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Physico-chemical and sensory analysis of Calcium-Fortified Cracker with Cricket Protein Source

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Abstract

Calcium (Ca) deficiency is a major public health problem that leads to bone health complications. This study aimed to develop a Ca-fortified cracker with a cricket protein source, a high-quality alternative source of protein that involves low-cost production. Four recipes of the cracker with cricket protein (*Acheta domesticus*) were prepared; control recipe, 15% of Ca by RDA per serving recipe (15% formula), 25% of Ca by RDA per serving recipe (25% formula), and 50% of Ca by RDA per serving recipe (50% formula). All recipes were assessed for satisfaction by 30 participants using the sensory evaluation method. The Ca-fortified cracker recipe which obtained the most acceptable rating by participants was sent for analysis, together with the control recipe. The findings of this study indicated that the 50% formula obtained significantly higher scores in taste and texture when compared with the other two Ca-fortified recipes ($p<0.05$). In addition, its overall satisfaction score stayed at an acceptable level. The proximate analytical results indicated there were comparable results between the 50% recipe and control recipe, such as ash (2.42 g/100g for 50% recipe and 2.03 g/100g for control), moisture (3.66 g/100g for 50% recipe 2.99 g/100g for control), and protein (4.46 g/100g for 50% recipe and 4.33 g/100g for control). For Ca, the 50% recipe obtained Ca 183.38 mg/100g and the control recipe obtained 68.89 mg/100g. In conclusion, the cracker recipe with cricket protein contained 50% of Ca by RDA per serving, was acceptable to participants and comparable on proximate composition with the control recipe.

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Introduction

Inadequate calcium (Ca) intake is commonly reported as one of the nutritional problems in many countries, for example, 30% of adolescents in Nigeria and 50-70% of adolescents in Ukraine were reported as having low Ca intake.[1,2] Long-term insufficient provision of Ca, according to Recommended Dietary Allowance (RDA), leads to calcium deficiency-related complications, such as osteoporosis and osteopenia.[3] These medical conditions cause suffering and affect the quality of life. Hence, encouraging adequate Ca intake by promoting food sources of Ca consumption, such as milk and milk products, can help to support Ca intake to meet accepted RDA. Also, this can lower the risk of low bone mineral density as the population ages.[4] However, milk allergies and lactose intolerance are major obstacles that make people avoid milk and milk product consumption.[5,6] This factor has increased the risk of inadequate Ca intake for many people.

Cricket protein is one of the important alternative protein sources that has advantages in cost efficiency production and bioeconomy compared with other animal protein productions, such as pork and beef.[7] In addition, it has been proven to contain high biological value protein.[8] Therefore, using cricket as the food source of protein is a trend increasingly popular in nutritional sciences. For example, a previous study that used cricket (*Acheta domesticus*) powder replacement in sausage, pasta, and brownies was shown acceptable by participants. 9 Cracker is one of the snacks that is well known for widespread consumption in Thailand due to its being easily prepared at the household level. According to the mentioned data on inadequate Ca intake among populations and the benefits of the cricket protein, this study, therefore, aimed to develop a Ca-fortified cracker using cricket protein.

Materials and Methods

Sample Preparation of Ca-fortified cracker with cricket protein

The Ca-fortified cracker samples with cricket protein used in this study were prepared and produced, adapted from the recipes available at online sources. Four formula recipes were prepared; control (no Ca fortification) recipe, 15% of Ca by RDA per serving recipe (15% formula), 25% of Ca by RDA per serving recipe (25% formula), and 50% of Ca by RDA per serving recipe (50% formula). A commercial food grade of calcium citrate powder was used as the source of Ca fortification in all the Ca-fortified recipes due to its efficiency in human metabolism and absorption.[10] All recipes were prepared with the same method and the same weight of all of the other ingredients, such as flour, garlic powder, etc. at the Nutrition and Dietetics Laboratory, Faculty of Allied Health Sciences, Burapha University, Chonburi province, Thailand (Figure 1).

