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Use of riceberry bran to reduce oil absorption in puffed cracker

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Abstract

A novel ingredient, riceberry bran (RB), was studied for its high fibre content in order to evaluate its potential to reduce oil content in puffed crackers. The objective of the present work was to study the effect of different ratios of tapioca starch (TS) and RB on the physical and chemical quality and sensorial characteristics of puffed cracker. The ratio of TS to RB used in the present work were 100:0, 75:25, 50:50, 25:75 and 0:100. The expansion ratio and oil absorption significantly decreased with increasing RB ratio. The minimum expansion was shown in cracker made with a ratio of 0:100. The amount of oil absorption decreased with increasing fibre content in the pellet. In term of sensorial descriptive analysis, adding RB resulted in increased hardness, but significant decreased in expansion. It was also found that puffed cracker made with a ratio of 75:25 scored the highest in appearance, colour, taste, flavour, crispness and overall preference. Furthermore, there was a decrease in acceptance among consumers with increasing ratio of RB. Therefore, it is henceforth suggested that RB should be included no more than 50%

Introduction

Riceberry (Oryza sativa L.) rice, hybridised from Hom Nil rice and Hom Mali (Jasmine 105) rice and created by the Science Centre of the National Research Council (Kasetsart University, Thailand), is purple rice possessing a unique aroma and high nutritional value. The Commerce Ministry of Thailand aims to increase riceberry rice cultivation by growing primarily in north and north-eastern Thailand. Riceberry has been recently developed with the aim of providing optimum nutritional benefit to consumers with high iron because riceberry has three times more iron than other rice varieties. Riceberry rice also has considerable antioxidant properties making it ideal for use with food products especially those oriented for dietetic uses. Riceberry bran (RB) is the part of the grain or a by-product from rice milling which contains many quality nutrients including fat, fibre, anti-oxidative compounds and vitamin E complex (tocopherols and tocotrienols) (Rogers *et al*., 1993; Gysin *et al*., 2002; Leardkamolkarn *et al*., 2011).

Fried cracker refers to a type of snack that has gained popularity amongst consumers, and is made from tapioca starch (TS) as the main ingredient. Meat, vegetables or fruit flavours may be mixed into the product with seasoning for added variety. The starch mixture is moulded as desired and steamed. Then the cooked dried starch is formed into pellets before frying. Pellets have moisture content of less than 12% by weight (Mariotti *et al*., 2006; Hoke *et al*., 2007; Nath and Chattopadhyay, 2008).

The process of frying the cracker gelatinises its starches. The flour and water content are critical components in the creation of gel. Starch or flour mixed with water becomes gelatinised through changes in the molecular arrangement of starch molecules. Heat destroys hydrogen bonds between starch molecules which combine with water resulting in swelling of the starch granules (Mariotti *et al*., 2006; Hoke *et al*., 2007; Nath and Chattopadhyay, 2008). Thus, water content affects the process of gelatinisation of starch. Conversely, the amount of expansion of cracker is reduced when the amount of water and flour are reduced (Mohamed *et al*., 1988). For the desirable characteristics of cracker products, starch dough must be made with at least 61% water content (Wang *et al*., 1991). The chilling process causes adjacent amylose molecules to align with hydrogen bonds. The resulting structure can absorb

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water forming an opaque gel through the process known as retrogradation in which the prolonged duration of aging gel caused increased hardness of the gel (Jiamjariyatam *et al*., 2015). After the gel is chilled and cut into thin strips, drying method can be used to reduce the moisture content of the cracker dough. As moisture is a vital factor in expansion of the cracker, the suitable amount of moisture content to puff the cracker has been determined at between 6-12% (Gutcho, 1973). The frying process causes steam to form inside the dough thus causing it to expand. As the product is porous, the moisture content is low (Lai and Cheng, 2004; Mariotti *et al*., 2006). Thus, products absorb oil in the cavitation remaining after water has evaporated, thereby leading products to have increased oil absorption (Moreira *et al*., 1997; Korkida *et al*., 2000). However, amylose content of starch in a range of 5-20% reduces oil absorption of fried products (Charles, 1969; Boischot *et al*., 2003; Cheow *et al*., 2004; Saeleaw and Schleining, 2010; Jiamjariyatam *et al*., 2015).

Deep-fat frying is puffing process using oil as heat transfer medium to modify the product above the boiling point of water (Varela *et al*., 1988; Chen *et al*., 2009), thereby causing oil to penetrate into the product while water is eliminated. Consequently, oil absorption is a crucial factor, though nutritionally undesirable, and more appealing for its organoleptic qualities which it provides to fried food (Pedreschi and Moyano, 2005). Thus, the fried cracker containing mainly flour or starch has a rather low nutritional value due to the high oil content.

