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Effects of Components on Qualities of Crispy Bamboo Shoot Snack

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Abstract

The objective of this research was to study the effect of ingredients on the quality of crispy bamboo shoot snack. The effects of different ratios of tapioca flour and bamboo shoots on the quality of crispy bamboo shoot snack were studied. It was found that the optimum ratio of tapioca flour and bamboo shoot was 50:50. It had good appearance and swelling rate after frying. Moreover, the aroma of bamboo shoots was clear. The effects of different flour types on the quality of crispy bamboo shoot snack were investigated. It was found that tapioca flour was suitable flour for crispy bamboo shoot snack production. It had good appearance and swelling rate after frying that it was higher than the formula using glutinous rice flour, rice flour and wheat flour. In addition, the texture of the crispy bamboo shoot snack was crispy at an appropriate level. The effects of flavoring with various flavors on the sensory acceptance of consumers were investigated. The original, seaweed mixed with black sesame and spicy flavors had a higher score in appearance, flavor, taste, texture and overall liking score than other flavors. The analysis of the chemical composition of crispy bamboo shoot snack was investigated. The moisture, protein, fat, total carbohydrate, ash, and energy were 2.73-3.50 %, 1.04-2.39 %, 26.91-28.53 %, 66.36-66.67 %, 1.89-1.98 % and 513.08-523.81 kcal, respectively. It can be used as a guideline for crispy bamboo shoot snack production for commercial distribution.

Introduction

Bamboo shoots are the young shoots of bamboo trees. It is a raw material for food products that is delicious and rich in nutritional value. It is considered one of the five most popular health foods in the world. Bamboo shoots are used as raw materials for cooking in many countries such as China, India, Japan and Southeast Asian countries. Currently, bamboo shoots are processed into food products at the industrial level, such as dried bamboo shoots, pickled bamboo shoots, bamboo shoots soaked in brine, and canned bamboo shoots, etc. In terms of nutritional value, the chemical composition of fresh bamboo shoots is high in protein content between 1.49 to 4.04 (average 2.65 grams) per 100 grams of fresh bamboo shoots and contains 17 amino acids. There are 8 types of essential amino acids, especially tyrosine, which is approximately 57-67 % of all amino acids and

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it has a low-fat content of approximately 0.26-0.94 % (Chongtham et al., 2011).

Bamboo shoots have a high fiber content of about 6-8 grams per 100 grams of fresh weight. Furthermore, it has high phytosterols, which is a useful chemical substance. It helps reduce cholesterol and has anti-cancer activity (Brufau et al., 2008). In addition, bamboo shoots are a good source of vitamin B, niacin, vitamin A, vitamin B6 and vitamin E. There are many important minerals in bamboo shoots such as potassium, calcium, manganese, zinc, chromium, copper, and iron (Nirmala et al., 2007). The benefits mentioned above, thus bamboo shoots are a potential raw material in the food industry. Nowadays, planting bamboo shoots in Thailand can be found in every region throughout the country. Bamboo shoots that are planted for sale tend to continuously grow. If properly maintained, it can produce throughout the year. The bamboo shoots have very low price in the rainy season, which is a problem encountered by agriculturists. If there is no proper management process after cutting the bamboo shoots, the quality of fresh bamboo shoots will decrease rapidly. Therefore, the food products from bamboo shoots processing is an interesting way that helps to extend the shelf life of bamboo shoots and value adding to agricultural products.

Crispy snack is a product obtained from mixing flour with seasoning. It may contain meat, vegetables, or fruits such as fish, shrimp, pumpkin, taro, black sesame, and white sesame, etc. It is mixed and molded into the desired shape. Next, the mixture is steamed until cooked and cut into thin strips or shaped as desired. It is dried using heat from sunlight or other energy sources. It may be fried before packing or not fried (Thai industrial standards institute, 2006). Generally, there are two types of crispy snack products, including raw crispy snack and ready-to-eat crispy snack. Currently, there are many crispy snacks producing research from a variety of raw materials, such as fish (Tantasuttikul & Samuankid, 2014) Champedak (Wongsudaluk, 2016) mushroom (Khaepimyi & Nepthangdee, 2018) Burma bean (Suriya et al., 2011) etc. The fresh bamboo shoots are used as raw materials for crispy snack production that help increase the nutritional value of products and as an alternative food to consumers. Normally, there are many factors affecting on the quality of the crispy snack including the proportion of flour and other ingredients, the type of flour, the process of partially making the dough, kneading, steaming, drying, and frying (Tangkanakul, 2003).

The objective of this research is to study the effect of ingredients on the quality of crispy bamboo shoot snack. The apparent, physiochemical, and sensory acceptance were investigated to select the suitable formula for production as a prototype of crispy bamboo shoot snack. The knowledge gained from this research can be used as a guideline for the crispy bamboo shoot snack production. Moreover, it is way for value adding to agricultural products as well as further expanding into production for commercial distribution.

Materials and methods

1. Raw materials

The ingredients used in crispy bamboo shoot snack were composed of sugar (Mitrphol, Suphan Buri, Thailand), salt (Prungthip, Nakorn Ratchasima, Thailand), glutinous rice flour and rice flour (Erawan brand, Nakhon Pathom, Thailand), tapioca flour (Fish brand, Nonthaburi, Thailand), wheat flour (Kite, Samut Prakan, Thailand), vegetarian mushroom seasoning powder (Fah Thai, Nakhon Pathom, Thailand), Barbecue seasoning powder (OK, Samut Sakhon, Thailand), black sesame and ground black pepper (Raithip, Nonthaburi, Thailand), dried seaweed and garlic (Tontawan, Samut Prakan, Thailand). The bamboo shoots (*Dendrocalamus asper* Backer) were obtained from the agriculture group in Sa Kaeo province. The fresh bamboo shoots were cut. The bamboo shoots with similar growth stages of equal size and length approximately 30 cm were selected. The fresh chilli (*Capsicum annum* L.) young galangal (*Alpinia galanga* (L.) Willd.) and Yanang leaves (*Tiliacora triandra* (Colebr.) Diels) were bought from a local market in Sa Kaeo province.

