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Development of a snack bar containing popped rice (Khai Mod Rin) for pre-school children

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Abstract

The objective of this study was to investigate the effect of moisture content (10%, 14% and 18%) and popping time (30, 60 and 90 s) on the expansion volume of popped, dried unhusked rice. Khai Mod Rin rice, a local rice from Nakhon Si Thammarat, was used. From this analysis, the development of popped rice snack bars was done for children from ages 3 to 5. Seven recipes of the snack bar (35 - 55% popped rice with 25 - 45% honey and 10 - 30% peanut butter) were obtained by using a mixture design. The hardness of the snack bar and the acceptability of the hardness (by the panel) were then assessed. Finally, acceptability by the preschool children was evaluated. Results showed that moisture content from 10% to 14% with the popping time at 90 seconds ($p < 0.05$) was found to be the best for providing the highest expansion volume from unhusked rice. In addition, from the hedonic testing of the target group children, the ideal popped rice snack bar recipe containing 55% popped rice, 35% honey and 10% peanut butter possessed the highest hardness value (114±9 N) and acceptability score (89%). Popped rice has a good opportunity to be served as a snack for preschool children.

Introduction

In 2012, the snack bar market was reported to reach $34 billion, and it is still growing today. With so many children consuming snacks (Lukovitz, 2012), the increasing rate of unhealthy diets for them has to be a concern (Harris *et al*., 2012). Some snacks contain high energy, fat, high sugar and high sodium (Potter *et al*., 2013). This can cause high blood pressure and increase the risk of cardiovascular diseases for humans (Rodrigues *et al*., 2014). Furthermore, a 2010 survey from the US about snacks and children reported that 25% of preschool children's daily intake of energy from snacks (Piernas and Popkin, 2010). Most of the snacks in the world contain a high energy density (Graaf, 2006). It is evident that energy-dense snack bar consumption and obese children are related (Mirmiran *et al*., 2014).

Normally, cereal grains such as rice, wheat and corn are used as the main ingredients for producing snack bars (Poutanen *et al*., 2014). In this research, rice was selected to be used in the snack bar because it is an important source of carbohydrates, protein, lipid, dietary fiber, vitamins and minerals (Slavin, 2004; Liu *et al*., 2013). In 2012-2013, Suhem *et al.* (2012) and Jaroenkit *et al*. (2013) reported that brown rice snack bars had high nutritional value suitable for preschool and primary school children in Thailand. Furthermore, as rice is the main grain in Asian countries, the intake of brown rice has been reported to lower risks of type 2 diabetes and cardiovascular diseases (Kim *et al*., 2011). In this research, popped rice of Khai Mod Rin, a local rice in Nakhon Si Thammarat, Thailand which contains high amounts of protein (9.7%), vitamins and minerals was selected as major ingredient of the snack bar developed for pre-school children ages 3-5 years."

Nevertheless, according to the sensory test from pre-primary school on the brown rice of snack bar, Suhem (2012) demonstrated that texture and expansion ration of brown rice snack bar was found to be related to children liking scale. Higher hardness and expansion of snack rice bar possessed higher hedonic scale. Therefore, the improvement of texture and expansion volume for rice snack bars is necessary for moods and emotions of children. In addition, to improve the taste and nutrition of popped rice snack bar, honey and peanut butter were selected as the main ingredients. Peanut butter is a good source of proteins necessary for the morning meal (McWatters *et al*., 2006). Honey collected from a wide range of flowering plants, usually contains proteins, lipids, minerals, and vitamins according to dietary

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requirements (Avni *et al*., 2014). Protein from honey is essential for proper development and function of children body tissue, muscles, membranes and glands (de Arruda *et al*., 2013). Therefore, searching for suitable recipe of popped rice snack bar with improved texture for pre-primary school children is the main aim of this research.

Materials and Methods

Unhusked rice collection

Khai Mod Rin (NSRC9500113) unhusked rice, a local rice grown in the Nakhon Si Thammarat province, was collected for this study and it was obtained from the Nakhon Si Thammarat Rice Research Center. It was harvested in February 2014.

