Asia-Pacific Journal of Science and Technology: Volume: 26. Issue: 03. Article ID.: APST-26-03-04. Research Article

APST

Asia-Pacific Journal of Science and Technology

https://www.tci-thaijo.org/index.php/APST/index

Published by the Research and Graduate Studies,
Khon Kaen University, Thailand

Effect of banana blossom substitution on quality characteristic of plant-based shiitake mushroom balls

Kanyarat Chaiwongsa[1], Nitit Charoenvitayavorakul[1], Charida Pakasap[2] and Krittiya Khuenpet[2,*]

[1]Suankularb Wittiyalai Rangsit School, Khlong Luang, Pathum Thani, Thailand
[2]Department of Food Science and Technology, Faculty of Science and Technology, Thammasat University, Pathum Thani, Thailand
[*]Corresponding author: krittiya23@tu.ac.th

Received 2 March 2021
Revised 15 May 2021
Accepted 20 May 2021

Abstract

The blanching time of banana blossom was studied to prevent browning and then applied to develop mushroom balls enriched with banana blossom. Ten min was the appropriate blanching time after soaking banana blossom slices in 0.5% citric solution for 30 min. Pre-treatment of the banana blossom was used to partially replace shiitake mushroom. To formulate the plant-based mushroom balls, four ratios of shiitake mushroom-banana blossom were studied: 100:0, 75:25, 50:50 and 25:75. It was found that higher ratios of banana blossom content increased hardness, chewiness and gumminess, while springiness was decreased. The replacement of mushroom with banana blossom did not affect sensorial scores. The mixture of shiitake and banana blossom at the ratio of 50:50 received the highest appearance score at the moderately like level (7.40±1.24). Improvement of the texture by using 14% cassava flour achieved the highest overall acceptability score at like slightly (6.21±1.19). Up to 20% mushroom-banana blossom mixture could be added to the recipe to improve the health benefits without decreasing consumer acceptance.

Keywords: Banana blossom, Mushroom balls, Pre-treatment, Shiitake mushroom

1. Introduction

Increasing awareness of health concerns, environmental protection, animal rights and ethics have driven the increasing requirement for plant-based food [1]. However, the texture, flavor and taste of meat alternatives are factors affecting consumer acceptance. Meat alternatives should not have an unpleasant odor and should have the smell of meat, which is what consumers expect [2]. Jackfruit, nuts and mushrooms are ingredients that can be used directly as a substitute for meat and do not need to undergo a complex process. They taste similar to meat and are high in fiber and protein contents [3]. Vegetarian diets are usually made from mushroom and the texture is improved by using texturized vegetable protein from soy and pea [4].

Mushrooms have been used as human food for a long time. Several researchers have reported on the replacement of meat by the addition of mushroom in various products for example patties, sausages, frankfurters and meatballs [5]. However, substitution may affect the textural properties of products. A-sun et al. [6] found that an increase in the mushroom content in fish balls affected the texture and decreased customer acceptance. Increasing the shiitake mushroom proportion in pork balls significantly decreased their sensorial score in terms of texture [7]. The sensory attributes and textural properties of products are important characteristics for customer satisfaction. Nonetheless, a fibrous matrix of vegetables has been widely used as a component to imitate meat muscle and to improve the meat-like texture in various diets [4].

Banana blossom is used as a vegetable and in side dishes in many Asian countries such as Thailand, Sri Lanka, Indonesia and Myanmar. Banana blossom is consumed boiled or deep fried with rice in Myanmar and is processed as a dehydrated vegetable and in pickled and canned food in Indonesia. In Thailand, banana blossom is usually consumed as a vegetable in traditional Thai dishes such as curries and as a vegetable accompaniment for the 'Pad

Thai' dish [8,9]. Banana blossom is considered as a highly nutritional vegetable because it is an excellent source of fiber (57 g/100 g) and a good source of potassium, iron, magnesium, and vitamin E (553.3, 56.4, 48.7 and 1.07 mg/100 g respectively). Furthermore, the consumption of banana blossom reduces the blood sugar level and increases the hemoglobin content [10]. In addition, banana blossom can be used as a meat alternative because it is rich in fiber that provides a meat-like appearance, taste and texture [11]. Amir and Mariani [12] found that the use of banana blossom as a main ingredient to produce abon (a type of food in the form of meat fibers) could provide good sensorial qualities in terms of taste, aroma, color and texture. Novidiyanto et al. [13] reported that a ratio of banana blossom and chicken meat of 25:7 was most preferred based on the sensory attributes of color, aroma, taste, texture and overall acceptability.

