Study of pre-treatment and frying condition for seasoned deep fried shredded bamboo shoots (*Thyrsostachys siamensis*)

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Abstract. The objective of this research is to develop a new product of bamboo shoots, which is a seasoned deep fried shredded bamboo shoot. The study was divided into three parts which were the assessment of pre-treatment process for seasoned deep fried bamboo shoot prior to frying, the frying conditions and the consumer acceptability of the seasoning and flavour of the final product. Three pre-treatment processes assessed were freezing, vacuum drying and freeze drying. Three frying temperature levels were 160, 170, and 180°C for 3 and 5 seconds. Two seasoning flavours, corn cheese and paprika, were chosen in this study for a consumer acceptance evaluation. The results showed that the appropriate pre-treatment and frying conditions were the vacuum drying at 60°C for 3 hours and frying at 180°C for 3 second. This condition provided the good characteristics of inflated light golden yellow of the product with a low moisture content of 3.40±1.08% wet basis (w.b.), crispness value of 7.58 N and colour value in L* a* b* term were 51.57±0.91, 6.44±0.19 and 21.96±1.09, respectively. The consumer acceptability of the product was evaluated by sensory test using 9-points hedonic scale, it was found that the overall acceptability on corn cheese and paprika flavours of the product were moderate to much with the score of 7.08±1.44 and 7.18±1.25, respectively. It can be concluded that the bamboo shoots processed in this way have the potential to be developed into a new product.

1. Introduction

Bamboo shoots are one of the favorite spring season vegetables in the East Asian region, particularly in China, Taiwan, Japan and other South-East Asian countries. In the northern part of Thailand, there are many regions planting bamboo for the wooden craft industry. In the raining season, a new shoot arises from underneath the root system which is then gathered, and eaten as a vegetable [1].

Bamboo shoots are a very low-calorie commodity. 100 grams of fresh cane has only 27 calories. Bamboo shoot contain moderate levels of soluble and non-soluble (NSP- non-starch carbohydrates) dietary fiber. 100 g of fresh shoots provides 2.2 grams of fiber. Dietary fiber helps maintain good bowel function, and can decrease bad (LDL) cholesterol levels by binding to it in the intestines. Studies suggest that a high-fiber diet can help cut down risk of colon-rectal cancer by protecting digestive organs from the toxic compounds in the food. Regular consumption of dietary fiber showed various health benefits such as prebiotic activity, lower risk of coronary heart disease, hypertension, obesity and some gastrointestinal diseases [2].

Bamboo shoots are also rich in the B-complex group of vitamins such as thiamin, riboflavin, niacin, vitamin B-6 (pyridoxine), and pantothentic acid, these are essential for optimum cellular enzymatic and metabolic functions. Bamboo shoots contain important minerals, especially manganese and copper. It
has small amounts of some essential minerals and electrolytes such as calcium, iron, and phosphorus. Manganese is utilized by the human body as a co-factor for the antioxidant enzyme, superoxide dismutase. Copper is employed in the production of red blood cells. Iron is essential for cellular respiration and red blood cell formation [3].

In addition, bamboo shoots contain excellent levels of potassium. 100 grams of fresh shoot offers 533 mg or 11% of daily required levels of potassium. Potassium is an important component of cell and body fluids that helps controlling heart rate and blood pressure by countering effects of sodium [4].

There bamboo shoots germinate in the raining season, which causes an oversupply of bamboo shoots in the community in this season but a lack of supply throughout the rest of the year. To process the bamboo shoots, the villagers normally apply an easy and simple method to preserve the bamboo shoots such as making a pickled bamboo shoot or boiling the bamboo shoot and keeping it in a vacuum-packed plastic bag. This can extend the shelf life of bamboo shoot but the price of these products is very low. The bamboo shoot is an abundant and costless plant crops in Thailand. Therefore, this study aims to determine if a new product could be produced from the bamboo shoot which would increase its value. The seasoned deep-fried shredded bamboo shoot was designated because the main characteristic of bamboo shoot is that it has a lot of fiber content. The pre-treatment processes for frying bamboo shoots was applied in order to promote a novel product with added-value with subsequent acceptance by local consumers.

2. Materials and methods

2.1. Materials

Bamboo shoots (Thyrostachys siamensis) were provided from the villagers in Mae-On district, Chiangmai province, Thailand. The bamboo shoots were preliminary prepared by boiling at 100°C for 10 minutes to eliminate cyanide, which is a toxic in bamboo shoots. It was reported in the literature that boiling process can reduce cyanide for 91% [5]. The initial weight of the sample was controlled to an average of 92.52±13.9 grams per one bamboo shoot. The moisture content of the sample was preliminary analysed as 80.06±1.29 g/100 g bamboo shoots. After that the boiled bamboo shoots were cut into small pieces with a dimension of 0.3 x 7 x 0.3 cm. They were then prepared according to the different pre-treatment processed outlined below.