2. Study on the effect of different ratios of tapioca flour and bamboo shoots on the quality of crispy snack

The bamboo shoots preparation, the shell was removed. It was washed with clean water, and was cut into small pieces before boiling in hot water for 30 min. It was removed from the hot water and was blended until fine. The ratio of tapioca flour to bamboo shoots was, 100:0, 75:25, 50:50 and 25:75, respectively. The blended bamboo shoots were heated with steaming for 1 min before mixing with tapioca flour that It was kneaded easily. The 60 % hot water was added in 100 % tapioca flour formula. The 25 % hot water was added in 75 % tapioca flour formula, while 50 % and 25 % tapioca flour formula without water added. The crispy snack production process was modified from Tangkanakul

(2003). First of all, tapioca flour and bamboo shoots according to the recipe were mixed and kneaded together. Secondly, the mixture was molded into a rectangle 40 mm long and 20 mm wide before steaming for 1 hr. Then, it was put in room temperature and cooled at 4˚C for 12 hr. It was cut into sheets with a thickness of about 2 mm and dried at 60˚C for 6 hr. The raw crispy snack products were kept in sealed container. The ready-to-eat crispy snack preparation, the raw crispy snacks were fried at 180˚C for 30 sec or until or until cooked throughout the sheet by observing from the blooming of the crispy snack and were kept in sealed container.

The appearance of crispy snack was observed, consisting of forming ability after mixing, swelling after steaming, gel stability after steaming, cutting ability after chilling, swelling rate after frying, hardness of raw crispy snack, hardness of ready-to-eat crispy snack, bamboo shoots flavor intensity of ready-to-eat crispy snack and yellow color intensity of ready-to-eat crispy snack. The analysis of the quality of the crispy snack in various areas as follows:

2.1 The weight loss value of ingredients after steaming, cooling, drying, and frying were analyzed. The crispy snacks before and after processing were weighted by balance (Zepper EPS-3001, China). Weight loss was defined as follows: weight loss (%) = [(Weight of crispy snacks before processing - Weight of crispy snacks after processing)/ Weight of crispy snacks before processing] x 100 (Kotoki & Deka, 2010).

2.2 The moisture content in raw crispy snacks and ready-to-eat crispy snacks were measured (Moisture Meter, GM640, China).

2.3 The swelling rate of crispy snacks was analyzed by replacing sesame seeds (Tiwthao, 2014). The swelling rate was defined as follows: swelling rate = (Volume of raw crispy snack (ml) / Weight of raw crispy snacks (g)) / (Volume of ready-to-eat crispy snacks (mg) / ready-to-eat crispy snacks (g))

2.4 The hardness of raw and ready-to-eat crispy snacks were measured using a hardness instrument (Daiichi FG 520K, Japan). The cylindrical probe was used, and the unit of force was newton (N).

2.5 Color of raw and ready-to-eat crispy snacks were measured by color meter (Colorimeter, WR10QC, China). The CIE system was defined by L * or brightness (0 = black, 100 = white), a * (+ a = red, -a = green) and b * (+ b = yellow, -b = Blue).

The optimum ratio of bamboo shoots and tapioca flour was selected to produce crispy bamboo shoot snacks in the next step.

3. Study on the effect of different flour types on the quality of crispy bamboo shoot snacks

The qualities of crispy bamboo shoot snack products using tapioca flour, glutinous rice flour, rice flour and wheat flour were compared. The ratio of tapioca flour to bamboo shoots selected in the previous step was used in the crispy bamboo shoot snack production. The crispy bamboo shoot snacks production, according to the steps mentioned above was carried out. The appearance of crispy bamboo shoot snack during the production process was observed, consisting of forming ability after mixing, swelling after steaming, gel stability after steaming, cutting ability after chilling, swelling rate after frying, hardness of raw crispy snack, hardness of ready-to-eat crispy snack, bamboo shoots flavor intensity of ready-to-eat crispy snack and yellow color intensity of ready-to-eat crispy snack. The weight loss, moisture content, swelling rate, hardness, and color value were investigated as follows above method. The suitable flour that had good quality of crispy bamboo shoot snacks was selected for production in the next step.

4. Study on the effects of flavoring of crispy bamboo shoot snacks with various flavors on the sensory acceptance

Raw material preparation: (1) The fresh garlic was peeled and washed before blending until fine. (2) Young galangal was washed and cut into small pieces before blending until fine. (3) Yanang leaves were washed and cut into small pieces. Yanang leaf to water ratio was 1: 1 by weight before blending until fine. It was filtered with a thin white cloth. Yanang water was boiled with bamboo shoots for 30 min. (4) Dried seaweed was blended into fine powder. (5) The fresh chilli was washed before blending until fine.

