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การใช้วัตถุดิบอาหารธรรมชาติเป็นแหล่งแคลเซียมสำหรับการเสริมแคลเซียมในข้าวเกรียบ

Use of Selected Natural Calcium Sources for Calcium Enrichment of Crisp Rice

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บทคัดย่อ

ก้างปลาผง กุ้งฝอยผง และปลากะตักผงเป็นแหล่งแคลเซียมที่ใช้เป็นส่วนผสมในการผลิตข้าวเกรียบเสริมแคลเซียม การศึกษานี้มีวัตถุประสงค์เพื่อหาระดับที่เหมาะสมของแหล่งแคลเซียมทั้ง 3 ชนิดในการผลิตข้าวเกรียบเสริมแคลเซียมที่เป็นที่ยอมรับ ผลการศึกษาพบว่า ก้างปลาผง กุ้งฝอยผง และปลากะตักผงที่ใช้ทดแทนแป้งมันสำปะหลังที่ระดับ 17.5 % มีคะแนนการยอมรับใกล้เคียงกับข้าวเกรียบปลาสูตรท้องถิ่นมากที่สุด และจากการทดสอบการยอมรับในผู้บริโภคที่เป็นนักเรียน 100 คน และผู้ใหญ่ 100 คน พบว่าข้าวเกรียบเสริมแคลเซียมจากกุ้งฝอยผงมีคะแนนความชอบสูงที่สุด ระดับของแหล่งแคลเซียมที่เติมในส่วนผสมที่เพิ่มขึ้น ทำให้การพองตัวของข้าวเกรียบลดลง แต่ไม่ทำให้ความกรอบของข้าวเกรียบแตกต่างกัน ข้าวเกรียบเสริมแคลเซียมจากก้างปลาผง กุ้งฝอยผง และปลากะตักผงในระดับ 17.5 % มีแคลเซียมคิดเป็น 46 22 และ 29 % ของปริมาณที่แนะนำให้บริโภคต่อวัน ต่อปริมาณข้าวเกรียบ 1 หน่วยบริโภค (30 กรัม) ตามลำดับ ผลการศึกษานี้แสดงให้เห็นว่าก้างปลาผง กุ้งฝอยผง และปลากะตักผงเป็นแหล่งแคลเซียมที่ดีในการผลิตข้าวเกรียบเสริมแคลเซียมได้ อย่างไรก็ตาม ก้างปลาผงน่าจะเป็นแหล่งแคลเซียมที่ดีที่สุดในระหว่างแหล่งแคลเซียมทั้งสามแหล่ง เนื่องจากทำให้มีแคลเซียมในข้าวเกรียบสูงที่สุด และไม่ทำให้ต้นทุนการผลิตข้าวเกรียบเพิ่มขึ้นเหมือนกับการใช้กุ้งฝอยผง

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ABSTRACT

Fish bone powder, small fresh water shrimp powder and anchovy powder were produced and used as calcium sources for calcium enriched crisp rice production. The addition levels suitable for human taste as well as the effects of natural calcium sources on the quality of crisp rice were experimentally determined in this study. The formula with 17.5% by weight of the three calcium sources had the closest acceptance score to that of local fish crisp rice. According to the consumer test done with 100 school children and 100 adults, small fresh water shrimp powder enriched crisp rice was the best accepted. The linear expansion decreased as the amounts of calcium sources increased but there was no change for crispiness. A 17.5% addition level and per one serving (30 g) of crisp rice, the fish bone enriched crisp rice provided 46% RDI; small fresh water shrimp enriched gave 22% RDI; and anchovy enriched contributed 29% RDI of calcium. The study has demonstrated that fish bone powder, small fresh water shrimp powder and anchovy powder are good sources for production of calcium enriched crisp rice. The largest effect on calcium intake is achieved, among these options, with fishbone powder, which is also cost effective. In contrast shrimp powder is the least likely option due to its high cost.