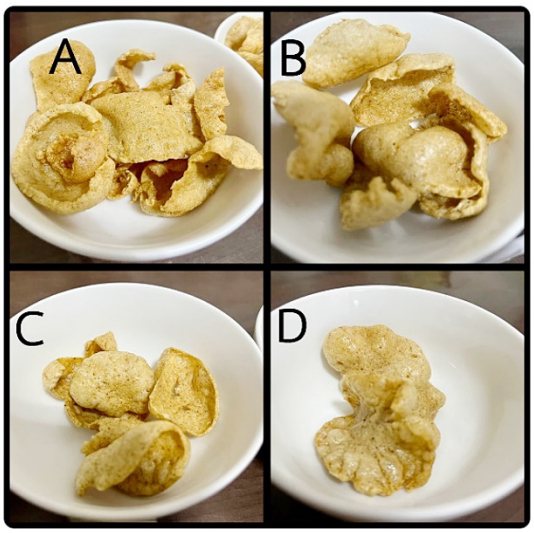

Fig. 1: All crackers with cricket protein samples (A; control, B; 15% of Ca by RDA per serving, C; 25% of Ca by RDA per serving, and D; 50% of Ca by RDA per serving)

Participants in this Study

Thirty participants[11] were recruited in this study to conduct the sensory evaluation on the developed four cracker recipes with the following inclusion criteria; Thai healthy people aged between 18-45 years, who can read and write Thai, and willingness to participate in the study. The exclusion criteria were people suffering from any illness that affects their sensory ability, having a medical history of food allergies, having a medical history of mental illness, and having a medical history of color blindness. All participants were able to be conveniently contacted and signed their informed consent before participating in the study. The study protocol was approved by the research Ethical Institutional Review Board of Burapha University (approval number IRB1-091/2566).

Sensory Evaluation

The nine-point facial-hedonic scale was used as the sensory evaluation questionnaire in this study because of its reliability and validity reported by the previous studies.[12] The questions used in the questionnaire asked the participants to assess their satisfaction with all four developed cracker recipes, regarding appearance, taste, flavor, color, texture, and overall satisfaction. The scoring method was terrible = 1 point, very bad = 2 points, bad = 3 points, just a little bad = 4 points, maybe good or maybe bad = 5 points, just a little good = 6 points, good = 7 points, very good = 8 points, and great = 9 points. The recipe that obtained an overall satisfaction score of more than 7.00 was considered as satisfactory and acceptable by participants.[11]

For the sensory evaluation procedure, participants were invited to the provided room at the Nutrition and Dietetics Laboratory, Faculty of Allied Health Sciences, Burapha University. All participants were served, blinded, with samples of all four cracker recipes on the table within an individualized and private partition. They were asked to rinse their mouth with water and smell roasted coffee to minimize the aftertaste effects before intake and evaluation of the next sample recipe.

Physico-Chemical and Ca Analysis of the Samples

The proximate composition analysis of the samples was based on the results of sensory evaluation. The control formula cracker and one of the Ca-fortified formula that sensory evaluation recorded as satisfactory and acceptable by participants was chosen to undergo proximate analysis on ash (In-house method T924 based on AOAC (2019) 923.03), Ca (In-house method T9152 based on AOAC (2019) 984.27), color (L*, a*, b*) using the Hunter Lab color Quest XE, moisture (In-house method T923 based on AOAC (2019) 925.10), and protein (In-house method T927 based on AOAC (2019) 991.20) at the National Food Institute, Thailand Ministry of Industry.

Statistical Analyses

Sensory evaluation scores were presented as Mean ± SD. Tukey's Honestly Significant Difference was used for the multiple pairwise comparisons of satisfaction scores among different formulas in each aspect using Statistical Package for the Social Sciences (SPSS Inc, Chicago, Il), version 21.0. A statistically significant difference was deemed at $p<0.05$.

Results

The average age among 30 participants who performed sensory evaluation in this study was 22 years with more than half (73%) being females. Participants' body mass index (BMI) stayed in the normal range (22.46) and most of them (80%) graduated a bachelor's degree (Table 1).