Pretreatment before processing can reduce enzymatic browning and maintain the natural color of banana blossom before food product formulation. Thaweesang [8] treated banana blossom in boiling water for 5 min but the blanched sample still had a dark brown color. This was supported by Wickramarachchi and Ranamukhaarachchi [14] who reported that hot-water blanching banana blossom slices at 96-98 ℃ for 3-4 min caused a rapid browning resulting in a dark black color, whereas immersion of banana blossom slices in 0.2 % citric acid solution for 30 min was effective in lowering browning.

Nonetheless, there have been few studies related to preserving the pale yellow-brown color of banana blossom and its application in plant-based balls. Thus, the objectives of this study were to study the blanching time of banana blossom to prevent browning and to investigate the effect of banana blossom substitution on the qualities of shiitake mushroom balls.

2. Materials and methods

2.1 Banana blossom preparation

Banana blossoms from Namwa bananas (*Musa* ABB cv.Kluai "Namwa") in the same maturity stage were purchased from a local market near Thammasat University, Thailand. The outer purple-red leaves were removed and the bunches of florets were discarded. Then, the blossoms were cut into small pieces and immersed in 0.5% citric acid solution for 30 min to avoid discoloration after which the banana blossom slices were blanched in boiling water for 3, 5 and 10 min and rinsed in cold water. The blanched samples were photographed, measured for color (based on the L*, a* and b* values) and their browning index was calculated. The blanched sample that presented a light color and a low intensity of brown was selected to use in the next step. The blanched banana blossoms slices were blended and then excess water was squeezed out through a straining cloth. The squeezed banana blossoms were substituted in mushroom ball formulas with the aim of improving the quality characteristics of the plant-based shiitake mushroom balls.

2.2 Production of mushroom balls

Konjac flour (PTK Solution and Supplies Co., Ltd, Bangkok, Thailand), wheat flour (UFM Food Center Co., Ltd, Bangkok, Thailand), texturized vegetable protein (TVP), Citri-Fi® (a natural citrus fiber that promotes high water holding and emulsification), shiitake mushroom, sugar, salt and vegetable oil were purchased from a local market near Thammasat University, Thailand. The recipe for the mushroom balls was shiitake mushroom 11%, TVP 10.5%, konjac flour 7%, wheat flour 7%, Citri-Fi® 0.9%, sugar 4.15%, salt 1.80%, vegetable oil 2.15% and water 55.5%.

The TVP was chopped into small pieces and soaked in potable water for 10 min. The shiitake mushrooms were washed, sliced and blended with vegetable oil for 2 min. The prepared TVP was added to the blended sample and mixed well for 2 min. Then, the konjac flour, wheat flour, Citri-Fi®, sugar and salt were added to the mixture and all were blended for 4 min. Approximately 5 g of mushroom ball mixture was rolled into a spherical shape and then cooked in boiling water for 3 min. The finished products were drained and cooled under cold running water at ambient temperature and used as the control sample.

2.3 Partial mushroom substitution with banana blossom

Using the basic mushroom ball formula mentioned above, mushroom (11%) was partially replaced by 25, 50 or 75% pre-treated banana blossom. Thus, the four ratios of mushroom-to-banana blossom were 100:0, 75:25, 50:50 and 25:75, respectively. After cooking, all samples were photographed and determined based on textural profile analysis (hardness, springiness, cohesiveness, chewiness, adhesiveness and gumminess), color (L*, a* and b*), hue, chroma and sensory evaluation.

2.4 Texture improvement using cassava flour

According to the control recipe in experiment 2.2, the wheat flour (7%) was 100% replaced with cassava flour to offer an alternative for gluten-free customers. Therefore, the texture of the selected mushroom ball mixed according to the banana blossom formula from experiment 2.3 was improved by adding various levels of cassava flour at 7%, 10.5%, 14% and 17.5% of the whole formulation and these were compared based on their qualities with the wheat flour recipe (control sample). The textural profile analysis (hardness, springiness, cohesiveness, chewiness, adhesiveness and gumminess), color (L*, a* and b*), hue, chroma and sensory evaluation of cooked samples were investigated.

2.5 Optimization level of mushroom-banana blossom mixture

From the developed recipe, various percentages of mushroom-banana blossom mixture at 10%, 15% and 20% of the whole formulation were added to the formulas. All samples were cooked and evaluated for their quality characteristics in terms of texture profile analysis (hardness, springiness, cohesiveness, chewiness, adhesiveness and gumminess), color (L*, a* and b*), hue, chroma and sensory evaluation.