Currently, health consciousness is becoming more common among the population. As such, many people are concerned to eat healthy foods beyond those containing typically recommended nutritional content, to those with substances with specific health benefits such as foods that may help prevent diseases. As can be seen from market demand for low fat products, reduced oil content in fried products is a major concern of consumers especially given the increase in rates of overweight and obesity in the last few years. In addition, obesity is of concerns as it may be related to other non-communicable diseases.

Oil absorption is influenced by the initial moisture content of food ingredients, product shape, porosity of coating, and the method of frying (Fan and Arce, 1986; Pinthus *et al*., 1993; Pinthus *et al*., 1995; Blumenthal, 1999; Parimala and Sudha, 2012). Low or no fat products are in increasing demand in the consumer food market which has resulted in more people seeking to consume products that reduce cholesterol, hypertension, and heart diseases (Haghshenas *et al*., 2014). The effect of rice bran on oil uptake has not been previously investigated. Specifically, it is not well known which kinds of carbohydrate (fibre) are known to reduce the oil absorption of fried foods. Hydrophilic hydrocolloids used for reducing oil absorption during frying have been shown effective in previous studies. Parimala and Sudha (2012) reported that the addition of 0.5% guar gum contributed to "puris" having a lower oil content frying while retaining a spongy texture. Other hydrocolloids have also been reported to reduce oil uptake in deep-fried products (Frietas *et al*., 2009; Kim *et al*., 2011) including basil seed gum and thymol (Khazaei *et al*., 2016), beta glucan (Lee and Inglett, 2007), oat and wheat brans (Yadav and Rajan, 2012) and methylcellulose (Usawakesmanee *et al*., 2008). Therefore, the use of RB could be the method to reduce the oil content of snack foods.

The present work expects high nutritional quality of fried products by reducing oil absorption. The evaluation of RB properties and possible uses has shown a high nutritional value, in particular due to a high fibre content of 24-29% (Juliano, 1993). Thus, RB can provide textural qualities, especially to deep-fried products. The objective of the present work was therefore to evaluate the effects of RB on the technical quality of puffed products with graduated replacement of 25, 50, 75 and 100% of TS.

It is hypothesised that RB can reduce the oil uptake of fried products. The present work also aimed to (a) evaluate the effects of RB on the properties of puffed cracker, (b) investigate the correlation between fibre content of pellet and oil absorption of final product, (c) and evaluate the sensory acceptability to consumers of the resultant puffed cracker. The information obtained can be used for application in the manufacture of deep fried products with desirable sensorial characteristics.

Materials and methods

Materials

Tapioca starch (TS) (Tonson, Thailand) was mixed with RB (Seri market, Thailand) in the ratios of 100:0, 75:25, 50:50, 25:75 and 0:100. This starch mixture contained 12.34 ± 0.23% moisture and was kept at 4°C for further processing. The proximate analysis of RB was determined according to AOAC (1990). The moisture content, total lipid, protein, total dietary fibre and carbohydrate of RB was 8.43 ± 0.80%, 17.92 ± 0.20%, 16.71 ± 0.20%, 24.17 ± 0.19% and 32.72 ± 0.54%, respectively.

Puffed product preparation

The basic formulation for the puffed cracker composed of 16.2% TS, 81.2% water, 0.5% salt, 0.6% sugar, and 1.5% pepper. To obtain pellets, the starch mixture in a ratio of 100:0, 75:25, 50:50, 25:75, and 0:100 of TS to RB was suspended by mixing with 60% water content according to Jiamjariyatam *et al*. (2015). The mixture starch and water was mixed for 5 min at 60°C by electric hand mixer (Binzzia MQ735, Germany) at maximum speed. Minor ingredients were then added to the starch paste and mixed for 5 min at 100°C. The starch paste was then transferred to paper moulds (approximately 35°C) and kneaded to a 2 mm thickness and placed in a chamber at 7°C for 36 h. After aging at 7°C, the starch gel produced was cut into 2 × 3 cm pieces and dried in a hot air oven (Binder, Germany) at 50°C for 24 h. To puff the product, the pellet was then fried in rice bran oil at 110°C for 5 sec. Puffed product samples were placed in the plastic container with oxygen absorber and stored at 27 ± 2°C and 75% RH for 3 d before evaluation.

Moisture content and fibre content of pellets

The moisture content of pellets was measured with moisture analyser (Ohaus MB25, USA) at 160°C. For the estimation of dietary fibre, the defatted pellets were processed using a blender. The dietary fibre content of pellets was determined by the AACC method 32-07.01 (AACC, 2010).