2.2. A study of pre-treatment process for preparing the bamboo shoots before frying

A Completely Randomized Design (CRD) was used to design the experimental plan. Three pre-treatment conditions were freezing at -18°C for 24 hours, vacuum drying at 60°C for 3 hours and freeze drying at -30°C for 3 hours [6,7]. 800 grams of bamboo shoots were prepared for each of the three pre-treatment conditions. After the process, the moisture content of the bamboo shoots was determined using moisture analyzer (MB45, Ohaus). Then, all bamboo shoots were fried at 180°C for 3 seconds. The moisture content and texture of the fried bamboo shoots were measured.

2.3. A study of frying condition of the shredded bamboo shoots

After the most optimal pre-treatment condition was established, next, the most suitable frying condition for the shredded bamboo shoots was also investigated. To design the experiment, 3×2 Factorial Design in CRD was used. There were three levels of frying temperature and two levels of frying time, which were 160, 170 and 180°C for 3 and 5 seconds [7]. Therefore, there were six conditions for this study. After frying, the chemical and physical properties (moisture content, texture and colour) of the products were measured, all analyses were performed in triplicate.

2.4. Physical and chemical characteristics

2.4.1. Moisture content. The moisture content was measured using moisture analyzer (MB45, Ohaus).
2.4.2. Texture. The texture of the fried sample was measured using Texture Analyzer CT3 in a compression test mode. A spherical probe with diameter of 13 mm was applied. A speed of compression was of 0.05 mm/min [8]. The base size was of 38 mm width and 14 mm thickness.

2.4.3. Colour. Colour is a key factor indicating an attractive appearance of the sample. In this study the colour of the sample was measured using a colorimeter (MINOLTA, CR-400) and expressed in term of $L^*$, $a^*$ and $b^*$ indicating the lightness, redness and yellowness, respectively.

2.5. A study of consumer acceptability in seasoning flavours
To investigate consumer acceptability of the seasoned deep-fried shredded bamboo shoots, two flavor seasonings were chosen, which were corn cheese and paprika. A sensory evaluation was conducted using a 9-point hedonic scale with 50 untrained panelists ranging from 18 to 65 years of age. To prepare the sample, the deep-fried shredded bamboo shoot sample was mixed with the seasoning powder in a ratio of 2% w/w and served to panelists seated separately in booths in order to allow unbiased evaluation of the sensory attributes. Samples of seasoned deep-fried shredded bamboo shoot were evaluated in terms of product specific colour, taste, flavour, texture (crispness and dryness) and overall acceptability on a 9-point hedonic scale. The acceptability attributes were valued from the lowest score 1 (dislike extremely) and the highest score 9 (like extremely).

2.6. Statistical analysis
Experimental data was statistically analyzed using EXCEL (version 2016) software program. One-way analysis of variance (ANOVA) was performed with pre-treatment and frying condition as factors and $P < 0.05$ was taken as indicator of statistical differences between the means. The differences among mean values of all data were also tested using EXCEL software program using Turkey’s multiple comparison test method at 95% confidence intervals.

3. Results and discussion

3.1. A study of pre-treatment process for preparing the bamboo shoots before frying

![Before frying](image1.png)

![After frying](image2.png)

**Figure 1.** The characteristics of the shredded bamboo shoots after three pre-treatment conditions. (a) Freezing at -18°C, (b) Vacuum drying at 60°C and (c) Freeze drying at -30°C.

The appearance of the shredded bamboo shoots after pre-treatment are illustrated in figure 1. It can be seen that the appearance of the shredded bamboo shoot under freezing was moist and light yellow colour which was different from the other two samples. The sample under vacuum drying and freeze drying were withered and darker in appearance. This can be explained by the fact that the freezing process did not cause any changes to these characteristics or obvious mass loss of the sample because the freezing process changes the water in the sample into ice but does not remove water from the sample. In the other
hand, vacuum and freeze drying are water removal process by evaporation and sublimation, respectively. The process of water removal contributed to the contraction of cell plant matrix that was previously occupied by the water [9]. The samples were dried but had a small change in colour. After pre-treatment, the samples were fried at 180°C for 3 seconds to preliminary observe the characteristic after frying of the sample and the fried samples were also shown in figure 1. The result showed that the sample from the freezing process had uneven colour and developed a curve shape. However, the other two sample from vacuum drying and freeze drying were straight and golden yellow colour. It can be assumed that pre-treatment had an effect on the final characteristics of the sample after frying, the vacuum drying and freeze drying provided a better appearance of the sample.