2.6 Quality determination

2.6.1 Texture profile analysis

The hardness, springiness, cohesiveness, chewiness, adhesiveness and gumminess of all samples were measured using a texture analyzer (plus-upgrade, Stable Micro System, USA). Spherical samples (20 mm in diameter) were analyzed by double compressing using a 50 mm cylindrical probe. The average values of at least 10 analyses were calculated.

2.6.2 Color

The color values of unblanched and blanched banana blossom samples and of all cooked mushroom ball samples were analyzed using a colorimeter (CX2678, Hunter Lab, USA). Sample was placed in a glass cell that was held on a base plate and then covered with an opaque lid. The results were expressed as lightness (L*), redness (a*) and yellowness (b*). Hue and chroma values of all samples were calculated based on equations (1) and (2):

$$Hue = \arctan (b^*/a^*) \quad (1)$$

$$Chroma = (a^{*2} + b^{*2})^{1/2} \quad (2)$$

2.6.3 Browning index

A browning index was used to assess browning in the banana blossom samples following equation (3):

$$Browning\ index = [100(x - 0.31)]/0.172 \quad (3)$$

(where, $x = (a^* + 1.75L^*)/(5.645L^* + a^* - 3.012b^*)$)

2.6.4 Sensory evaluation

Cooked samples were prepared and sensory evaluation was performed by 30 untrained panelists using a 9-point hedonic scale (where 9 = like extremely, 5 = neither like nor dislike and 1 = dislike extremely).

2.7 Statistical Analysis

All quality determinations were conducted in triplicate except for the texture profile analysis and the results were expressed as the mean ± standard deviation. A completely randomized design was applied on physical parameters. Sensory evaluation was carried out using a randomized complete block design. The data were analysed using the SPSS software version 20.0. One-way analysis of variance was used to determine significant ($p \leq 0.05$) differences between formulations. Multiple comparisons of means were performed using Duncan's multiple range test.

3. Results and discussion

3.1 Quality of shiitake mushroom balls substituted with treated banana blossom

Table 1 presents the photographs and color values of the chopped banana blossom samples after soaking in citric acid solution and blanching in boiling water for different periods. The banana blossoms without blanching after immersion in 0.5% citric solution had the highest browning index value with the most intense color. Therefore, immersion of the banana blossom slices in an acidic solution could not inactivate enzymatic browning completely. Sikora et al. [15] reported that 0.2-20 mM of citric acid produced 8.33-43.18% polyphenol oxidase (PPO) inhibition. PPO is the main enzyme causing the enzymatic browning reaction in foods [16]. Residual PPO may cause the change of color in banana blossom. In this experiment, all treatments prepared using blanching in boiling water had higher lightness (L*) and yellowness (b*) values than the unblanched treatment because the PPO was denatured in the range 50-70 °C [17]. PPO in paprika and chili had the lowest heat stability and was completely inactivated by heating at 80 °C for 10 min [18]. The current results showed that blanching banana blossom slices for 3 min produced the highest browning index among blanched treatments, followed by blanching for 5 min. In accordance with the research of Wickramarachchi and Ranamukhaarachchi [14], it was found that pre-treatment of banana blossom by blanching in hot water at 96-98 °C for 3-4 min incompletely inhibited PPO activity. Clearly, short-time blanching (3 or 5 min) was less effective at PPO inactivation, while a longer blanching period (10 min) produced a brighter color with the lowest browning index value. Thus, the appropriate condition for preparing banana blossom was to blanch it in boiling water for 10 min.

Table 1 Photographs, color values (L*, a*, b*), browning index of banana blossom treated by blanching in boiling water at different period time.

Boiling time (min)	0	3	5	10
				
L*	$43.94{\pm}0.24^{d}$	$46.94{\pm}0.43^{c}$	$48.01{\pm}0.51^{b}$	$51.22{\pm}0.23^{a}$
a*	$6.83{\pm}0.26^{a}$	$5.46{\pm}0.38^{b}$	$5.13{\pm}0.83^{b}$	$5.67{\pm}0.32^{b}$
b*	$19.84{\pm}0.43^{c}$	$20.27{\pm}0.25^{bc}$	$20.88{\pm}0.45^{b}$	$21.18{\pm}0.22^{a}$
Browning index	$69.81{\pm}0.97^{a}$	$63.62{\pm}0.64^{b}$	$62.26{\pm}0.16^{c}$	$59.40{\pm}0.28^{d}$

Note: In each row, different superscripts represent significant differences ($p \leq 0.05$).

The textural properties of mushroom balls replaced with banana blossom at difference levels are shown in Table 2. The lowest hardness value was in the control sample (ratio of shiitake to banana blossom; 100:0). Soft texture is a particular characteristic of mushroom [19]. Banana blossom is an excellent source of dietary fiber [20] and has high chewiness [21] and replacement of shiitake mushroom with various banana blossom levels significantly increased hardness, chewiness and gumminess. Springiness values trended to decrease with increased banana blossom content because of the fibrous structure of the banana blossom.