Hardness, expansion ratio and bulk density

The hardness of the puffed cracker was measured using TA-XT2i texture analyser (TA-XT2i; Stable Micro Systems Ltd., Surrey, UK) using 20 kg load cell. Pre-test speed and test speed were 1 mm/sec, while the post-test speed was 10 mm/sec. Three-point bending test were applied to measure the maximum force (N), which is referred as hardness of the cracker, and at least ten different samples were measured. The dimension of pellets was measured to calculate the characteristics of the puffed product. The expansion ratio was calculated from the ratio of volume from puffed cracker to pellet according to the method of Saeleaw and Schleining (2010). The bulk density of the puffed product was measured using sesame seed displacement according to the AACC method 10-05.01 (AACC, 2010), and calculated as the ratio of apparent volume to weight.

Oil absorption of puffed cracker

The oil absorption (oil content) was analysed using Soxhlet's method according to AOAC (1990).

Image of the puffed cracker

A photograph of the puffed product was taken with a camera (Nikon SMZ 1000, Japan).

Microstructure of puffed cracker

The surface and cross section of puffed crackers was illustrated using a scanning electron microscope (SEM) (JEOL: JSM-5800LV; Jeol Ltd., Tokyo, Japan).

Descriptive sensorial analysis

Training and vocabulary development

A total of 30 panellists who like to eat fried snack more than three times/week were screened and selected by the basic taste and threshold ranking test. The panel was composed of 10 panellists (male = 5, female = 5) who were students aged 20-23 years from the Department of Home Economics, Srinakharinwirot University, Bangkok, Thailand. The panel was trained over a period of 36 h to learn the techniques for sensorial evaluation using 15-point intensity scale to describe the snack's attributes. The definitions and evaluation methods were discussed by the panellists. The five sensorial attributes and representative reference were obtained from the panellists' opinions. Commercial snacks from markets were chosen to describe the textural mouth feel, and model samples were selected to refer to the appearance characteristics of the experimental cracker products. The intensity scores for all attributes were conducted by consensus of the panellists. The ballot or handout was used by each panellist.

Product evaluation

Five puffed cracker products were evaluated with descriptive analysis. The evaluation of all five puffed cracker took approximately 15 h. Each sample was evaluated for the five listed attributes including appearance, texture and after taste using a 15-point numerical scale with anchored references.

Acceptance test

Thirty staff and students (male = 15, female = 15) who were 20-23 years from the Faculty of Science, Srinakharinwirot University were recruited to evaluate the cracker preferences. The five test samples were randomly presented in a white dish coded with random 3-digit numbers. Puffed crackers were evaluated for preference according to appearance and texture using seven-point hedonic scales (1 = not like at all, to 7 = like very much).

Statistical analysis

All measurements were done in triplicate. The analysis of variance (ANOVA) was used to determine the effects of RB content on the cracker's characteristics. Duncan's new multiple range test was used to compare means at $\alpha = 0.05$.

Results and discussion

Moisture content of pellets

The moisture content of the pellets containing different ratios of TS to RB was about 4.4-4.7% (data not shown) and not significantly different ($p > 0.05$). This could be due to control of cooking, cooling, aging and the drying process of starch. Furthermore, the moisture content of pellet was also not significantly different.

Dietary fibre of pellets

The dietary fibre of pellet cracker made from TS and RB in ratios of 100:0, 75:25, 50:50, 25:75 and 0:100 is shown in Figure 1a with differences measured at a significance of $p \leq 0.05$. The puffed cracker containing TS to RB at ratios of 100:0 had the least fibre content at 3.58%. Increasing RB resulted in significant increase in fibre content ($p \leq 0.05$). The puffed cracker at ratio of TS to RB of 0:100 had the highest fibre content at 9.91% due to rice bran fibre range of 24-29% (Juliano, 1993). Therefore, increasing the proportion of RB provided an increased percentage of fibre in the pellet.

The oil content of puffed cracker

The differences in oil absorption ability of five crackers ($p \leq 0.05$) are shown in Figure 1b. Cracker containing a ratio of TS to RB of 100:0 had the most oil content at 36.62%. Increasing RB content resulted in significant decrease in oil content ($p \leq 0.05$). Thus, cracker with TS to RB ratio of 0:100 provided the minimum amount of oil content at 13.80%. This result suggests that the oil content of puffed cracker correlated to the fibre content in the pellets.