The crispy bamboo shoot snacks production using various flavors, consisting of original, garlic and pepper, young galangal and Yanang leaves, seaweed and black sesame, spicy and barbecue were investigated. The 1% sugar and 0.3% vegetarian mushroom seasoning powder were added in original formula and other formulas of crispy bamboo shoot snacks. The 0.5% garlic and 0.1 % pepper were added in garlic and pepper formula. The 0.5% young galangal was added in galangal and Yanang leaf formula. The 2% black sesame and 1% seaweed were added in seaweed and black sesame formula. The 0.5% fresh chilli was added to spicy formula. The 1% barbecue flavor was added to barbecue formula. The production of crispy bamboo shoot snacks

according to the steps mentioned above was carried out. The sensory evaluation by 30 untrained panelists was investigated. The importance of liking of appearance, flavor, taste, texture, and overall liking were expressed by 9-point hedonic scale. The suitable formula was selected for crispy bamboo shoot snacks prototype products.

5. Chemical composition analysis

Chemical composition of the crispy bamboo shoot snacks including moisture content, protein, fat, carbohydrate, ash and total energy were investigated (Association of Official Analytical Chemists, 2012).

6. Statistical analysis

The completely randomized design (CRD) was used. The statistical technique one-way ANOVA was used for calculating. Duncan's new multiple-range Test (DMRT) was used to compare the difference in the average values at the 95% confidence level.

Results and discussion

1. Effect of different ratios of tapioca flour and bamboo shoots on the quality of crispy snack

Effects of different ratios of tapioca flour and bamboo shoots on the observable characteristics of crispy snacks are shown in Table 1. It was found that the ratio of tapioca flour to a bamboo shoot at 25:75 was not suitable for crispy snack production. Obviously, it was formulated with a low tapioca flour and high bamboo shoots content. It was difficult to mold due to there being too little tapioca flour resulting in the low agglomeration of the mixture. The texture of crispy snacks during forming was very soft. There was a low swelling rate after steaming. The gelling structure after steaming was weak and unstable. It was quite difficult to cut into pieces after chilling. The crispy snack had the lowest swelling rate after frying. The texture of raw crispy snack and ready-to-eat crispy snack were quite fragile. Apparently, the ratio of tapioca flour and bamboo shoots at 100:0, 75:25 and 50:50 was suitable for crispy snack production. It was molded easy due to the appropriate ratio of tapioca flour and bamboo shoots, resulting in better agglomeration of raw materials. The texture of crispy snacks during forming molds easily, not too sticky or too messy. There was a high swelling rate after steaming. The gel structure was quite strong and stable. It was quite easy to cut into pieces after chilling. The crispy snack had the highest swelling rate after frying. The suitable texture of raw crispy snack and ready-to-eat crispy snack were suitably crispy were not easily broken, not sticky or hardened.

The ratio of tapioca flour and bamboo shoots were an important factor in the quality of the crispy snack. If the bamboo shoots add too little, there will be no fragrance of bamboo shoots such as the ratio of tapioca flour to bamboo shoots at 100:0 and 75:25. Conversely, the bamboo shoots were added in high volume such as the ratio of tapioca flour to bamboo shoots at 25:75, resulting in the low swelling rate. In terms of color, 100 % tapioca flour was used in crispy snack which was white in color. Bamboo shoots were added at 25 %, 50 % and 75 % that was yellow color of crispy snack. The intensity of the yellow color will increase, according to the amount of bamboo shoots in the formula. Basically, the production of crispy snack relies on the basic principle of gelatinization of the flour granule is occurring, which must be completely produced to get a good product (Tangkanakul, 2003). In general, characteristics of crispy snack according to product standards are specified. The raw crispy snack must be dry, non-sticky, and in separate pieces. The ready-to-eat crispy snack must be crispy, not sticky, or more hardened, good, and consistent swelling (Thai industrial standards institute, 2006). The flour solution is gelatinization when heated during steaming. It causes changes in the internal molecules because the hydrogen bonds within the starch molecules was destroyed by the heating process. The amylose and amylopectin polymers that are tightened in the granule will relax and combine with the surrounding water, resulting in changes in appearance, puffed of grain, and the viscosity of the flour solution continuously increasing (Damondaran & Parkin, 2017).

Table 1 Effect of different ratios of tapioca flour and bamboo shoots on the observable appearance of crispy bamboo shoot snack

Observable appearance	The ratio of tapioca flour to bamboo			
	100 : 0	75 : 25	50 : 50	25 : 75
Forming ability after mixing	+++++	+++++	+++++	++
Swelling after steaming	+++++	++++	++++	+
Gel stability after steaming	+++++	+++++	+++++	+
Cutting ability after chilling	+++++	+++++	+++++	++
Swelling rate after frying	+++++	+++++	+++++	+
Hardness of raw crispy snack	+++++	++++	++++	++
Hardness of ready-to-eat crispy snack	++++	+++	+++	+
Bamboo shoot flavor intensity of ready-to-eat crispy snack	-	++	++++	+++++
Yellow color intensity of ready-to-eat crispy snack	-	++	++++	+++++

Remark: + = very low, ++ = low, +++ = moderate, ++++ = high, +++++ = very high

The effects of different ratios of tapioca flour and bamboo shoots on weight loss, moisture content, swelling rate and hardness of crispy bamboo shoot snack are shown in Table 2. It was found that the weight loss after steaming varied directly as the amount of bamboo shoots. The weight loss after freezing, drying and low frying were inversely proportional to the amount of bamboo shoots. Specifically, the amount of tapioca flour had the lowest content that it caused the gel weakness after gelatinization. Moreover, the high initial moisture content of boiled bamboo shoots was 91.90-93.50 % (Mogkhuntod et al., 2017). It caused an unbalanced composition with a higher amount of liquid than solid. The free water had a higher evaporation during steaming, resulting in greater water loss than other formulas. In contrast, the formulas using the ratio of tapioca flour to bamboo shoots at 100:0 75:25 and 50:50 were observed. It was formulated with the right amount of tapioca flour and bamboo shoots. The gelatinization during steaming had a strong structure that the low weight loss.