Table 2 Texture profile analysis of mushroom balls substituted with banana blossom at different ratios.

Ratios of shiitake and banana blossom	100:0	75:25	50:50	25:75
Hardness (g_{force})	$373.31{\pm}40.05^{b}$	$388.82{\pm}49.55^{b}$	$437.08{\pm}59.54^{a}$	$452.78{\pm}72.85^{a}$
Springiness	$0.78{\pm}0.05^{a}$	$0.73{\pm}0.03^{b}$	$0.75{\pm}0.04^{a}$	$0.75{\pm}0.05^{a}$
Cohesiveness ^{ns}	0.62±0.05	0.64±0.03	0.63±0.03	0.63±0.04
Chewiness	$177.17{\pm}20.38^{b}$	$186.74{\pm}23.28^{b}$	$209.67{\pm}35.71^{a}$	$209.37{\pm}42.46^{a}$
Adhesiveness^{ns}	-14.00±6.71	-16.20±5.54	-16.36±5.58	-16.02±6.55
Gumminess	$230.80{\pm}19.09^{b}$	$277.27{\pm}40.51^{a}$	$276.61{\pm}16.29^{a}$	$286.47{\pm}52.41^{a}$

Note: In each row, different superscripts represent significant differences ($p \leq 0.05$), ns = non-significant.

Table 3 presents the color values (L*, a* and b*), hue and chroma of shiitake-banana blossom balls with banana blossom at various ratios. The substitution of banana blossom in the shiitake mushroom balls affected the color of the final product as the brightness (L*) decreased and the redness (a*) increased with a higher quantity of banana blossom replacement. Not only banana blossom effected brown color as PPO is also found in shiitake [22]. Devece et al. [23] reported that extracted PPO was still active from mushroom treated by blanching in hot water for 6 min. Thus, the shiitake mushroom might promote browning development in the shiitake-banana blossom balls because no pretreatment method was applied to inactivate enzymes before using the shiitake as an ingredient in formulation. Moreover, the Maillard reaction might have occurred during cooking the shiitake-banana blossom balls because sugar and protein were in the recipes. It was noticed that both enzymatic and non-enzymatic browning reactions could happen during shiitake-banana blossom ball production which could have produced brown pigments and affected the ball color. The hue angle measures the shade or tonality of color and the hue of all samples was in the range 68.78-76.96, which indicating a red-yellow tone [24]. The reduction in hue values demonstrated that replacement of mushroom by banana blossom provided red-toned final products.

Table 3 Color values (L*, a* and b*), hue and chroma of balls replaced with banana blossom at various ratios.

Ratios of shiitake and banana blossom	100:0	75:25	50:50	25:75
				
L*	45.14±0.60^{a}	45.15±0.65^{a}	43.20±0.51^{b}	43.06±0.01^{b}
a*	2.71±0.14^{c}	4.20±0.23^{b}	4.56±0.51^{b}	5.39±0.01^{a}
b*	12.18±0.22^{c}	13.17±0.77^{b}	12.81±0.45^{bc}	13.88±0.04^{a}
hue	76.69±0.23^{a}	71.34±0.66^{b}	69.88±0.07^{c}	68.78±0.11^{d}
chroma	12.32±0.02^{d}	13.84±1.14^{c}	14.17±0.01^{b}	14.89±0.03^{a}

Note: In each row, different superscripts represent significant differences ($p \leq 0.05$).

The sensory evaluation results of the samples are shown in Figure 1. There was no significant difference in the sensorial scores in terms of color, flavor, taste, texture and overall acceptability. However, a greater amount of banana blossom decreased the taste score perhaps because the banana blossom has a slightly bitter flavor and in addition the increased banana blossom content may have diluted the umami taste, which is typical of shiitake mushroom [25]. The highest appearance score was observed in the treatment produced from the 50:50 ratio of mushroom and banana blossom.