คำสำคัญ: ข้าวเกรียบ แหล่งแคลเซียม อาหารเสริมแคลเซียม ขนมขบเคี้ยว

Keywords: Crisp rice, Calcium sources, Calcium enriched foods, Snacks

Introduction

Calcium is the most abundant micronutrient found in human body. It accounts for 1.5% of the body weight and 99% of it is in bone and teeth while the rest is in blood and other tissues. Calcium is needed for bone health, as a neurotransmitter, for muscle contraction and in the blood clotting process (Wood, 2000; Zimmermann, 2001). Osteoporosis or significantly reduced bone density is common in elderly people, with a major disease burden in Thailand (Pongchaiyakul et al., 2008) as well as many other countries (International Osteoporosis Foundation, 2011). The serious consequence of osteoporosis is the fractures that lead to morbidity and mortality. In Thailand, median cost of hip fracture treatment in 1 year is 116,459 baht per case (Pongchaiyakul et al., 2008).

Osteoporosis is preventable by adequate intake of calcium especially during the first 20 to 30 years of life to maximize peak bone mass (International osteoporosis foundation, 2011) so that the bone density will not become dangerously low when the bone resorption rate increases, this normally will happen to all individuals later in life. In

addition, adequate calcium intake is crucial for promoting optimal growth in children.

Low calcium intake is a known issue in Thailand, where the 5th National Food and Nutrition Survey indicated that all age-groups had calcium intakes approximately 20-30% of recommended dietary allowance (Bureau of nutrition, 2006). The Thai government has launched a school milk program in order to increase the calcium intake of primary school children. However, milk alone cannot fill the calcium gap of Thais because many children do not like milk and many adults have lactose intolerance. Many attempts have been made to develop alternative calcium rich sources such as calcium fortified foods.

Various foods are commonly fortified with calcium including soy products, juices and breakfast foods or snack foods (Williams, 2011). These can be especially good choices if milk is not consumed. Selection of the right combination of food and calcium source is a major consideration in the development of calcium fortified foods. Generally, the selected foods should be consumed in the significant serving amounts to have an impact in the target population and have a wide user base. The calcium source can be either synthetic or derived from natural food components. By-products from processed foods are promising as good natural calcium sources such as egg-shell (Hormsukon et al., 2011), chicken bone and fish bone (Phiraphinyo et al., 2006; Chuamani, 2010).

Fish crisp rice is popularly consumed among people in the southernmost provinces of Thailand. There are hundreds of fish crisp rice producers including households and small & medium size factories in Pattani and Narathiwat provinces. According to a survey on fish crisp rice production in Pattani in 2003, there were 103 producers and the average production capacity was 448.1$\pm$225.8 (range from 40 to 1000) kg/week/factory. The total large quantity of crisp rice produced was partly distributed locally and partly exported to Malaysia and other countries (Chaimongkol et al., 2003).

This local popularity suggests that fish crisp rice could be used as a carrier of calcium for the vulnerable population not only in southernmost provinces of Thailand but also more widely. Fish bone, small fresh water shrimp and anchovy are available and inexpensive in Thai coastal areas such as Pattani, Songkhla, and etc. Fish bone is a by-product of processed fish foods, so using it as a calcium source for calcium fortified foods will convert waste from fishery industries to a value-added product. Hence, the aims of this study were 1) to examine the proper levels of fish bone powder, small fresh water shrimp powder and anchovy powder in formulations for calcium enriched crisp rice production, 2)

to determine the nutritional values of calcium enriched crisp rice in comparison to local fish crisp rice, and 3) to explore the consumer acceptance of the products.