Physical measurements of fried-puffed cracker

Hardness and expansion ratio

The hardness of puffed cracker is shown in Figure 2a. The minimum hardness was obtained from cracker with no RB content. Increasing RB content resulted in significant ($p \leq 0.05$) increase in hardness of cracker. The significant difference ($p \leq 0.05$) in expansion ratio of cracker containing TS to RB in ratios of 100:0, 75:25, 50:50, 25:75 and 0:100 are shown in Figure 2b. The maximum expansion ratio (10.17) was obtained from cracker with no RB content. Increasing RB content resulted in significant ($p \leq 0.05$) decrease in the expansion ratio of cracker. The ratios of TS to RB of 75:25, 50:50 and 25:75 provided expansion ratio of 8.77, 7.66 and 3.73, respectively. Cracker composed only of RB had the lowest expansion ratio of 1.05. Figure 4 also shows that increasing the amount of RB in pellets resulted in smaller air cavities in the cracker. This also affected the higher hardness of puffed cracker.

The ratio of TS to RB of 100:0 resulted in a spongier and more expanded texture. TS has a greater ability to absorb water, thus starch granules can swell leading to increased gelatinisation. Starch gelatinised through retrogradation also provides a more desirable appearance. Cracker expansion was reduced by the presence of RB which is a source of fibre. This form of fibre thereby interrupts the gelatinisation process and makes the starch gel form a weakened texture. Starch is the main component of snacks, and is responsible for their structural attributes. The addition of fibre in snacks most often leads to effects on product quality due to poor expansion volume, greater density and hardness, and less crispness (Robin *et al.*, 2012). Insoluble fibres, such as cereal bran, can result

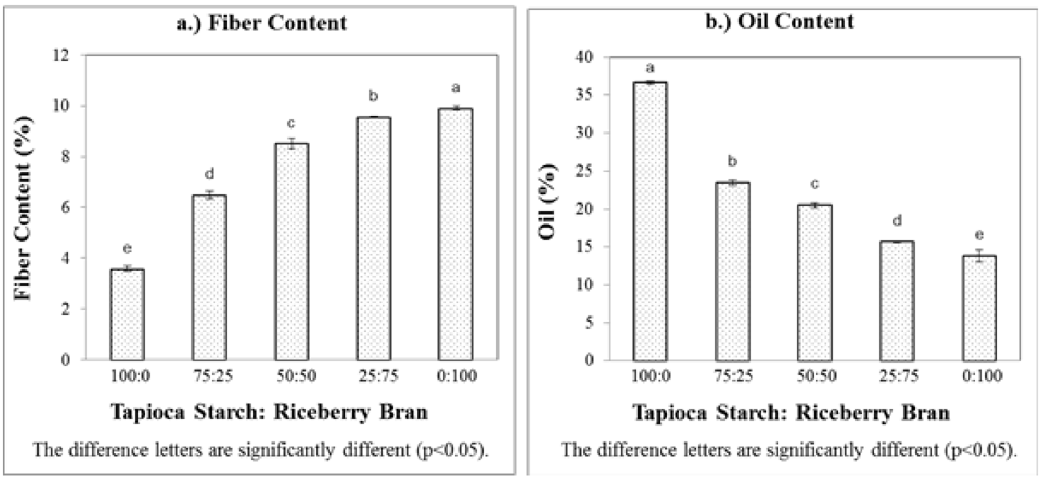

Figure 1. Effects of tapioca starch and riceberry bran on (a) fibre content of pellet, and (b) oil content of puffed cracker (b).