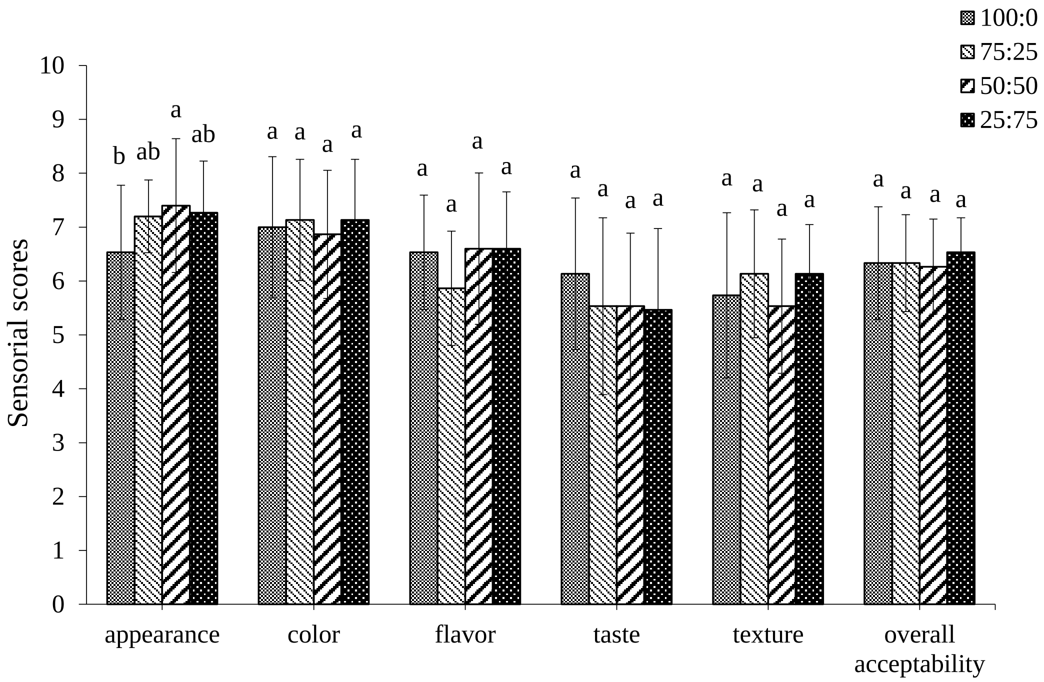

Figure 1 Sensory evaluation of mushroom balls replaced with banana blossom at difference levels. The same attribute with different letters are significantly different ($p \leq 0.05$).

3.2 Texture improvement from cassava flour addition

The texture of the mushroom-banana blossom balls was improved by replacing wheat flour with cassava flour, which also produced a vegan gluten-free product. Cassava flour was selected to improve the quality because it has greater swelling power and water-binding capacity than wheat flour [26]. The textural properties of balls made from wheat flour or cassava flour are shown in Table 4. The results showed that hardness, springiness, cohesiveness, chewiness and gumminess values of the balls made from cassava flour were higher than those made from wheat flour and that the increase was significant as the cassava flour content increased. This was because the cassava flour contains a high ratio of amylopectin, while wheat flour has a high ratio of amylose [26]. The amylose/amylopectin ratio has a direct effect on the behavior of starch that is evident in the viscosity and gelatinization, which affect the texture of final product [27]. Zhang et al. [28] reported that the high content of amylopectin in the starch increased its gel strength, whereas the greater amylose content in the starch reduced the strength of the gel.

Table 4 Texture profile analysis of shiitake-banana blossom balls added wheat flour or various cassava flour contents.

Texture Profile analysis	Wheat flour (7%)	Cassava flour (%) 7	10.5	14	17.5
Hardness (g_{force})	446.08±48.73^{b}	457.82±78.13^{b}	455.57±48.10^{b}	633.33±71.74^{a}	624.64±74.72^{a}
Springiness	0.73±0.02^{c}	0.84±0.03^{b}	0.93±0.03^{a}	0.93±0.02^{a}	0.93±0.01^{a}
Cohesiveness	0.64±0.03^{d}	0.68±0.02^{c}	0.72±0.02^{b}	0.73±0.02^{b}	0.74±0.01^{a}
Chewiness	217.38±27.92^{c}	264.59±50.39^{c}	305.94±36.76^{b}	430.96±53.62^{a}	433.97±47.26^{a}
Adhesiveness	-15.81±17.54^{c}	-10.67±10.41^{d}	-44.80±26.64^{b}	-58.09±26.57^{a}	-70.31±15.83^{a}
Gumminess	268.43+27.34^{c}	312.42±34.31^{b}	329.00±44.11^{b}	461.57±56.74^{a}	464.51±50.49^{a}

Note: In each row, different superscripts represent significant differences ($p \leq 0.05$).

The values for lightness (L*), redness (a*) and yellowness (b*) of all samples were in the ranges 42.89-46.58, 4.05-4.49 and 12.96-14.64, respectively. The lowest hue value was in the balls made from wheat flour, indicating that the color of these balls was closer to red than those of balls made from cassava flour, which had a brighter color than the balls made from wheat flour. This may have been due to the protein content in wheat flour being greater than for cassava flour [26], as a high protein content promotes a Maillard reaction in food [29]. Thus, the cassava flour substitution treatments had a brighter color than for the wheat flour formula. The mushroom-banana blossom balls with cassava flour had a smoother surface than for the wheat flour formulation because cassava flour is usually applied in food as a thickening agent, which can influence the appearance of product [30].