Table 1. Participants' characteristics

Participants' data	Results
Age, mean (SD)	**22.76 (2.51)**
Sex	
Male, n (%)	8 (26.66)
Female, n (%)	22 (73.34
BMI, mean (SD)	**22.46 (2.59)**
Education	
Bachelor degree, n (%)	24 (80.00)
Graduate degree, n (%)	6 (20.00)

The satisfaction and acceptance of participants toward the developed four cracker recipes were assessed by the sensory evaluation questionnaire. The results found that Ca-fortified cracker with 50% of Ca by RDA per serving recipe obtained significantly higher satisfaction scores than other recipes in many aspects such as appearance (7.00 points), flavor (6.00 points), texture (7.13 points), taste (7.06 points), and overall satisfaction (7.23 points) ($p<0.05$). The Ca-fortified cracker with 25% of Ca by RDA per serving recipe obtained the lowest satisfaction scores that were significantly lower than the other recipes such as flavor, texture, and taste ($p<0.05$). In addition, the cracker in the control formula recipe and Ca-fortified cracker with 50% of Ca by RDA per serving recipe obtained a satisfaction score above 7.00 which indicated acceptability by participants (Table 2).

Based on the sensory evaluation results the crackers in the control group and 50% of Ca by RDA per serving recipe were scored as acceptable criteria by participants. Hence, it was selected to perform the physico-chemical analyses. The ash content of both the recipes was comparable with 2.03 g/100g for the control recipe and 2.42 g/100g for 50% of

Ca by RDA per serving recipe. For Ca content, the control recipe possessed 68.89 mg/100 g, and the 50% of Ca by RDA per serving recipe possessed 183.38 mg/100g. HunterLab colorQuest XE method indicated color analysis for control recipe L*=54.40, a*=4.02, and b* = 20.43 and the 50% of Ca by RDA per serving recipe L*=42.24, a*=6.33, and b* = 21.55. The moisture content of the control recipe was 2.99 g/100g and the 50% of Ca by RDA per serving recipe was 3.66 g/100g. In addition, the protein content of two recipes was similar with 4.33 g/100g for control recipes and 4.46 g/100g for the 50% of Ca by RDA per serving recipe (Table 3). Results indicated all analyzed characteristics obtained the value that significant differences between the control recipe and the Ca-fortified recipe ($p<0.05$).

Table 2. Sensory evaluation scores on the cracker samples in different formulas

Aspects	Control (mean±SD)	15% Ca by RDA formula recipe (mean±SD)	25% Ca by RDA formula recipe (mean±SD)	50% Ca by RDA formula recipe (mean±SD)
Appearance	7.10±1.32^{a}	6.23±1.69^{b}	6.16±2.21^{b}	7.00±1.48^{a}
Color	6.53±1.88^{a}	6.40±1.81^{a}	6.16±2.10^{a}	6.33±1.78^{a}
Flavor	6.46±1.52^{a}	6.13±1.45^{a,b}	5.90±1.95^{b}	6.00±1.61^{a,b}
Texture	5.83±2.00^{c}	6.33±2.18^{b}	5.86±2.16c	7.13±1.61^{a}
Taste	7.13±1.52^{a}	6.00±1.98^{b}	5.76±2.31^{b}	7.06±1.79^{a}
Overall satisfaction	7.03±1.44^{a}	6.50±1.99^{b}	6.00±2.10^{c}	7.23±1.43^{a}
Total score = 9				

Different superscript letters in the same row were significantly different for given satisfaction aspect ($p<0.05$)

Table 3. Physico-chemical analysis

Characteristics	Control	50% Ca by RDA formula recipe
Ash (g/100g), mean ± SD	2.03 ± 0.02	2.42 ± 0.03^
Ca (mg/100g), mean ± SD	68.89 ± 0.02	183.38 ± 0.01^
Color		
L*, mean ± SD	54.40 ± 0.02	42.24 ± 0.04^
a*, mean ± SD	4.02 ± 0.01	6.33± 0.02^
b*, mean ± SD	20.43 ± 0.05	21.55 ± 0.03^
Moisture (g/100g), mean ± SD	2.99 ± 0.10	3.66 ± 0.03^
Protein (g/100g), mean ± SD	4.33 ± 0.02	4.46 ± 0.02

^Significantly difference with the control recipe at $p<0.05$ analyzed by simple paired t-test