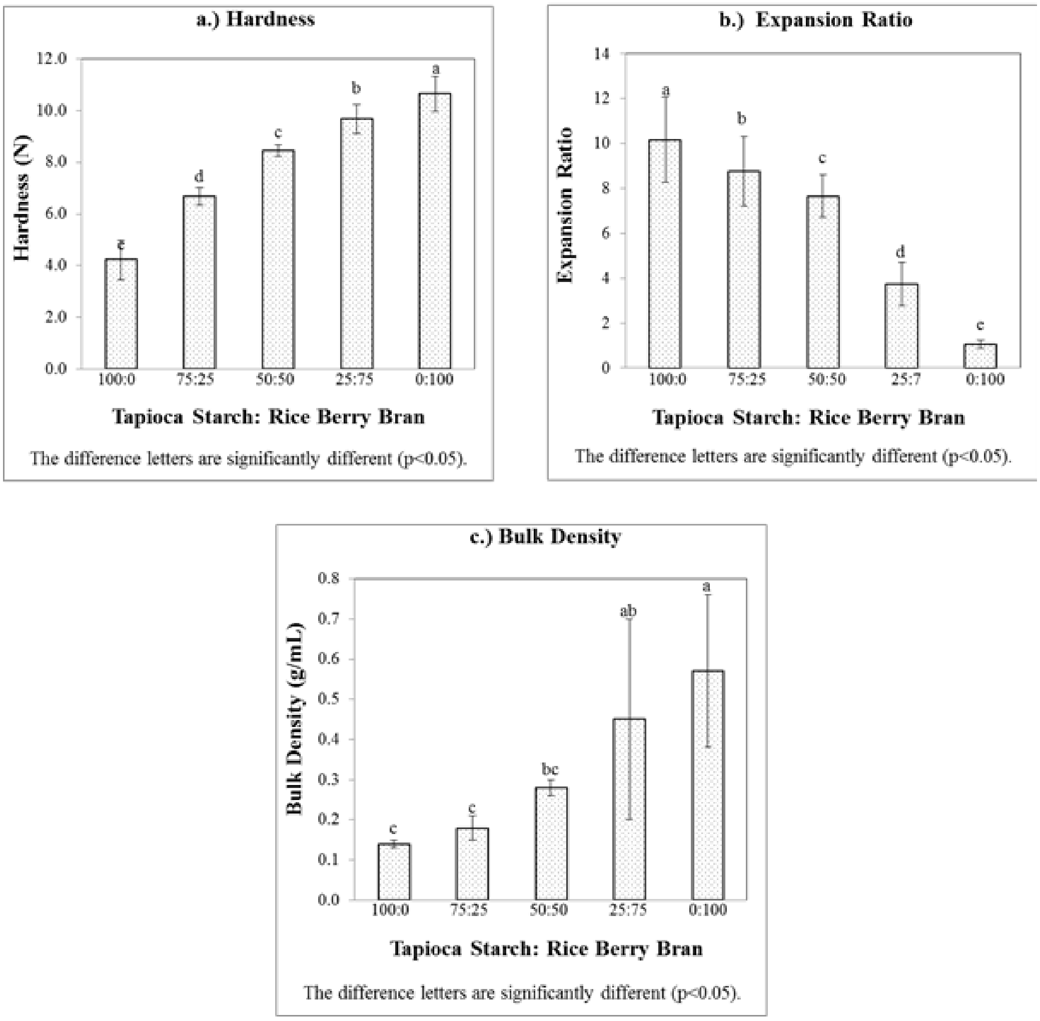

Figure 2. Effects of tapioca starch and riceberry bran on (a) hardness, (b) expansion ratio, and (c) bulk density of puffed cracker.

in poor water absorption of starch dough in the gelatinisation process and may cause unstable bubble membranes during the frying process (Brennan *et al*., 2008; Foschia *et al*., 2013). Therefore, crackers with higher fibre and protein content had poor expansion properties.

Bulk density

The bulk densities of puffed cracker based on a ratio of TS to RB of 100:0, 75:25, 50:50, 25:75 and 0:100 are shown in Figure 2c. The minimum bulk density (0.14 g/mL) of cracker was found with content ratio of TS to RB of 0:100. Bulk density increased significantly ($p \leq 0.05$) with increasing ratio of RB. Thus, cracker bulk density is proportional to the RB content.

Bulk density is correlated with the expansion ratio. The lower the bulk density, the higher the expansion ratio. This is consistent with the results obtained in the cracker made with a ratio of TS to RB of 0:100 which had the maximum bulk density and the minimum expansion ratio. This was the consequence of the addition of RB whose fibre prevented starch gelatinisation, thereby resulting in a soft gel. The wall of the starch network was too weak to resist steam or vapour pressure from inside the dough. Therefore, cracker with high bulk density had a low expansion capability. This corresponds with dietary fibre which increased bulk density and cellular structures have smaller cell sizes and a higher cell density (Brannan *et al*., 2008). A fibre ratio will significantly affect the dough by decreasing its extensibility with bubble release occurring due to the weakened starch network of the dough, thus resulting in a hard texture and loss of crispness (Foschia *et al*., 2013). Moreover, the high protein in RB was determined from proximate analysis about 16.7%. The increasing RB in the formulation of puffed cracker was due to high protein content in cracker. Protein was one factor causing the increase in hardness and bulk density but decrease in expansion ratio of puffed cracker.