Table 5 Photographs and color values (L*, a* and b*), hue and chroma of balls added wheat flour or various cassava flour contents.

Color	Wheat flour (7%)	Cassava flour (%) 7	10.5	14	17.5
					
L*	42.89±0.42^{b}	46.58±1.53^{a}	45.81±1.89^{a}	45.50±1.09^{a}	42.96±0.09^{b}
a* ^{ns}	4.48±0.63	4.39±0.35	4.49±0.28	4.31±0.41	4.05±0.43
b* ^{ns}	12.96±0.53	13.16±3.66	14.64±1.23	14.12±1.62	13.34±1.59
hue	70.73±1.17^{c}	73.51±0.17^{a}	72.61±0.08^{b}	72.71±0.06^{b}	72.87±0.23^{b}
chroma	13.53±0.71^{b}	14.33±0.08^{a}	14.17±0.03^{a}	13.24±0.01^{b}	12.44±0.07^{c}

Note: In each row, different superscripts represent significant differences ($p \leq 0.05$), ns = non-significant.

Replacement of the wheat flour with casava flour did not affect the sensory attributes (appearance, color, flavor, taste and overall acceptability) of the shiitake-banana blossom balls because cassava flour is colorless, odorless and tasteless [31]. However, the texture sensorial score significantly increased when cassava flour was replaced wheat flour. The texture profile analysis results shown in Table 4 show that the mushroom-banana blossom balls with cassava flour at 14 and 17.5% had higher hardness, springiness, chewiness and cohesiveness values than for the wheat flour formula which was related to the higher sensory evaluation scores for texture, indicating a stronger texture and more acceptable mouthfeel. Thus, cassava flour provided a better texture and the most suitable amount of cassava flour addition for texture improvement was 14%.

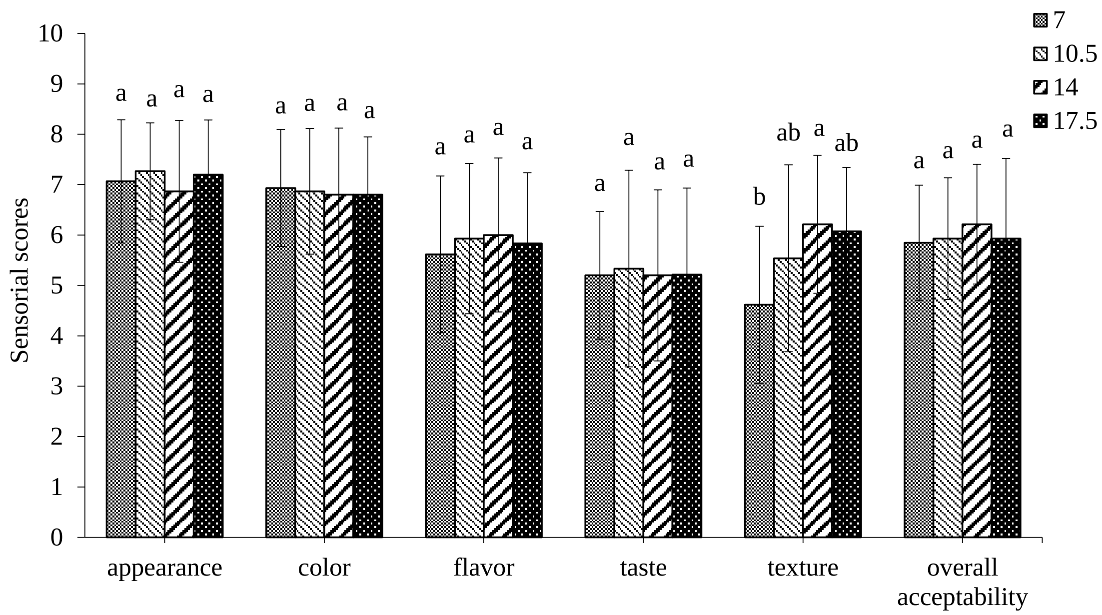

Figure 2 Sensory evaluation of balls added various cassava flour contents. The same attribute with different letters are significantly different ($p \leq 0.05$).