Research Methodology

Preparation of fish bone powder, small fresh water shrimp powder and anchovy powder

The bone of purple-spotted bigeye fish (*Priacanthus tayenus*) was obtained from Lamtong Seafresh Company, Pattani while small fresh water shrimp and anchovy (*Encrasicholina* sp.) were bought from Songkhla. They were processed to calcium rich powder by methods modified from Pitakphol (1986). In brief after cleaning, the fish bone and anchovy were each boiled under 15 pound/inch^2 pressure for 45 minutes to soften the bones, while small fresh water shrimp was boiled for 15 minutes. Excess water was removed by filtration. The materials were coarsely ground and then dried in a hot air oven at 55 to 60 ^{0}C until the moisture content was 3 to 6%. Finally, they were finely ground into powder and sieved through a no. 40 mesh screen. The proximate compositions and calcium contents of these powders were analyzed.

Production of calcium enriched crisp rice

Anchovy powder and small fresh water shrimp powder were used to replace cassava flour by 15%, 17.5%, and 20% while the fish bone powder substituted for 17.5%, 20%, and 22.5% of cassava, as shown in the formulations of Table 1. The cassava flour was kneaded with water before heating in a water bath for 3 to 4 minutes, to swell the starch granules. Then, it was mixed with the other ingredients including the powdered calcium source. The dough was formed into a cylindrical shape with approximately 4 centimeters diameter. It was steam cooked and then cooled overnight in a refrigerator to make it firm for slicing. The cooked and cooled dough was cut to 1.5 millimeters thick slices by slicing machine, which were dried in a hot air oven at 55 to 60^{0}C to approximately 10$\pm$1% moisture. The experimental design was a completely randomized design (CRD) with triplicates.

Analysis of the crisp rice quality

The dried crisp rice was puffed by frying in vegetable oil at 175-180^{0}C for 2 to 3 seconds and analyzed for the following quality characteristics.

The expansion

The linear expansion of puffed crisp rice was assayed according to the method described by Yu et al. (1981).

The crispiness

A texture analyzer (TA-XT2) was used to determine the compression force that breaks the puffed crisp rice (alternatively called "hardness"). A higher breaking force means that the crisp rice is less crispy.

Table 1. The formulations of calcium enriched crisp rice in gram

Calcium sources	**Fish bone powder**			**Anchovy powder**			**Small fresh water shrimp powder**		
Formulation id#	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Ingredients									
1. Cassava flour	82.5	80.0	77.5	85.0	82.5	80.0	85.0	82.5	80.0
2. Calcium source	17.5	20.0	22.5	15.0	17.5	20.0	15.0	17.5	20.0
3. Salt	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
4. Ground pepper	3	3	3	3	3	3	3	3	3
5. Sugar	4	4	4	4	4	4	4	4	4
6. Garlic	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5

Sensory evaluation

The sensory evaluation was performed by 30 panelists. The quality profiles including crispiness, flavor, fishy smell, and overall preference were quantified by using a 9-point hedonic scale. The sensory qualities of the calcium enriched crisp rice were compared with that of the local fish crisp rice bought from a factory in Pattani. Randomized complete block design (RCBD) was used in these experiments.

Nutritional values

The three chosen formulas of calcium enriched crisp rice and local fish crisp rice were analyzed for moisture, crude fat, and crude protein according to A.O.A.C., (2000). Calcium content was determined by flame atomic absorption spectroscopy. Carbohydrate content was calculated as what remains aside from other components. Energy was computed by using the Atwater factor.

Consumer test

The selected calcium enriched crisp rice was tested for consumer acceptance in 100 primary school children and in 100 adults living in Muang district, Pattani province. The 5-point hedonic scale was used.

Statistical analysis

Analysis of variance was performed and Duncan's multiple range tests was used in multiple comparisons. *P*-values below 0.05 were considered statistically significant.

Results

Three calcium sources in powder form were prepared from fish bone, anchovy and small fresh water shrimp. Fish bone

powder had the highest amount of calcium (19.2%w/w) while anchovy powder had 2.5% and small fresh water shrimp had 1.8% (Table 2.).