The correlation between dietary fibre and oil content

The correlation between pellet fibre content and oil absorption properties of five crackers showed significant differences ($p \leq 0.05$) as shown in Figure 3. Increasing pellet fibre content decreased oil absorption capacity of puffed crackers. This was due to RB being a source of dietary fibre in which the bran has high water retention capacity causing less moisture loss which has a great effect by reducing oil uptake during deep-frying (Waszkowiak *et al*., 2001; Altunakar *et al*., 2004). Several researchers have also found that the addition of RB to starch pellets resulted in higher fibre content thus reducing the amount of oil in the final product. For instance, Karlovic *et al*. (2009) reported that the addition of fibre to batter reduced oil absorption in fried chicken products because the added fibre interrupts oil penetration into the chicken. Therefore, the addition of fibre to batter resulted in decreased hardness but increased flexibility of the fried product. Yadav and Rajan (2012) studied the addition of fibre to reduce oil absorption in fried bread (poori) made from wheat flour mixed with wheat bran and oat bran. They found that the use of oat bran had a significant oil absorption reduction impact on products. Specifically, it was found that oil absorption decreased with the addition of 3 g wheat bran and 11 g oat bran per 100 g wheat flour. Moreover, the addition of gellan gum and guar gum as hydrocolloid coatings was found to markedly reduce oil absorption in potato strips (Kim *et al*., 2011). The reduction of oil content was due to protein content in puffed cracker. The increasing protein content was found from adding the RB. The RB was source of high protein (16 g/100 g). Both fibre and protein were the main factors for decreasing the oil content of product. Freitas *et al*. (2009) stated that whey protein showed great effectiveness in reducing fat absorption, offering a reduction of 27% for a tapioca purée product.

Photographic image of pellet and puffed cracker

Figure 4 shows the images of pellets and puffed crackers formulated in the present work. As RB increased, no obvious differences were observed in the five pellets. However, increasing RB content tended to limit the expansion of the puffed cracker which had fine porosity. No RB containing crackers displayed significant expansion or large pore. Expanded products were high in RB and protein content, and provided for less expansion or puffiness in the final product due to the inhibition of gas-bubble coalescence which led to a finer and harder structure.

Microstructure of puffed cracker

Figure 4 shows the structural changes as affected by RB content in the surface and cross-sections of puffed crackers using SEM. Interior air cells of high TS puffed cracker were larger in size but fewer in number as compared to cracker with increasing RB content. As RB content increased, obvious differences were observed in the puffed crackers. Increasing RB caused the cracker to become more compact but with a finer structure and more homogenous air cell walls or porosity. Thus, it is believed that the RB content may have contributed to the difference in the structural integrity of cells in cracker.

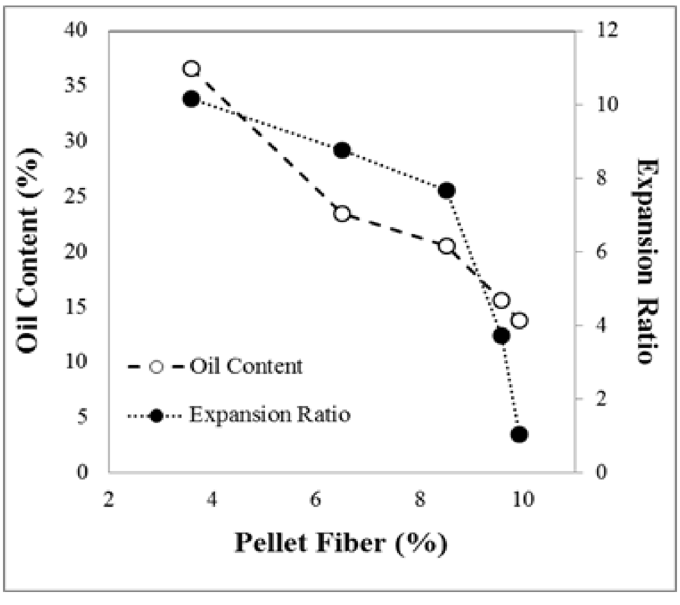

Figure 3. Correlation between pellet fibre and oil content, and pellet fibre and expansion ratio of puffed cracker.