To further determine the influence of the pre-treatment on the physical and chemical properties of the samples, the moisture content and texture were measured. The moisture content of the samples from all three pre-treatment processes before and after frying were compared with the control sample without any pre-treatment and shown in figure 2. The initial moisture content of the sample from a control, freezing, vacuum drying and freeze-drying processes before frying were 80.06±1.29, 79.50±0.66, 6.57±0.77 and 6.50±1.08%w.b. respectively. The moisture content of two samples from vacuum frying and freeze drying were much lower than that of the control and the sample from the freezing process because drying process removed the water from the sample. After frying, the moisture content of all samples decreased significantly to 7.50±0.39, 7.44±0.42, 2.88±0.13 and 2.88±0.34%w.b., respectively. This was because the water inside the sample evaporated due to the high temperature of frying process [10]. The lowest moisture contents were found in the sample from vacuum drying and freeze drying because their moisture content before frying were lower as a result of the pre-treatment process.

![Figure 2](image-url)

**Figure 2.** The moisture content of the shredded bamboo shoots from all three pre-treatment processes before and after frying.

A compression test was done to give an indication of the crispness of the fried sample and the results are shown in figure 3. From the force vs displacement profile, it can be seen that the fried sample from vacuum drying and freeze-drying processes showed a fluctuating pattern, which is typical of a brittle and crispy sample. However, there was no pattern for the control and the sample from the freezing process and no breakage of the shoots was observed during compression. The texture profile showed a smooth curve. It means that these two samples were not crispy according to a high initial moisture content and no crust occurring on their surface during frying. High moisture content absorbed oil during frying resulting a soft texture [11,12].

From the result, it can be concluded that vacuum drying and freeze drying were able to use in order to prepare the sample in the pre-treatment process before frying because these two methods offered the required characteristics of the fried shredded bamboo shoot. However, freeze drying is a costly method and take considerably longer than the other processes. Therefore, the suitable pre-treatment method for
the fried shredded bamboo shoot was vacuum drying at 60°C for 3 hours.

**Figure 3.** The force displacement profile from the compression test of fried shredded bamboo shoots from all three pre-treatment processes.

### 3.2. A study of frying condition of the shredded bamboo shoots

The dried shredded bamboo shoot from the pre-treatment process in the previous step was further studied to investigate the frying condition. Six frying conditions were applied, which were 160, 170 and 180°C for 3 and 5 seconds. The physical and optical properties of the final fried shredded bamboo shoots were measured namely colour moisture content and texture. The moisture content and colour values in terms of $L^*$ (lightness) $a^*$ (redness) and $b^*$ (yellowness) are shown in Table 1. It was found that the moisture content of the fried samples decreased with increasing frying temperature and time because water rapidly evaporated with higher amount at higher temperature and longer time. The lowest value was found in the highest frying temperature with the longest time. The same results were found in many studies about frying e.g. mushroom [7,13], potato chips [14] and banana [15]. The final moisture content of samples fried at 160, 170 and 180°C for 3 were 4.40±0.88, 4.28±1.25, 3.96±1.10 and 5 seconds were 3.65±0.69, 3.40±1.08 and 1.77±0.40% w.b., respectively. These moisture content values were below the critical moisture content (10% w.b.) for microbial growth in a dried food product [16]. The lightness ($L^*$) and yellowness ($b^*$) of the fried sample decreased with increasing time and temperature, but the redness ($a^*$) decreased. This was seen as the sample became darker because the non-enzymatic browning reaction took place on the sample surface [17-22]. The higher the temperature and longer the time, the higher non-enzymatic browning reaction the more browning occurred [23-25].