Calcium enriched crisp rice was produced using nine formulas. Fish bone powder substituted for 17.5, 20.0 and 22.5% of cassava flour while both anchovy powder and small fresh water shrimp powder substituted for 15.0, 17.5 and 20.0%. With higher amounts of powder in the formulas, the percent linear expansion of the crisp rice were lower (Figure 1.). The breaking force of local fish crisp rice was statistically significantly lower than that for anchovy powder and small fresh water shrimp powder enriched crisp rice but higher than that for fish bone powder enriched crisp rice. However, there was no significant difference in pressing force used to break the crisp rice between the three levels of the same calcium source formulas (Figure 2.).

Table 2. The nutritional values of fish bone powder, anchovy powder, and small fresh water shrimp powder per 100 g (wet basis)

Nutrient compositions	Fish bone powder	Anchovy powder	Small fresh water shrimp powder
Calcium (mg)	19,212.39±1.46^{a}	2,484.67±1.53^{b}	1,764.08±0.94^{c}
Protein (g)	60.41±0.02^{c}	78.21±0.12^{a}	65.66±0.13^{b}
Ash (g)	31.29±0.17^{a}	18.38±0.20^{b}	17.48±0.30^{c}
Moisture (g)	2.17±0.01^{b}	1.23±0.03^{c}	3.49±0.07^{a}
Fat (g)	5.94±0.03^{b}	1.72±0.09^{c}	12.87±0.04^{a}
Carbohydrate (g)	0.19	0.46	0.50
Energy (kcal)	295.86	330.16	380.47

Note: The means with different superscripts (a, b and c) within a row are significantly different ($p<0.05$).

The fish bone powder enriched crisp rice provided 364.2 mg calcium per one serving (30 g crisp rice) corresponding to 46% of the recommended dietary intake (ThaiRDI for calcium is 800 mg). This is about twice higher than from small fresh water shrimp or anchovy powder enriched crisp rice (Table 3.).

In the consumer test, the students and adults preferred small fresh water shrimp powder crisp rice. The preference scores of students for small fresh water shrimp powder, anchovy powder and fish bone powder enriched crisp rice ranged from liking to moderate liking (4.4±0.8, 4.2±0.8, and 4.1±0.6, respectively). The preference scores of adults for these crisp rice were lower: 4.0±0.7, 3.0±0.9 and 3.3±0.6, respectively (Figure 3a). More than 80% of the consumers would buy

the calcium enriched crisp rice if they were available in the market (Figure 3b).

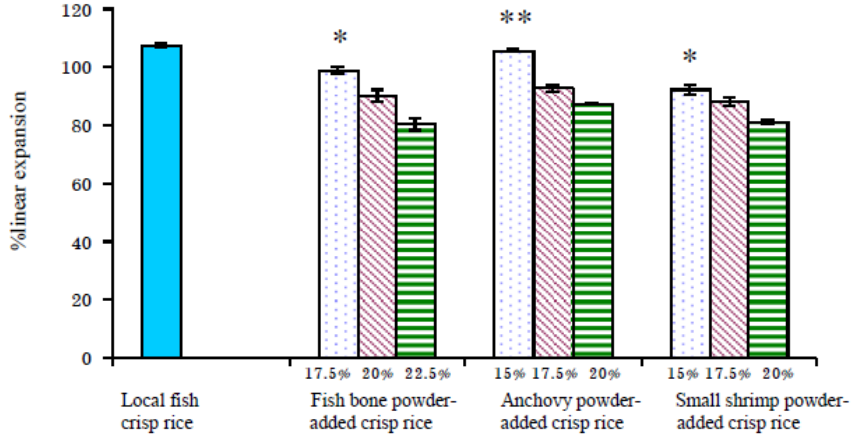

Figure 1. Linear expansion of crisp rice

Note: * indicate significant differences from local fish crisp rice and between the three levels of the same calcium source.

** indicate significant differences between the three level of the same calcium source but no significant difference from the local fish crisp rice.