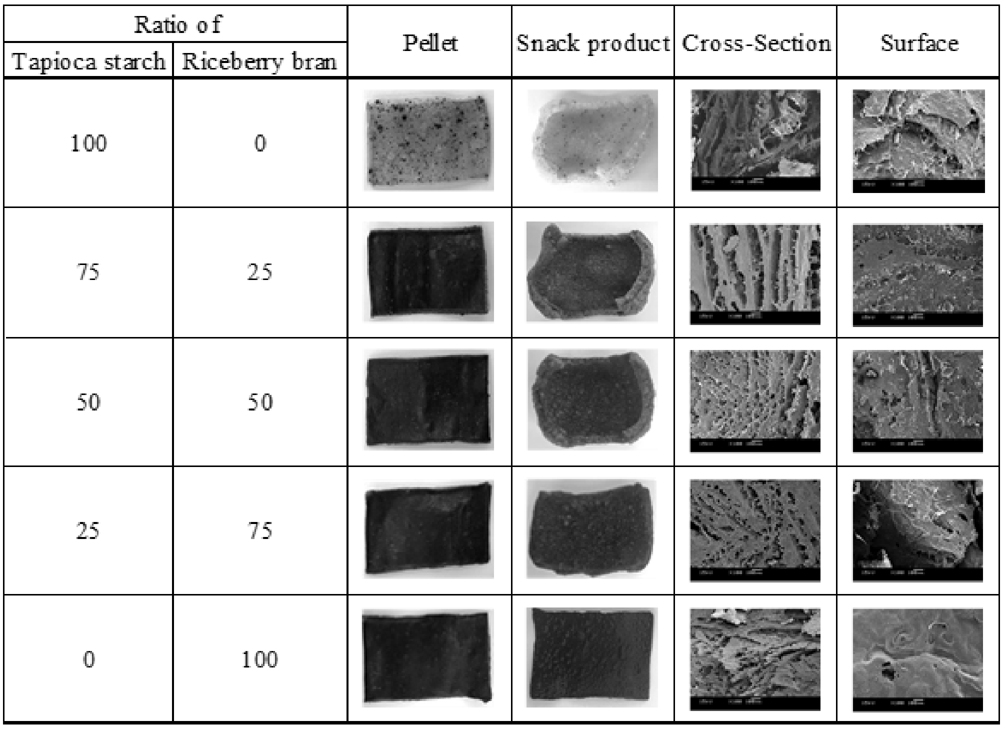

Figure 4. Images of pellet and puffed crackers as affected by tapioca starch and riceberry bran at different ratios.

Descriptive sensorial analysis

A lexicon composed of 11 sensory attributes with definitions was developed by the panellists. Sensorial characteristics were divided into two main categories: appearance and texture. The reference products (commercially available in Thai markets) were used in the sensorial analysis. The intensity of organoleptic characteristics of crackers containing ratios of TS to RB of 100:0, 75:25, 50:50, 25:75 and 0:100 is shown in Figure 5a. The five different ratios of TS and RB elicited significant ($p \leq 0.05$) differences in intensity scores in terms of hardness and brittleness. Increasing the content of RB was accompanied by an increase in hardness but significant ($p \leq 0.05$) decrease in expansion, puffiness, crispness and oiliness. Sensorial characteristics were in accordance with physical and chemical properties as previously determined.

In terms of the sensorial quality of the cracker, it was found that adding more RB to pellets increased hardness but decreased brittleness and crispness. It is believed that the part of fibre in RB interfered with the gelatinisation process of starch leading to unstable starch gel network. Incomplete gelatinisation results in loose starch interaction. A weakened network of dried starch cannot resist the high vapour pressure from inside the pellet during the frying process (Foschia *et al*., 2013). As a result, crackers with higher RB showed poor expansion and less crispness. These crackers tended to be crunchier and more brittle. The cracker appearance displayed fine air cells and high porosity. However, the degree of oiliness was found to decrease with increasing RB content. Similarly, Karlovic *et al*. (2009) reported that increasing dietary fibre from 0.5 to 2.5% in batter coating decreased oil absorption of fried chicken

Acceptance

Significant difference ($p \leq 0.05$) were found in the overall sensorial acceptance of the five crackers according to preference in terms of crispness, colour, flavour and taste as shown in Figure 5b. Crackers made with a ratio of TS to RB of 75:25 provided the highest score in all attributes at the level of "like slightly - like very much" (5.3-5.9). Crackers containing a ratio of TS to RB equal to 0:100 had a minimum preference score at the level of "do not like to dislike". Increasing the ratio of TS to RB significantly ($p \leq 0.05$) decreased the preference score.

The addition of RB to the puffed cracker resulted in poor expansion and a very dark purple colour in the final product with a brittle to hard texture. Moreover, the panellists stated that the optimal RB content cracker had a unique smoky or burnt flavour thus affecting acceptance. It was found that the overall acceptance of the final product decreased with increased RB content but the ratio of TS to RB of 50:50 in crackers showed the greatest consumer acceptance.