3.3 Optimization level of mushroom-banana blossom mixture

In the texture improvement experiment, the content of mushroom-banana blossom mixture in the developed formula was reduced from 11% to 10% and used as a control recipe. This study was performed to optimize the level of mushroom-banana blossom mixture in the developed formula to enrich the health benefits of the product. The mushroom-banana blossom mixture was formulated at 15% and 20% and the subsequent results of texture profile analysis are shown in Table 6. The addition of higher shiitake-banana blossom mixture contents significantly decreased the hardness, chewiness and gumminess values. The shiitake-banana blossom mixture content of 20% had the lowest hardness, cohesiveness, chewiness and gumminess values perhaps because the cassava flour concentrate in formula was diluted by increasing the mushroom-banana blossom content and the decrease in the cassava flour content may have had a negative effect on the structure resulting in a softer texture. Savadkoohi et al. [32] studied the improvement of quality of plant-based sausage by adding bleached tomato pulp and showed that consumer acceptance was related to increasing the hardness and chewiness of the meat analog.

Table 6 Texture properties of balls made with difference levels of mushroom and banana blossom.

Texture profile analysis	Shiitake-banana blossom mixture (%)		
	10 (control)	15	20
Hardness (g_{force})	633.33 ± 71.74^a	435.81 ± 43.99^b	329.08 ± 53.41^c
Springiness	0.93 ± 0.02^c	0.95 ± 0.02^a	0.94 ± 0.01^{ab}
Cohesiveness	0.73 ± 0.02^a	0.70 ± 0.01^b	0.70 ± 0.02^b
Chewiness	430.96 ± 53.62^a	290.59 ± 29.99^b	217.68 ± 31.20^c
Adhesiveness	-50.21 ± 13.95^a	-46.07 ± 16.86^b	-52.34 ± 10.59^a
Gumminess	452.78 ± 23.43^a	306.41 ± 31.40^b	231.49 ± 33.67^c

Note: In each row, different superscripts represent significant differences ($p \leq 0.05$).

The color values of the shiitake-banana blossom ball samples are shown in Table 7. There was a significant ($p \leq 0.05$) decrease in the lightness (L*) of these samples with increased content of mushroom and banana blossom mixture because the shiitake mushroom has a brownish color [33] and a high protein content [34], which could have been involved in a reaction by the reducing sugar and produced browning pigment, leading to a reduction in lightness (L*). The hue and chroma values of all samples were in the ranges 73.26-76.06 and 15.54-16.29, respectively.

Table 7 Photographs and color values (L*, a* and b*), hue and chroma of shiitake-banana blossom balls.

Color	Shiitake-banana blossom mixture (%)		
	10 (control)	15	20
			
L*	45.50±1.09^{a}	44.31±0.87^{b}	44.36±0.19^{b}
a* ^{ns}	4.31±0.41	4.00±0.09	4.25±0.25
b*	14.12±1.62^{b}	16.15±0.17^{a}	14.94±1.62^{ab}
hue	73.26±0.03^{b}	76.06±0.43^{a}	74.00±2.52^{ab}
chroma^{ns}	16.29±0.03	16.64±0.15	15.54±1.40

Note: In each row, different superscripts represent significant differences ($p \leq 0.05$), ns = non-significant.

Figure 3 shows the sensorial scores of the shiitake-banana blossom balls produced with different levels of mushroom-banana blossom mixture. The results revealed that the fortification with a high mushroom and banana blossom mixture content did not affect the sensorial attributes of the final products. Thus, the content of mushroom and banana blossom mixture could be used up to 20%. The sensorial scores in term of appearance and color were in the ranges 6.87-7.27 and 6.6-6.8, respectively. The flavor and taste scores were at the slightly like level (5.67-6.40), perhaps due to the high amino acid content in the shiitake mushroom, namely glutamic acid [35]. Glutamic acid is a monosodium glutamate-like component that provides the umami taste [36]. The texture sensorial scores were in the range 5.87-6.40. However, the addition of mushroom and banana blossom mixture contents up to 20% produced a soft texture. The hardness and chewiness values (Table 6) significantly decreased with an increase in the mushroom-banana blossom content up to 20%. Overall, the acceptability score was at the slightly like level, in the range 5.93-6.33.