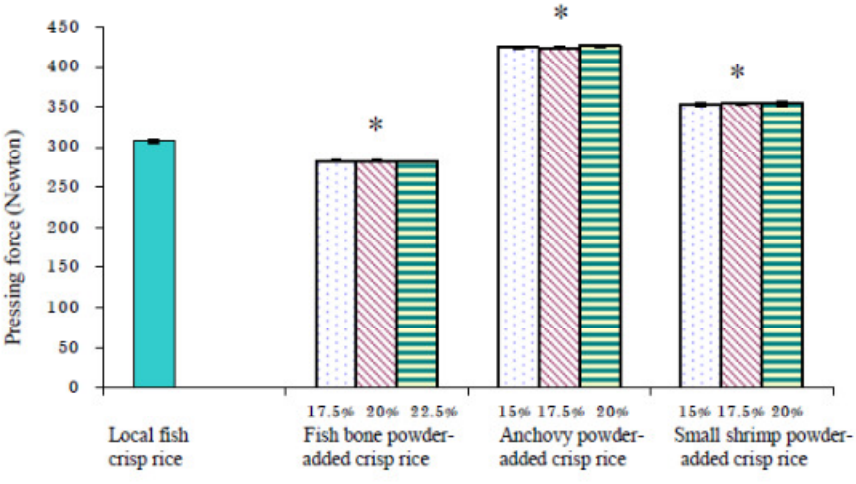

Figure 2. Force used to break the puffed crisp rice in texture analyzer

Note: * indicate significant differences from local fish crisp rice but no significant difference between the three levels of the same calcium source.

Table 3. The nutritional values per one serving of local fish crisp rice and of three types of calcium enriched crisp rice (1 serving size is 30 gram)

Nutrient compositions	Local fish crisp rice	Various formulas of calcium enriched crisp rice		
		17.5%of fish bone powder	17.5%of anchovy powder	17.5%of small shrimp powder
Calcium (mg)	19.6(2%RDI[1])	364.2(46%RDI[1])	231.8(29%RDI[1])	178.1(22%RDI[1])
Protein (g)	1.66	1.37	2.71	2.57
Fat (g)	10.41	10.15	9.38	8.07
Carbohydrate(g)	16.20	17.16	16.43	18.20
Energy (kcal)	165.12	165.44	161.03	155.73

Note: [1] RDI is Recommended Dietary Intake for Thais aged at least 6 years old; RDI for calcium is 800 mg.

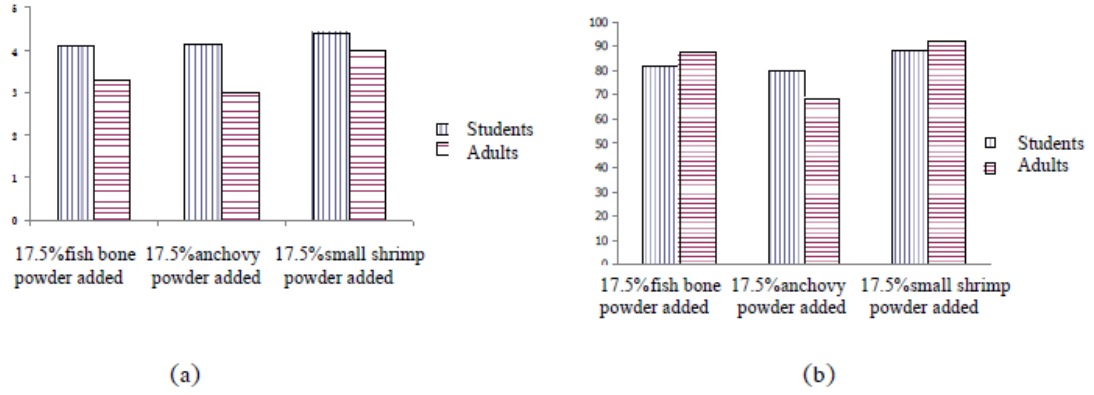

Figure 3. In (a) acceptability scores for selected calcium enriched crisp rice by children and adults; (b) percentages of consumers who agreed to buy the calcium enriched crisp rice