Effect of moisture content and popping time on the expansion volume of popped rice

Unhusked rice (100 g) at different moisture content (14% and 18%) was prepared in a stainless sieve inside a plastic container (120 mm wide x 150 mm long). The initial moisture of unhusked rice was 12%. The container was filled with sterilized water until it reached a depth of 25 mm. Then the container was covered with a plastic lid to achieve moisture on the inside. The container was kept at a temperature (~30°C) for 24 and 48 hours to reach the moisture content of approximately 14% and 18% on the unhusked rice, respectively. For preparation, 10% of the unhusked rice was dried by a natural convection at room temperature (~30°C) for 24 hours or until moisture drops to nearly 10%. Before popping, the determination of each sample's moisture content was done according to the AOAC (1995). The unhusked rice was dried at 105°C (Binder, Tuttlingen, Germany) for 24 hours or until a constant weight was found. The weight loss was used to calculate the moisture content (% wet basis).

Each unhusked rice sample was then popped with an electric pan (MP-16Q, Imarflex Industrial Co.,Ltd., Thailand) at a temperature of roughly 200°C (Infrared Thermometer (UT301A, UNI-T Technology (China) Co., Ltd., China). For this study the popping times were set at 30, 60 and 90 s. After being popped, the expansion volume of the popped rice was determined by the method of Dofing *et al*., (1990) as follows:

$$\text{Expansion volume (EV)} = \frac{\text{Popped volume (ml)}}{\text{Sample weight (g)}} \quad \text{Eq.1}$$

Texture properties of the popped rice snack bar using mixture design

This work used a mixture experiment with the three main components (35 - 55% popped rice, 25 - 45% honey (75 ºBrix, Thai honey, Henglee community Business Co., Ltd.) and 10 - 30% peanut butter, (Skippy, Unilever China Co., Ltd.) of the 64g popped rice snack bar. The design consisted of seven runs and is shown in Table 1. From the design point, each run was prepared. For example, point 1 consisted of 35% popped rice, 35% honey and 30% peanut butter, totaling 64g. Then, the minor ingredients (13g resin, 12 g dried pineapple, 4 g pumpkin seeds, 3g black sesame seeds, and 8g sunflower seeds) were mixed in with the main ingredients and added into stainless boxes (10 cm wide x 10 cm long x 3 cm thickness). All boxes were placed into an oven (EO-18K, Sharp Thai Co. LTD., Thailand) at 175°C for 15 minutes. The popped rice snack bars were removed from the boxes and hardness was then measured by using a texture analyzer (LR 5K, Lloyd Instruments, United Kingdom). A piece of popped rice snack bar was cut into 2 cm wide × 5cm long × 1.5 cm thick. Then, the snack bar was compressed by a probe blade with knife (LR 5K, Lloyd Instruments, United Kingdom). Hardness measurement conditions had the diameter at 30 mm, the test speed at 5 mm s-1 and the compression at 70% of the sample's height at 25°C. Replication (n=8) was done for each recipe. Hardness (N) was assessed using the Lloyd Instruments NEXYGEN data analysis software.

Table1. Components of each recipe prepared according to mixture design

Recipe No.	Popped rice (%)	Honey (%)	Peanut butter (%)
1	35	35	30
2	35	45	20
3	45	25	30
4	45	45	10
5	55	25	20
6	55	35	10
7	45	35	20

Next up was selecting the best recipe from the seven popped rice snack bar recipes. However, because of limited analytical abilities of pre-school children, hardness test was therefore performed by adults to find consumer acceptability on the snack bar's hardness. Results from our preliminary test revealed no differences in hardness liking of snack bar between children and adults ($P > 0.05$). Ninety untrained panelists (67 females and 23 males) ranging from 18 to 25 years of age was used. Each panelist was either a student or on the staff from Walailak University, Thailand. A 9-point hedonic

scale ranging from 9 for "like extremely" to 1 for "dislike extremely" (Meilgaard *et al.* 1999) was used to determine the degree of acceptance of the specimens in terms of hardness liking.

Pre-school sensory

The sensory study of preschoolers included 70 healthy children (ages 3 to 5) recruited from the Wat Thasung preschool child care center in the Thasala district of Nakhon Si Thammarat. Only recipe no. 6 containing 55% popped rice, 35% honey, and 10% peanut butter with 3 g of resin, 12 g of dried pineapple, 4 g of pumpkin seeds, 3 g of black sesame seeds and 8 g of sunflower seeds was selected for the test. Children rated their liking of the popped rice snack bar on a 3-point face scale (like, ok, dislike) for overall liking. Happy, neutral, and sad faces were used in conjunction with the words "like," "ok" and "dislike (Burgess-Champoux *et al*., 2006).

Statistical analyses

Experimental data was tested for normality by applying the Kolmogorov-Smirnov test and homogeneity of variances was assessed by using Levene's test. Data transformation was performed where necessary. Results were expressed as mean ± standard deviation. The data was statistically treated by ANOVA and Duncan's post hoc test with $p < 0.05$ was considered to be statistically significant.

