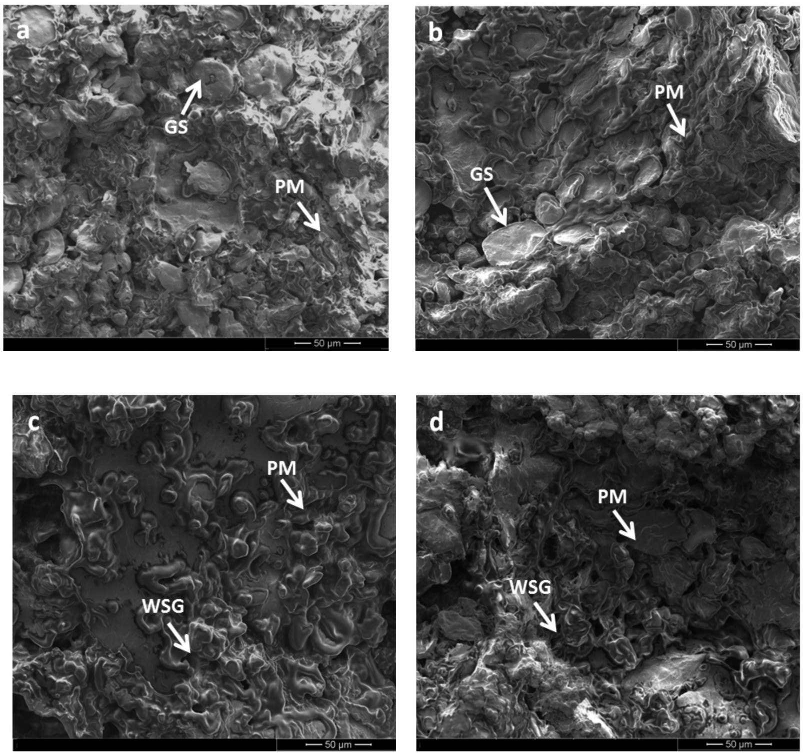


FIGURE 2. Scanning electron micrograph of cake crumbs incorporated with avocado puree in butter cakes (magnification 1000×). (a) 0%; (b) 10% fat-replaced cake; (c) 30% fat-replaced cake; (d) 50% fat-replaced cake. PM: protein matrix; GS: gelatinized starch; and WSG: wrapped starch granules

granules and gelatinized starches both were visible in the micrograph of cake crumb with 50% avocado incorporation (Figure 2(d)). Next, discontinuous and ruptured protein matrices were observed in the micrographs (Figure 2(a)-2(d)). The control cake and cake with minimal replacement of fat (Figure 2(a)-2(b)) had a thinner protein matrix as compared to the higher fat-replaced cake (Figure 2(c)-2(d)). Increment of avocado incorporation in the butter cakes resulted in smoother and thicker protein matrix. The network covering starch granules was the protein components of wheat flour. These matrix components were composed of proteins, lipids and solubilized starch (Sowmya et al. 2009).

Conclusion

In general, addition of avocado in the butter cakes affected its microstructure and physical properties. Batter specific gravity increased as the addition of avocado puree was increased. Addition of avocado puree causes lower number of air cells and promotes the formation of bigger bubbles and resulted in lower cake volume. The texture profile analysis indicated that the hardness and chewiness values increased significantly while cohesiveness was not affected. Some modification in the formulation is necessary to improve the product and further work is needed to determine the storage stability condition and sensory acceptance of the new products.

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