The weight loss after chilling of all formulas have no significant difference to the 95% ($P > 0.05$). The weight loss after chilling may result from starch retrogradation. It occurs when a gelatinized starch paste was cooled. The glucose molecules in amylose and amylopectin chains are reconnected with hydrogen bonds and the water is eliminated. It is called syneresis that new crystals were created (Damondaran & Parkin, 2017). The weight loss after drying varied directly as the amount of tapioca flour. The water is eliminated during drying when air or hot air blows over the surface causing weight loss. The heat is transferred to the surface of the crispy snack and the water is eliminated by the latent heat of vapor formed. The water vapor is spread through the air film and is blown away by moving hot air. It causes the vapor pressure at the surface of the crispy snack that it is lower than the pressure on the inside of the crispy snack, resulting in differences in vapor pressure. The inner layer of crispy snack will have high vapor pressure and gradually decrease when the crispy snack layer near the dry air. This difference of vapor causes pressure to expel water from the crispy snack (Fellows, 2017).

The weight loss after frying varied directly as the amount of tapioca flour. In general, the method used for crispy snack frying is deep-fat frying. The heat transfer in the oil, frying is the convection of the hot oil and the heat conduction inside the products. The product surface will receive similar heat, resulting in consistent color and external appearance (Mogkhuntod et al., 2017). Most water is eliminated during the drying process. Therefore, there will be only a small amount of free water in raw crispy snack, resulting in a slight weight loss during the frying process. There are oil particles replacing the amount of evaporated water and the space inside the product, causing the oil content to increase and moisture to be reduced (Rattanathammawat et al., 2003).

The moisture content of all raw crispy snacks had an average of 9% by weight and ready-to-eat crispy snack has an average of 3% by weight. It was in the value range as according to the standard crispy snack products. The moisture content of raw crispy snacks must not exceed 12% by weight and the moisture content of ready-to-eat crispy snack must not exceed 4% by weight (Thai industrial standards institute, 2006). Drying was an important step affecting on puffing and pore consistency which was related to the moisture content in the crispy snacks. Generally, a crispy snack is heated from oil, which causes the water in the flour to vaporize. The vapor pressure in the crispy snack expands into a pore. The optimum moisture of raw crispy snack is approximately 12% by weight. If the raw crispy snack has moisture below 7-8%, that is baked too long, the raw crispy snack will crack. Conversely, if it is baked, or dried in the sun is a short time, will get a raw crispy snack with high humidity. There are some large, small, irregular porous holes when deep-frying that is characteristic of low-quality crispy snack (Tangkanakul, 2003). The hardness and swelling rates from raw crispy snack to ready-to-eat crispy snack after frying were observed. It is found that all formulas of crispy snack, a swelling rate and hardness have significance differences of the 95% ($P \leq 0.05$). The swelling rate and hardness of crispy snack varied directly as the amount of tapioca flour. Basically, the swelling of crispy snack is caused by many factors, such as the tapioca flour processing, kneading, steaming, chilling, drying and heating under high temperature by frying until causing the puffiness of the crispy snack (Fellows, 2017). The swelling rate of the crispy snack using the ratio of tapioca flour to bamboo shoot 25:75 had the lowest value because it is a low amount of tapioca flour. The swelling rate is related to the hardness of the crispy snack. If the amount of tapioca flour is high, it will cause the high gelatinization. It affects the viscosity of the crispy snack and making the strong structure of crispy snack. The hardness of raw and ready-to-eat crispy snacks were compared. It was found that ready-to-eat crispy snack was lower hardness than a raw crispy snack. Because the frying causes the expansion

of the structure that the structural strength to decrease (Kengkhetkit et al., 2019).

Table 2 Effect of different ratios of tapioca flour and bamboo shoots on the quality value of crispy bamboo shoot snack

Quality value of crispy snack	The ratio of tapioca flour to bamboo			
	100 : 0	75 : 25	50 : 50	25 : 75
Weight loss after steaming (%)	-1.67±0.29^{b}	-1.07±1.51^{b}	-0.33±0.47^{b}	9.33±1.70^{a}
Weight loss after chilling ns (%)	2.46±0.50	2.12±1.37	1.99±0.80	1.85±1.07
Weight loss after drying (%)	32.98±1.39^{a}	29.62±1.36^{ab}	26.09±3.37^{bc}	23.98±0.34^{c}
Weight loss after frying (%)	-0.95±0.78^{a}	-1.53±0.54^{a}	-1.85±0.69^{a}	-3.96±0.79^{b}
Moisture content of raw crispy snack (% by weight)	9.20±0.00^{a}	9.19±0.01^{a}	9.18±0.00^{ab}	9.17±0.02^{b}
Moisture content of ready-to-eat crispy snack^{ns} (% by weight)	3.14±0.04	3.11±0.02	3.10±0.00	3.09±0.01
Swelling rate after frying	1.02±0.01^{a}	0.90±0.01^{b}	0.85±0.02^{b}	0.56±0.02^{c}
Hardness of raw crispy snack (N)	17.63±0.14^{a}	14.30±0.13^{b}	12.32±0.04^{c}	7.23±0.02^{d}
Hardness of ready-to-eat crispy snack (N)	11.23±0.09^{a}	9.20±0.06^{b}	7.27±0.04^{c}	3.29±0.10^{d}