For expansion volume, differences in the parameters were considered significant when less than 0.05 ($p < 0.05$). The proportion of variance explained by the polynomial models obtained was given by the multiple coefficient of determination, R^2 and its statistical significance was determined by the F-test. The statistical analysis was performed by using Statistica software (StatSoft, USA).

For analyzing the data, a second order polynomial quadratic equation was fitted to the data (eq. 2).

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2 \quad \text{Eq.2}$$

Where Y is the expansion volume of popped rice snack bar, X_1 and X_2 are the main components (X1 =moisture and X_2=popping time), b_0 is the intercept, b_1, b_2, b_{11}, b_{22}, and b_{12} were the linear, cross product and quadratic coefficients.

Results and Discussion

Moisture content and popping time on the expansion volume of popped rice

The results of the effect of moisture content and popping time to various expansion volumes of popped rice are shown in Table 2. Unhusked rice with 10% to 14% moisture and popping time at 90 seconds showed highest expansion volume (7.97±0.57 mlg^{-1} and 7.74±0.49 ml g^{-1}, respectively). No EV difference at 90s was observed in unhusked rice with 10% to 14% moisture. Surface and contour plots (Figure 1) show that, as the level of the popping time increased (from 30 to 90 s), EV of unhusked rice with 10% to 14% moisture increased. However, as moisture content of unhusked rice increased to 18%, the EV decreased. EV is best predicted by the model equation 3:

Table 2. Full factorial (32) design with experimental values of expansion ration (EV; ml g^{-1})

Moisture (%)	Popped time (s)	EV (ml g^{-1})
10	30	5.37±0.15
10	60	6.46±0.04
10	90	7.97±0.57
14	30	5.16±0.47
14	60	6.30±0.24
14	90	7.74±0.49
18	30	4.49±0.12
18	60	6.10±0.41
18	90	7.04±0.86

$$Y = 2.01 + 0.36X_1 + 0.04X_2 - 0.016X_1^2 + 9.26\times10^{-5}X_2^2 \quad \text{Eq.3}$$

Where Y_1 predicted EV, moisture content (X_1) and popped time (X_2), the coefficient of determination (R^2) was 0.98 which indicated that the model equations adequately fit the data. Moisture content had significant impacts on the EV of husked rice. It should be noted that the RSM equations obtained only valid within a range of the collected data

Expansion volume was observed when the rupture of the pericarp was done. Suitable moisture content inside the unhusked rice caused high pressure and resulted in high mechanical resistance of the popped rice. After suitable amount of moisture diffused in the unhusked rice, the hygroscopic swelling reduces the remaining strain available before the elastic limit was reached. The presence of cracks and expandsion in the unhusked rice is an indication that it could break during cooking (Genkawa *et al*., 2011). Differences in research report that the optimum moisture content for maximum expansion volume in rice depends on mechanical properties such as hardness and viscosity that affects the water transfer capacity inside the

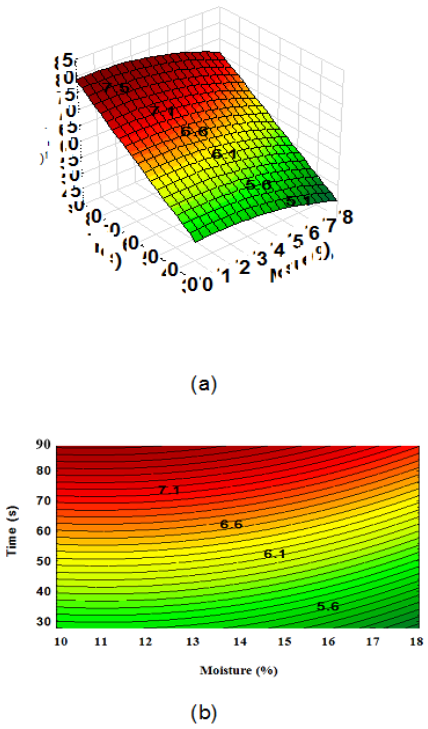

Figure 1. Response surface plots (a) and contour plots (b) showing the effect of moisture content (%) and popped time (s) on expansion volume of popped rice