### Table 1. The moisture content and colour value of fried shredded bamboo shoots.

| Frying Conditions | 3 seconds | 5 seconds |
|-------------------|----------|----------|
|                   | MC (% w.b.) | $L^*$  | $a^*$ | $b^*$ | MC (% w.b.) | $L^*$  | $a^*$ | $b^*$ |
| 160°C             | 4.40±0.15 | 61.71±1.4 | 4.29±0.0 | 29.38±0.1 | 3.65±0.5 | 61.70±1.1 | 3.12±0.2 | 25.63±0.5 |
|                   | a<sup>1</sup> | 8<sup>a</sup> | 5<sup>b</sup> | 1<sup>a</sup> | 7<sup>a</sup> | 6<sup>c</sup> | 8<sup>b</sup> | 8<sup>b</sup> |
| 170°C             | 4.28±0.18 | 60.72±1.3 | 5.28±0.3 | 25.30±0.9 | 3.40±2.4 | 51.58±1.3 | 4.22±0.3 | 21.96±0.7 |
|                   | a<sup>2</sup> | 5<sup>a</sup> | 4<sup>a</sup> | 9<sup>b</sup> | 3<sup>a</sup> | 5<sup>b</sup> | 1<sup>b</sup> | 7<sup>c</sup> |
| 180°C             | 3.96±0.28 | 51.57±0.9 | 6.44±0.1 | 21.96±1.0 | 1.77±0.3 | 50.15±0.9 | 5.28±0.2 | 16.83±1.0 |
|                   | a<sup>2</sup> | 1<sup>b</sup> | 9<sup>a</sup> | 9<sup>c</sup> | 2<sup>b</sup> | 1<sup>b</sup> | 2<sup>b</sup> | 2<sup>d</sup> |

<sup>a</sup>Mean ± standard deviation (n = 3). Means within a column bearing the same superscript letter were not significantly different (p > 0.05).
However, from those previous two properties, the moisture content and colour, it cannot be concluded that which frying condition was the best. Therefore, the texture of the samples was also analyzed. The texture profile was shown in figure 4. From the profile, it was found that all samples showed the fluctuation pattern presenting all samples were crispy and brittle. It was also found that the texture profiles of the samples frying at 170°C for 5 seconds, 180°C for 3 and 5 seconds were higher and had more fluctuation than that of other three frying conditions, which were lower temperature and shorter time. The first compression force was found as 3.07, 4.68 and 5.71 N for frying at 160, 170 and 180°C for 3 seconds, respectively and 3.44, 5.16 and 5.37 N for frying at 160, 170 and 180°C for 5 seconds, respectively. The higher frying temperature and time, the higher crispness was obtained. The highest crispness of the sample was found in the sample fried at 180°C for 3 seconds. However, the crispness of the sample dropped when frying at 180°C for a longer time of 5 second since too long frying time resulted in more oil absorption [8]. Therefore, the best frying condition was 180°C for 3 seconds because this condition provided a good characteristics in the moisture content, colour and texture of sample.

![Figure 4](image)

**Figure 4.** The force displacement profiles from the compression test of fried shredded bamboo shoots at different frying temperature and time.

### 3.3. A study of consumer acceptability in seasoning flavours

A sensory evaluation was conducted on the seasoned deep fried shredded bamboo shoots to investigate the acceptability of the consumer on the developed product. The sensory evaluation showed a high score for all sensory attributes, the scores were between 94.5±1.44 and 7.24±1.44 as shown in figure 5. The consumer acceptability was like moderately to like very much and showed similar scores in every sensory attributes for these two flavours. However, the customers liked paprika flavour more than corn cheese flavour in some attributes e.g. taste, flavour and overall acceptance. This may be because paprika flavour delivered more taste than corn cheese flavour. The sensory evaluation in deep fried shredded bamboo shoot corn cheese flavour showed the highest score in overall acceptability (7.08±1.44) followed by colour (6.82±1.34), flavour (6.74±1.68), taste (6.68±1.52), dryness (6.54±1.83), crispness (6.24±2.50) and odour (5.94±2.05). For the paprika flavour, the highest score was obtained in flavour (7.24±1.44) followed by overall acceptability (7.18±1.25), taste (6.92±1.55), dryness (6.34±1.88), colour (6.26±1.55), crispness (6.22±1.89) and odour (5.94±1.80). It can be seen that the customers like less the odour and crispness of the product because the bamboo shoot has an unpleasant smell. Thus this problem should be solved in an additional study. From the result, it can be concluded that corn cheese and paprika seasoning were possible to use in order to produce the seasonned deep fried bamboo shoots as a commercial product.
Figure 5. Spider web diagram of the sensory evaluation of the seasoned deep-fried shredded bamboo shoots in two flavours.

4. Conclusion
From the result, it can be concluded that the pre-treatment process had influence on the final characteristics of the fried shredded bamboo shoot e.g. texture and color. In this case, the appropriate pre-treatment condition was vacuum drying at 60°C for 3 hours since vacuum drying reduced the moisture content of the sample without any adverse effect to the appearance e.g. colour. The low moisture content of the sample resulted in good characteristics for colour and texture of the product after frying. The suitable frying condition was 180°C for 3 seconds. The sensory evaluation on seasoned fried shredded bamboo shoot in two flavours (corn cheese and paprika) showed that the consumer accepted both these flavours with overall moderate approval.

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