Remark: mean±SD, $^{a-d}$ means within each row indicate significant differences ($P \leq 0.05$) and ^{ns} means not statistically significant ($P > 0.05$) using Duncan's multiple range test

The effects of different ratios of tapioca flour and bamboo shoots on the color values of raw and ready-to-eat crispy snacks are shown in Table 3. It was found that the brightness (L *) varied directly as the amount of tapioca flour. The brightness of ready-to-eat crispy snack is greater than raw crispy snacks. The a * shows the red to green color values. If a * is negative, is in the green range and a * is positive, is in the red range. The a * value of ready-to-eat crispy snacks varied directly as the amount of bamboo shoots. The b * value indicates the yellow to blue range. If the b * value is negative in the blue range and the b * positive value is in the yellow range. The b * value of crispy snacks varied directly as the amount of bamboo shoots. Specifically, the crispy snacks without adding bamboo shoots had white color from tapioca flour. The yellow color of bamboo shoots is caused by the chemical composition which affects the color change such as carotenoids and chlorophyll (Bal et al., 2011). Carotenoids are yellow, orange, red, and red orange pigments. It is found in plants and organisms that can be synthesized by light. It is worked with chlorophyll, which is a green pigment. The chlorophyll absorbs energy from sunlight, photosynthesis and helps plant growth and protection from light hazards. Generally, chlorophyll is unstable to heat. If it exposed to heat, it changes to phytotin causing the green color to turn greenish brown (Damondaran & Parkin 2017). The crispy snack is heated by steaming, drying, and frying. It is resulting in chlorophyll being destroyed and changing color. The observable appearance and various quality values were considered. The suitable ratio was selected for development into crispy bamboo shoot snack in the next step. The tapioca flour and bamboo shoot equal to 50:50 was suitable formula. It is easy molding, good swelling, and strong structure after steaming, cut into pieces easily, good swelling after frying, and a clear aroma of bamboo shoots.

2. Effect of different flour types on the quality of crispy bamboo shoot snack products

The effect of different types of flour at the ratio of flour and bamboo shoots equal to 50:50 on the observable characteristics of crispy snacks shown in Table 4. It was found that tapioca flour has better the observable appearance than the other flours, such as forming ability after mixing, swelling after steaming, gel stability after steaming, cutting ability after chilling, swelling rate after frying, hardness of raw crispy snack, and hardness of ready-to-eat crispy snack. The aroma of bamboo shoots in all formulas has no significance differences of the 95% ($P > 0.05$). The tapioca flour and wheat flour formulas had a darker yellow color than glutinous rice flour and rice flour formulas. The kneading and molding process using glutinous rice flour, rice flour and wheat flour were more difficult than tapioca flour and sticky of texture, the puffiness after steaming of all formulas was compared. It was found that tapioca flour had the highest swelling rate, followed by glutinous rice flour, wheat flour and rice flour, respectively. The rice

Table 3 Effect of different ratios of tapioca flour and bamboo shoots on the color value of crispy bamboo shoot snack

The ratio of tapioca flour to bamboo	Raw crispy snack			Ready-to-eat crispy snack		
	L*	a*	b*	L*	a*	b*
100 : 0	70.74±0.21^{a}	-0.82±0.03^{d}	-0.25±0.02^{d}	77.19±0.17^{a}	-0.13±0.01^{d}	0.81±0.04^{d}
75 : 25	54.17±0.19^{b}	-0.32±0.02^{c}	2.83±0.03^{c}	65.58±0.10^{b}	0.45±0.06^{c}	9.31±0.03^{c}
50 : 50	52.59±0.05^{c}	-0.27±0.10^{b}	3.72±0.06^{b}	60.29±0.04^{c}	4.92±0.01^{b}	12.24±0.09^{b}
25 : 75	45.50±0.07^{d}	1.70±0.07^{a}	9.73±0.06^{a}	48.84±0.07^{d}	8.43±0.04^{a}	16.28±0.09^{a}

Remark: mean±SD, $^{a-d}$ means within each column indicate significant differences ($P \leq 0.05$) using Duncan's multiple range test

flour formula had the lowest swelling rate and high gel stability after steaming. The rice flour gel had a rather more the dense texture than other flour. It had low flexibility that different from the tapioca flour gel. It was soft and flexible. The glutinous rice flour and wheat flour gel had low stability. The cutting ability after chilling was investigated. It was found that the tapioca flour and rice flour formulas were cut easily. The glutinous rice flour and wheat flour formulas were difficult for cutting due to being sticky. In terms of swelling after frying, the tapioca flour had the highest swelling rate, followed by glutinous rice flour, wheat flour and rice flour, respectively. The texture of raw crispy snacks was stronger than ready-to-eat crispy snacks. The ready-to-eat crispy snacks using tapioca flour had a suitable hardness. The rice flour formula had the least hardness, brittle and easily broken.

The type of flour is an important factor that affects the quality the crispy snack. In various flour had different quality, such as the characteristics of cooked flour, temperature for making the dough cooked, the texture of the toughness, swelling, and crispy. Because each type of flour contains amylose and amylopectin in different proportions. The amount of amylose to amylopectin in tapioca flour, rice flour, wheat flour, and glutinous rice flour were, 17:83, 17:83, 28:72, and 0:100, respectively. The texture of cooked flour that contains high amylose had high hardness while the high amylopectin flour had highly sticky and flexible. The ratio of amylose to amylopectin was related to swelling rate. The flour that high amylopectin was good swelling, lightweight, and brittle products 1 (Tangkanakul, 2003).