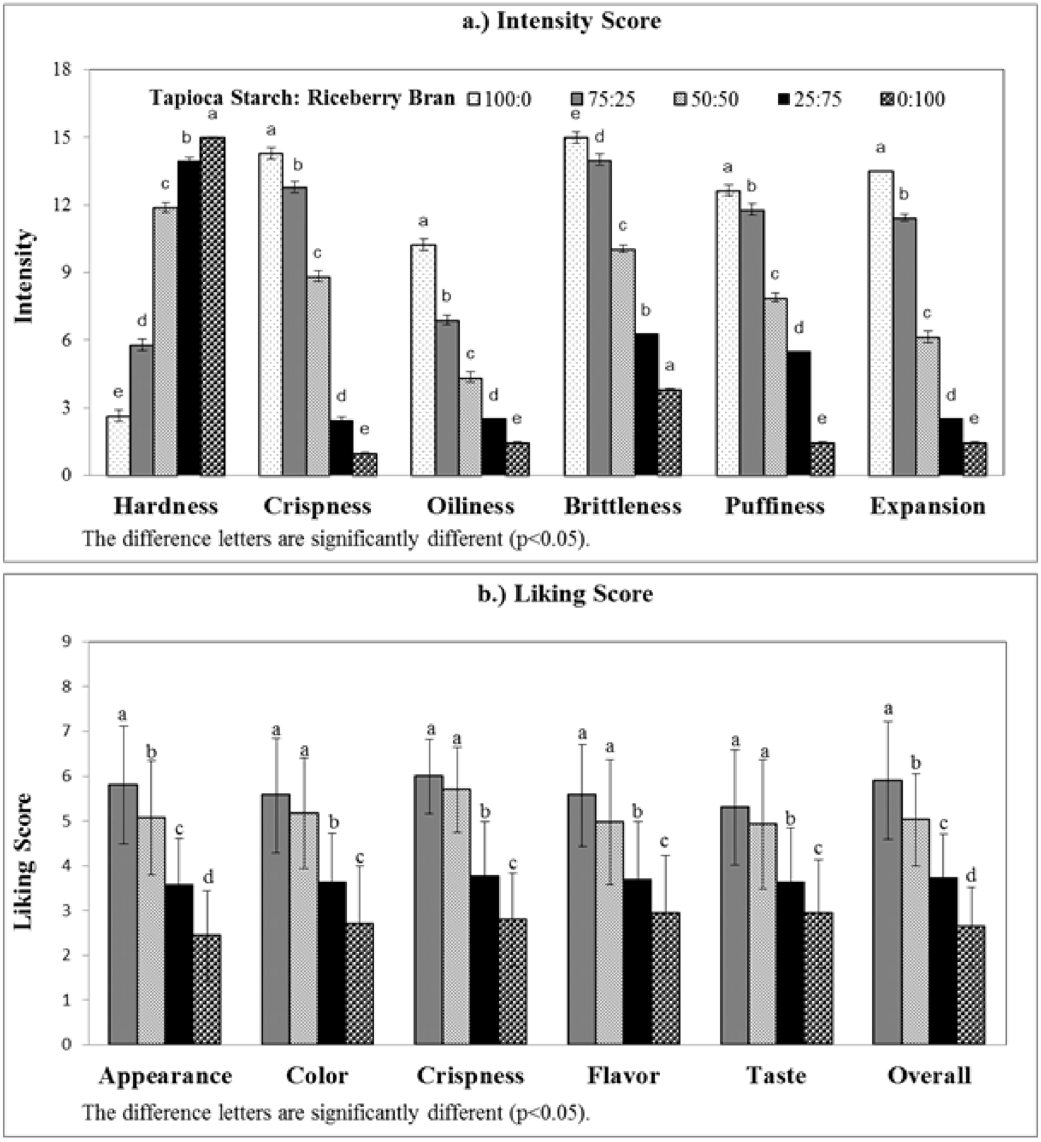

Figure 5. Effects of tapioca starch and riceberry bran on (a) intensity score, and (b) liking score of puffed cracker.

Conclusion

Increasing concern on overweight has led to an awareness of the importance of reduced fat food products, in particular, low fat snack products. In the present work, it was found that replacement of TS with RB significantly altered the fibre content in pellets as well as the expansion ratio, bulk density, sensory characteristics and acceptance of the resulting puffed products. Sensorial characteristics, as well as crispness of puffed products, were influenced by higher levels of RB. Increasing RB content resulted in a decrease of expansion ratio but an increase in bulk density of the puffed cracker. The addition of RB was responsible for an increase in fibre content resulting in lower oil absorption in the cracker. Increasing RB also resulted in increased hardness but decreased brittleness, expansion and crispness. Crackers composed of a ratio of TS to RB of 75:25 were found to have the highest preference score. Although, the replacement of TS by using RB will cause the increase of the cost of production, the replacement of TS with RB could decrease oil absorption and good for health. The snack composed of 100% RB yielded poor characteristics but it is potential to reduce oil content for further food. The technical process and main ingredient of each product should be further studied to improve the product attributes for desire texture.

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