Discussion

Nowadays, there are variety of food products, marketed for health improvement, available in the markets. The Ca-fortified products are found in the form of traditional snacks in Thailand, such as Sticky Rice in Bamboo (Khao Lam).[13] In other countries various forms of Ca-fortified products such as fruit juice and baked goods have shown an effective health outcome among participants.[14] This study innovated a Ca-fortified cracker with a cricket protein source to promote the nutritional status and Ca intake among people, that distinguished it from the developed cracker used in previous studies, such as the Sacha inchi leaf (*Plukenetia volubilis*)-fortified cracker with Tuna. Those results found that modified recipes were acceptable to participants.[15] However, food product innovators have to focus on vitamin D due to its being an enhancer of Ca absorption, therefore essential in bone formation.[16] Also, consumption of other food sources of Ca

should take into account the amount of phytate and oxalate content, these natural compounds being commonly found in tea, coffee, and some green leafy vegetables, because of their action as Ca absorption inhibitors.[17,18]

The findings of the study revealed that the satisfaction score on the appearance of crackers in the 50% Ca by RDA formula recipe was comparable with the control recipe, whereas the 15% and 25% Ca by RDA formula recipes obtained lower satisfaction scores when compared to the other two recipes. This could be explained by the amount and taste of Ca fortification, affected and enhanced by a puffy cracker, due to binding with carbohydrates after frying.[19] However, the satisfaction scores on color, on all recipes, were low. It is possible that the replacement with cricket protein powder, instead of other commonly used powders, based on meat, fish and shrimp, caused the darker color that is unfamiliar to participants.[20] Other aspects, such as the taste and texture of crackers in the 50% Ca by RDA formula recipe, scored higher than other recipes. This could be explained by the amount of Ca fortification in this recipe, that created enhanced stability and improved the crunchiness of the sample, due to the higher density of Ca molecules in the carbohydrate. This is shown in the participants ratings, as tabulated.[21] In contrast, previous study performed the physicochemical evaluation of noodles fortified with commercial calcium salts found that no significant influence on texture and springiness.[22] For proximate analysis and color values, ash, moisture, and protein, the differences in the analyzed characteristics were found between the control recipe and the Ca-fortified recipe. These possibly added Ca affected the proximate composition of the sample. The previous study pointed out that the amount of Ca in foods led to higher ash, moisture accumulation, and changes in food color.[23,24] This could be the reason why the proximate and color analysis is different between the two recipes, whereas protein was prepared in the same weight, hence no difference in protein content was found.

The Ca powder used in fortification was the food grade of calcium citrate which is easily found in the markets at affordable prices and has high bioavailability in the human body. However, there are still other forms of Ca that can be used for fortification due to its high bioavailability, such as calcium carbonate, calcium phosphate, etc.[25] For the cricket powder, this study used the *Acheta domesticus* species in the product sample, whereas another species, *Brachytrupes portentosus*, produced flour that was low in carbohydrate, protein, and fat. Some other species, such as *Gryllus bimaculatus* and *Glyptotendipes testaceus*, are not farmed in Thailand. They are commonly found in South Korea and China and produce flour that is lower in carbohydrate, protein, and fat than the species used in this study.[26]

Conclusion

In conclusion, the cracker with cricket protein in the 50% Ca by RDA formula recipe is acceptable by participants and the intention is to use this preparation in further clinical studies. A future study is suggested to investigate the effectiveness of the cracker, in the 50% Ca by RDA formula recipe, on biochemical markers related to bone health, such as parathyroid hormone and alkaline phosphatase, and also the effect on bone mineral density among the participants.

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Conflict of Interest

The author(s) do not have any conflict of interest.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Statement

The study protocol and the informed consent form were approved by Ethical Institutional Review Board of Burapha University (approval number IRB1-091/2566).

Informed Consent Statement

Written informed consent has been obtained from the participants to publish this study.

Clinical Trial Registration

This research does not involve any clinical trials.

Author Contributions

- **Alongkote Singhato:** Conceptualized the study and wrote the draft of manuscript.
- **Narisa Rueangsri:** Created the cracker recipes and performed the statistical analyses.
- **Rungsima Daroonpunt:** Conducted the sensory evaluation.
- **Phutthida Kongthitilerd:** Conducted the sensory evaluation.
- **Natthapaninee Thanomsridetchai:** Conducted the sensory evaluation.

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