Table 4 Effect of different flours on the observable appearance of crispy bamboo shoot snack

Observable appearance	Flours			
	Tapioca	Glutinous rice	Rice	Wheat
Forming ability after mixing	++++	++	++	++
Swelling after steaming	++++	+++	+	++
Gel stability after steaming	+++++	++	+++++	+++
Cutting ability after chilling	++++	++	+++++	++
Swelling after frying	++++	+++	+	++
Hardness of raw crispy snack	++++	+++	+	++
Hardness of ready-to-eat crispy snack	+++	++	+	+
Bamboo shoot flavor intensity of ready-to-eat crispy snack	++++	++++	++++	++++
Yellow color intensity of ready-to-eat crispy snack	++++	+++	+++	++++

Remark: + =very low, ++ = low, +++ = moderate, ++++ = high, +++++ = very high

The effects of different flour types on weight loss, moisture content, swelling rate and hardness of crispy snack are shown in Table 5. It was found that the weight loss after steaming, after cooling, and after drying of all formulas have no significant differences of the 95% ($P > 0.05$). The weight loss of tapioca flour and rice flour formulas were higher than rice flour and wheat flour lightly. The moisture content of raw and ready-to-eat crispy snacks after frying were 8.94-9.21 % by weight and 2.98-3.13 % by weight. It was in the standard range of general crispy snack products (Thai industrial standards institute, 2006). The swelling rate and hardness of crispy snacks after frying using tapioca flour had the highest, followed by glutinous rice flour, wheat flour and rice flour, respectively. Totally, the hardness of raw crispy snacks was higher than ready-to-eat crispy snacks.

There are many factors affecting on the swelling of flour, such as non-carbohydrate composition in starch granules, types of starch, strength, and appearance of the network structure within the grain, etc. Non-carbohydrate composition in starch granules, gluten in wheat flour which is a glycoprotein found in the endosperm of wheat. It is caused by the combination of glutenin and gliadin proteins in equal proportions. It is creating a disulfide bond, insoluble in water, making the gluten tough and flexible (Damondaran & Parkin, 2017). The glutinous rice flour, rice flour and wheat flour, which is flour from cereals, have a 2-puffing pattern. The bonding forces in flour are crystal and the amorphous bond. The cereal flour has the highest number of bonds but has the lowest swelling and dissolving. It has a high amount of amylose which amylose will strengthen the network structure and low swelling (BeMiller & Whistler, 2009). Glutinous rice flour is without amylose but is high amylopectin. It had good swelling, light weight, but easily brittle (Tangkanakul, 2003). Tapioca flour made from the root section or the middle of the stem. There is only one layer of swelling. Puffing power is higher than flour from cereals since there are fewer bonds. In addition, the flour from the root section causes gelatinization at lower temperatures than cereal flour, which is related to the hardness of the crispy snack. It may be caused by the number and type of bonds within the starch molecules. The factors affecting on the number of bonds including, size, shape, composition, distribution of the network structure within the starch granule, the ratio of amylose and amylopectin, molecular weight, molecular distribution, number of branches, the arrangement of molecules and the length of the branch in the amylopectin structure, etc

(BeMiller & Whistler, 2009). These factors resulted in different hardness values of crispy snack produced from different types of flour. The rice flour formula had the lowest hardness, brittle and easily broken that consistent with the observable appearance.

Table 5 Effect of different flours on the quality value of crispy bamboo shoot snack

Quality value of crispy snack	Flours			
	Tapioca	Glutinous rice	Rice	Wheat
Weight loss after steaming ^{ns} (%)	-0.33±0.47	-1.00±1.63	0.33±1.70	-2.00±1.63
Weight loss after chilling ^{ns} (%)	1.99±0.80	2.63±1.22	3.66±0.88	1.94±1.35
Weight loss after drying ^{ns} (%)	26.09±3.37	25.76±0.20	28.12±1.26	26.32±2.45
Weight loss after frying (%)	-1.85±0.69^{a}	-2.75±1.15^{a}	-5.81±1.25^{b}	-5.45±1.15^{b}
Moisture content of raw crispy snack (% by weight)	9.18±0.00^{b}	9.10±0.01^{ab}	8.94±0.00c	9.21±0.02^{a}
Moisture content of ready-to-eat crispy snack (% by weight)	3.10±0.00^{b}	3.13±0.00^{a}	2.98±0.01^{d}	3.00±0.02^{c}
Swelling rate after frying	0.85±0.02^{a}	0.72±0.01^{b}	0.06±0.02^{d}	0.54±0.01^{c}
Hardness of raw crispy snack (N)	12.32±0.04^{a}	10.40±0.03^{b}	5.19±0.07^{d}	8.20±0.03^{c}
Hardness of ready-to-eat crispy snack (N)	7.27±0.04^{a}	5.43±0.01^{b}	2.13±0.0^{2d}	4.00±0.02^{c}

Remark: mean±SD, $^{a-d}$ means within each row indicate significant differences ($P \leq 0.05$) and ^{ns} means not statistically significant ($P > 0.05$) using Duncan's multiple range test

The effects of different types of flour on the color value of raw and ready-to-eat crispy snack are shown in Table 6. The results indicated that raw crispy snack using rice flour for the production had the highest brightness, followed by glutinous rice flour, tapioca flour and wheat flour, respectively. In terms of ready-to-eat crispy snack, glutinous rice flour had the highest brightness, followed by tapioca flour, rice flour and wheat flour, respectively. The a * value of raw crispy snack produced from tapioca flour had a negative value that was in the green range. There was a positive value for other formulas in the red range. The a * value of ready-to-eat crispy snack was positive in the red range. The b * values of raw and ready-to-eat crispy snack in all formulas were positive in the yellow range. The yellow color of the crispy snack was the result of the pigment in bamboo shoots that mentioned above. In addition, using different flours results in the brightness of ready-to-eat crispy snack was different. The tapioca flour formula and glutinous rice flour had a high swelling rate, resulting in the structure of the cracker to expand. The brightness of ready-to-eat crispy snack was higher than a raw crispy snack. The rice flour formula and wheat flour to produce raw crispy snack had a higher brightness value than ready-to-eat crispy snack that due to having a low swelling rate. The fried crispy snack had darker color, result in the Maillard reaction. It is a non-enzymatic browning reaction. It occurs between reducing sugar and amino acids, protein or other nitrogen compounds under the heat catalyzed. The various compounds that give brown color and various flavorings were the products of Maillard reaction (Damondaran & Parkin, 2017).