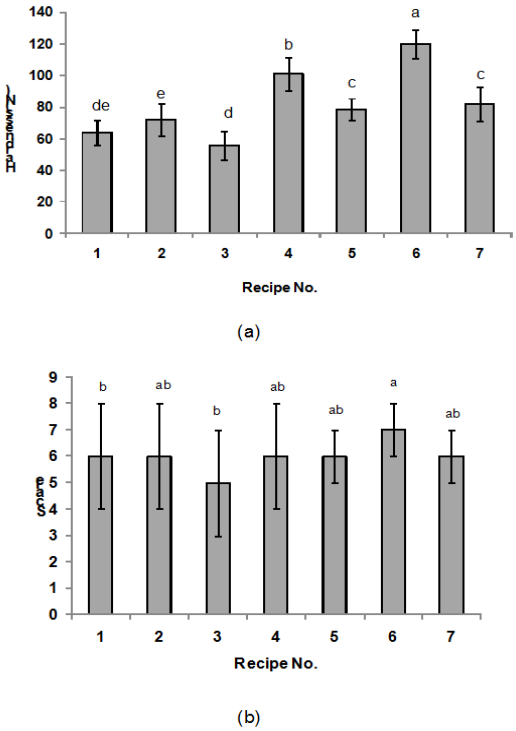

Figure 2. Hardness value from texture analyzer (a) and from sensory (b) for seven recipes prepared from popped rice, honey and peanut butter

grain (Zhang *et al*., 2005). Molecular weights of starch in rice, and thickness of the husk, equilibrium moisture of the paddy and cracked grains were also significant factors (Murugesan and Bhattacharya, 1989; Murugesan and Bhattacharya, 1991a). Within this test, the optimum moisture content for maximum expansion volume was 10% to 14% with the popped time at 90 s. The results agree well with the previous studies of Murugesan, and Bhattacharya (1991b) and Swarnakara *et al*. (2014) who reported that expansion ratio was highest at initial moisture contents between 14.15% and 14.94% for particular popped times required for the energy levels to reach 36 and 48 kJ, respectively.

Hardness properties of popped rice snack bar

The main materials of the snack bar used were popped rice, honey and peanut butter. From this snack bar the hardness values and the sensory test results are shown in Figure 2. It was found that the hardness of each snack bar recipe ranged from 65N to 114N. Recipe no.6 had highest hardness value (114±9N) and was followed by recipes no. 4, 5 and 7 with hardness values of 101±10N, 77±N and 81±10N, respectively. In addition, the sensory test showed that recipe no.6 had the highest score of hardness liking (7; like moderately). Therefore, the recipe no.6 was then selected for the children evaluation in the next section. The results show that the hardness of the popped rice snack bar samples could be improved, especially when the popped rice level increase from 35% to 55%. For consideration, recipe no. 6 contained a high level of popped rice (55%), a middle level of honey (35%), and a low level of peanut butter (10%). This result confirmed that high percentage of popped rice in snack bar recipe has been found higher hardness. For honey, fructose and glucose were the highest monosaccharides in honey (Anjos *et al*., 2015). Normally, monosaccharides and sugar affects food hardness, flavor and color (Gallagher *et al.*, 2003). In this study, sugar from the honey could have helped to build up the hardness of the popped rice snack bar. Karim *et al*. (2008) and Teng *et al*. (2013) reported that starch-sugar mixtures increased viscosity of products during the heating process. Furthermore, sugar was reported to be related to the hardness of many food products such as chocolate (Aidoo *et al*., 2014) and sausage (González-Fernández *et al*., 2006). Also, the popped snack bar with a low level of peanut butter was found to be better for consumer acceptability and was rated higher on the hedonic scale for this test for the Thai consumer. It could be caused by behavior of Thai consumers. Normally, peanut butter is not common in Thai recipes.

Hedonic testing with children

According to the result in texture section, recipe

Table 3. Hedonic ratings by pre-school children (3-5 years old)

Scale	Word	(n)	%
	Like	62	89
	OK	3	4
	Dislike	5	7

no.6 was showed a good hardness and also a high hedonic rating, thus, was selected for children test. Evaluated acceptability on a 3-point scale for the popped rice snack bar from recipe no. 6 using preschool children (n=70) is shown in Table 3. The result from this study found that more than 89% (n=62) of pre-school children (totally n=70) were rated "like" to this recipe.

Conclusion

Popped rice snack bar product development for preschool children was investigated. Results showed that moisture content at 10 - 14% and 90 seconds of popping time were the best conditions for processing the high expansion volume of popped rice. Moreover, the best popped rice snack bar formula included 55% of popped rice, 35% of honey and 10% of peanut butter (10%). The hardness measured 114±9N. and the hardness hedonic value was 7, rated "like moderately." All in all, the acceptability score found by tested preschool children was 89%.

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