Discussion

Fish bone powder had significantly higher calcium content than the other two because calcium is concentrated specifically in bones (Table 2.). These sources did not have as high calcium contents as those found in some other studies. Phiraphinyo and colleagues (2006) processed the bones of hoki, giant seaperch and chicken to calcium rich powders. Protein was removed by enzymatic digestion before powdering. Total calcium contents determined by complexometric analyses were 31.8, 28.1 and 32.2% w/w in hoki, giant seaperch and chicken bones, respectively. All samples had the calcium in carbonate form. The main difference to the current study may be the protein removal, leading to the higher calcium contents but also wasting the protein. Another potential calcium source from the by-products of food processing is the egg shells – they had 39% calcium (Hormsukon et al., 2011). The protein in the three calcium sources of this study was not wasted to achieve higher

intermediate calcium contents of the enriching powders.

The linear expansion is an indicator of crisp rice quality and also relates to the crispiness. When dried crisp rice was fried in oil at the appropriate temperature, the remaining water in dried-crisp rice rapidly evaporated and expanded the network structure of amylose and amylopectin. This results in expansion of the deep-fried crisp rice. Addition of fish bone powder, anchovy powder and small fresh water shrimp powder in the formulation lessens the expansion of crisp rice by two mechanisms. Firstly, substitution of cassava flour by calcium sources reduces the amount of amylose and amylopectin which are the major components being puffed. Secondly, the particles of calcium sources depositing within the starch gel structure interfere with that structure. The higher levels of calcium sources added to the formulations lead to smaller size pores or air cells in the puffed crisp rice and by this means make the crisp rice less crisp. However, there were no differences in crispiness between crisp rice formulated with the different levels of the same calcium source despite the differences found in expansion. The sensory evaluation also indicated similarity of crispiness and flavor profiles between different levels of the same calcium source. However, as higher levels of the calcium sources were added, also a stronger fishy smell was observed. This can result in the lower overall preference scores for the higher levels of calcium sources. (data not shown). Based on the sensory evaluation, three calcium-enriched crisp rice, which had the overall acceptance score closest to that of local fish crisp rice, were selected (one for each of the three calcium sources used in the formulations). Finally, the level of 17.5% of all three calcium sources was chosen as the appropriate level.

Interestingly, the calcium enriched crisp rice had 9-18 times higher calcium contents than the local plain fish crisp rice (Table 3.). Consuming 30 grams or one serving of calcium enriched crisp rice provides the calcium equivalent to 200 ml of milk. In comparison, one serving of Thong-pap (Thai traditional snack) enriched with tri-calcium phosphate gave 120 mg calcium (Sinchaipanich and Banchong, 2009). Cashew nut cookies and crisped bread enriched with calcium from egg-shell powder gave 352 mg calcium per one serving while garlic-pepper flavor coated peanut with calcium from egg shell powder provided 800 mg calcium per one serving (Hormsukon et al., 2011).

The consumer test (Figure 3a-b) suggested that calcium enriched crisp rices would be accepted by the target population in southern Thai provinces. The cost of raw

materials for making calcium enriched crisp rice by using fish bone powder and anchovy powder as calcium sources was similar to that of local fish crisp rice while using small fresh water shrimp powder about doubles the raw material costs (data not shown).

Conclusions

This study indicates that fish bone powder (a by-product of fish processing), anchovy powder and small fresh water shrimp powder are potentially good sources of calcium when used in formulations for calcium enriched crisp rice. The optimum level of these calcium sources which can be used to substitute for cassava flour was 17.5%. Fish bone powder and anchovy powder would not affect the raw material cost of local fish crisp rice in Pattani, Thailand.

However, the bioavailability of calcium in these enriched crisp rice has not been determined. To ensure the usefulness of these products as a calcium source for humans, the bioavailability should also be determined.

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