The observed appearance and quality of the crispy snack were considered. It was found that tapioca flour has better the observable appearance than the other flours, such as forming ability after mixing, swelling after steaming, gel stability after steaming, cutting ability after chilling, swelling rate after frying, hardness of raw crispy snack, and hardness of ready-to-eat crispy snack. Therefore, the tapioca flour was suitable flour for crispy snack production in the next step.

3. Effects of flavoring of crispy bamboo shoot snacks with various flavors on the sensory acceptance

The results of flavoring of crispy snacks with various flavors on the sensory acceptance are shown in Table 7. It was found that all crispy snacks flavored had a high average score in appearance, flavor, taste, texture, and overall liking in the medium to like very much. The original, seaweed and black sesame, and spicy flavor had a higher average score in appearance, flavor, taste, texture, and overall liking than other flavors. All crispy snacks flavored had unique characteristics. The original flavor had the sensory characteristics like the crispy snacks that was commercially available in the market. The garlic and pepper flavor were outstanding in the aroma of garlic-pepper mixture. The young galangal flavor mixed with Yanang leaves was the aroma of young galangal like herb

Table 6 Effect of different flours on the color value of crispy bamboo shoot snack

Flours	Raw crispy snack			Ready-to-eat crispy snack		
	L*	a*	b*	L*	a*	b*
Tapioca	52.59±0.05^{c}	-0.27±0.10^{d}	3.72±0.06^{d}	60.29±0.04^{b}	4.92±0.01^{d}	12.24±0.09^{b}
Glutinous rice	53.29±0.08^{b}	2.26±0.08^{a}	4.87±0.06^{c}	70.41±0.07^{a}	5.35±0.02^{c}	13.57±0.07^{a}
Rice	70.47±0.07^{a}	0.45±0.03^{c}	14.33±0.06^{a}	56.74±0.04^{c}	7.37±0.02^{b}	10.40±0.11^{c}
Wheat	50.06±0.04^{d}	1.38±0.06^{b}	9.29±0.08^{b}	45.35±0.03^{d}	8.39±0.04^{a}	7.38±0.07^{d}

Remark: mean±SD, $^{a-d}$ means within each column indicate significant differences ($P \leq 0.05$) using Duncan's multiple range test

flavor. There are black sesame and seaweed distributed in pieces of crispy snacks with the fragrant aroma of black sesame seeds. The spicy flavor had fresh chilies and slightly spicy flavor. It was suitable for consumers who like spicy taste. The aroma of barbecue had the taste like the crispy snacks on the market that is flavored with barbecue flavor. All crispy snacks flavored had an average score in the medium to like very much. It can be used as a guideline to develop crispy bamboo shoot snacks for further commercial distribution.

Table 7 Effect of different flavors on sensory evaluation of crispy bamboo shoot snack

Crispy snack flavors	Attribute				
	Appearance	Flavor	Taste	Texture	Overall liking
Original	7.83±0.83^{ab}	7.53±0.82^{ab}	7.77±0.68^{ab}	7.73±0.87^{ab}	7.87±0.73^{ab}
Garlic and pepper	7.76±1.21^{ab}	7.40±0.81^{b}	7.73±0.98^{ab}	7.67±0.92^{ab}	7.53±0.97^{b}
Galangal and Yanang leaves	7.53±1.10^{b}	7.47±0.88^{ab}	7.50±1.10^{b}	7.57±0.93^{b}	7.50±1.06^{b}
Seaweed and black sesame	8.13±0.90^{a}	7.93±0.87^{a}	8.10±0.71^{a}	8.10±0.84^{a}	8.13±0.94^{a}
Spicy	8.03±0.93^{ab}	7.87±0.82^{ab}	8.00±0.91^{ab}	7.87±0.73^{ab}	8.07±0.91^{a}
Barbecue	7.53±1.11^{b}	7.57±1.01^{ab}	7.80±0.92^{ab}	7.67±0.99^{ab}	7.53±0.97^{b}

Remark: mean±SD, $^{a-b}$ means within each column indicate significant differences ($P \leq 0.05$) using Duncan's multiple range test

4. Chemical composition of crispy bamboo shoots snack products

The original, seaweed and black sesame, and spicy flavor of crispy bamboo shoots snack products (Fig.1) had the highest score of sensory acceptability in appearance, flavor, taste, texture and overall liking. It was selected for chemical composition analysis (Table 8). The crispy bamboo shoot snack produced is rich in nutrition. It is an interesting alternative product for consumers who enjoys eating snacks.

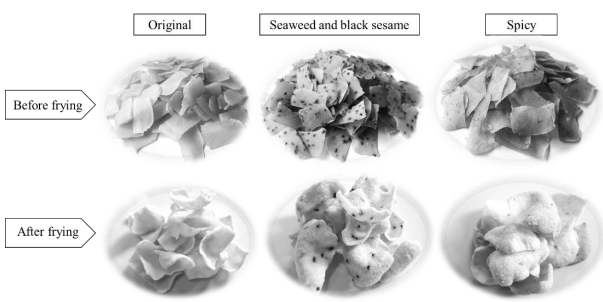

Fig. 1 Appearance of of crispy bamboo shoots snack products

Table 8 Chemical composition of crispy bamboo shoots snack products

Chemical composition	Crispy snack flavors		
	Original	Seaweed and black sesame	Spicy
Moisture content (%)	3.50 ± 0.25	2.73 ± 0.22	3.46 ± 0.19
Protein (%)	1.06 ± 0.39	2.40 ± 0.41	1.04 ± 0.35
Fat (%)	26.91 ± 0.45	28.53 ± 0.51	26.93 ± 0.55
Total carbohydrate (%)	66.64 ± 0.15	64.36 ± 0.12	66.67 ± 0.15
Ash (%)	1.89 ± 0.50	1.98 ± 0.66	1.90 ± 0.86
Energy (kcal)	513.08 ± 0.49	523.81 ± 0.60	513.12 ± 0.52

Conclusion

The optimum ratio of tapioca flour and bamboo shoots in the production of crispy snack was 50:50, which has easy molding, good swelling rate and strong structure of the gel after steaming, easy cutting, and good swelling rate after frying. Tapioca flour was a suitable raw material for crispy snack producing because of obtaining good quality products. The original, seaweed and black sesame, and spicy flavor had a higher score in appearance, flavor, taste, texture, and overall liking than other recipes. The prototype crispy bamboo shoot snack can be used as a guideline for further development of commercial production as alternative food products for consumers. It also creates added value for agricultural products. There may be additional studies on the packaging. That helps extend the shelf life of the product including modern packaging designs that attract consumer attention.

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References

Association of Official Analytical Chemists. (2012). *Official methods of analysis* (19th ed.). Washington, D.C.: Author.

Bal, L.M., Kar, A., Satya, S., & Naik, S.N. (2011). Kinetics of colour change of bamboo shoot slices during microwave drying. *Journal of Food Science and Technology, 46,* 827–833.

BeMiller, J.N., &Whistler, R.L. (2009). *Starch : Chemistry and technology.* London: Academic Press.

Brufau, G., Canela, M.A., & Rafecas, M. (2008). Phytosterols: Physiologic and metabolic aspects related to cholesterol-lowering properties. *Nutrition Research, 28,* 217-225.

Chongtham, N., Bisht, M.S., & Haorongbam, S. (2011). Nutritional properties of bamboo shoots: Potential and prospects for utilization as a health food. *Comprehensive Reviews in Food Science and Food Safety, 10,* 153-169.

Damondaran, S., & Parkin, K.L. (2017). *Fennema's Food Chemistry.* Florida: CRC Press, Taylor &. Francis Group.

Fellows, P.J. (2017). *Food Processing Technology: Principle and Practice.* Uxbridge: Woodhead Publishing.

Kengkhetkit, N., Mopoung, R., Tassanaudom, U., & Yodphet, A. (2019). Effect of wheat flour content on characteristics of spicy fermented fish paste crackers. *NSRU Science and Technology Journal, 11,* 1-14.

Khaepimyi, N., & Nepthangdee, P. (2018). *Consumer satisfaction per craker mushroom products.* Retrieved November 16, 2020, from https://dspace.bru.ac.th

Kotoki, D., & Deka, S.C. (2010). Baking loss of bread with special emphasis on increasing water holding capacity. *Journal of Food Science and Technology, 47,* 128-131.

Mogkhuntod, S., Denrungruang, P., & Chitchak, C. (2017). *Nutrients and toxins in the bamboo shoots.* Retrieved November 16, 2020, from http://forprod.forest.go.th

Nirmala, C., David, E., & Sharma, M.L. (2007). Changes in nutrient components during ageing of emerging juvenile bamboo shoots. *International Journal of Food Sciences and Nutrition, 58,* 345–352.

Rattanathammawat, R., Suwonsichon, T., Chompreda, P., Sriroth, K., & Haruthaithanasan, V. (2003). *Effect of moisture content of half-snacks and frying time on physicochemical properties of taro flour snack.* Retrieved November 16, 2020, from http://www.lib.ku.ac.th/KUCONF/KC4106006.pdf

Suriya, P., Thamaragsa, N., Kaewtein, S., Pocarat, R., & Arkanit, K. (2011). Product development of Burma bean chip. In *The 2nd MJU-Phrae National Research Conference* (pp. 276-283). Phrae: Maejo University Phrae Campus.

Tangkanakul, P. (2003). Making cracker as a quality product. *Food, 33,* 90-93.

Tantasuttikul, A., & Samuankid, N. (2014). Development of seasoning fish cracker. *Rajabhat Agriculture Journal, 13,* 71-79.

Thai industrial standards institute. (2006). *Community product standards: Crispy snack, khaogriab (107/2554).* Retrieved November 16, 2020, from http://tcps.tisi.go.th/pub/tcps107_54.pdf

Tiwthao, O. (2014). *Study of salmon skin puffing by microwave oven and frying* (Master's Thesis). Retrieved November 16, 2020, from http://kb.psu.ac.th/psukb/bitstream/2010/10010/1/388040.pdf

Wongsudaluk, W. (2016). *Application of champedak* (Artocarpus integer) *seed flour in cracker product.* Retrieved November 16, 2020, from http://ird.skru.ac.th/RMS/file/21388.pdf