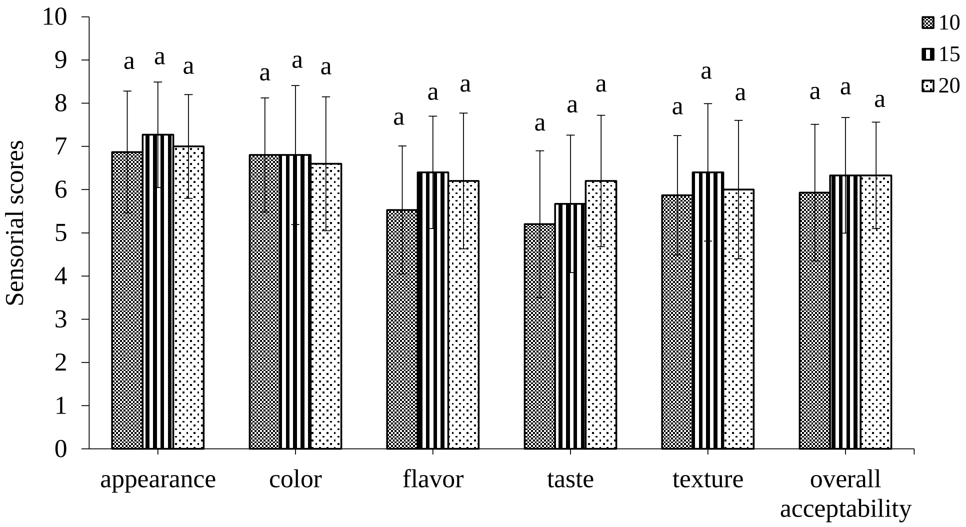

Figure 3 Sensory evaluation of shiitake-banana blossom balls.

4. Conclusion

Blanching in boiling water for 10 min was a suitable method to reduce the brown color in prepared banana blossom. Adding high ratios of banana blossom in the shiitake mushroom ball mixture caused a significantly harder texture and darker color than for the only mushroom formula. There were no significant differences in the overall acceptability scores of the mushroom balls and the mushroom-banana blossom balls. The ratio of mushroom-to-banana blossom at 50:50 produced the highest appearance score. The use of 14% cassava flour replacement could improve product qualities and produce shiitake-banana blossom balls with a bright color, chewy texture and smooth appearance. The mushroom-banana blossom mixture could be applied in the formula up to 20%, with this recipe still receiving overall acceptability scores in the liked slightly level. The banana blossom could be substituted in the mushroom ball recipe to create a plant-based food that was acceptable to consumers and improved the health benefits.

5. References

[1] Joshi VK, Kumar S. Meat analogues: plant based alternatives to meat products - a review. Int J Food Ferment Technol. 2015;5(2):107-119.

[2] Wild F, Czerny M, Janssen AM, Kole APW. The evolution of a plant-based alternative to meat: from niche markets to widely accepted meat alternatives. Agro Food Ind Hi Tech. 2014;25(1):45-49.

[3] C, Clayton ER, Specht L. Plant-based meat mind maps: An exploration of options, ideas, and industry, https://www.gfi.org/files/PBMap.pdf; 2017 [Accessed 25 August 2020].

[4] De Angelis D, Kaleda A, Pasqualone A, Vaikma H, Tamm M, Tammik M, et al. Physicochemical and sensorial evaluation of meat analogues produced from dry-fractionated pea and oat proteins. Foods. 2020;9:1-15.

[5] Pintado T, Delgado-Pando G. Towards more sustainable meat products: extenders as a way of reducing meat content. Foods. 2020;9:1-19.

[6] A-sun K, Sillapapakdee J, Charoensuk I, Thumthanaruk B. Textural profile of fish ball mixed with mushroom. Agricultural Sci J. 2013;44(2):593-596.

[7] Ruangchai S. Development and study of storage of pork balls mixed with shiitake mushrooms. University of the Thai Chamber of Commerce J. 2009;29(3):84-100.

[8] Thaweesang S. Antioxidant activity and total phenolic compounds of fresh and blanching banana blossom (Musa ABB CV.Kluai "Namwa") in Thailand. In: 3rd International Conference on Chemistry and Energy Research; 2020 Oct 23-25; Shenzhen, China: IOP Publishing; 2019.

[9] Swe KNN. Study on phytochemicals and nutritional composition of banana flowers of two cultivars (Phee kyan and Thee hmwe). Univ Res J. 2012;5(1):1-8.

[10] Singh S. Banana blossom-an understated food with high functional benefit. Int J Curr Res. 2017;9(1): 44516-44519.

[11] Wijaya W. Banana blossom floss (Rich in vitamin A,C,E, fiber, and potassium) [dissertation]. Citraland: Akademi Kuliner dan Patiseri Ottimmo International; 2020.

[12] Amir FL, Mariani NWR. Abon quality with the main substance of banana blossom. In: Proceedings of the 2nd International Conference on Tourism, Gastronomy, and Tourist Destination: 2018 March 8-9; Jakarta, Indonesia. Atlantis Press; 2018. p. 195-199.

[13] Novidiyanto N, Enardi OP, Devriany A, Pratiwi AP, Airuni M. Acceptability and antioxidant activity level of shredded banana flower chicken meat. Amerta Nutr. 2020;4(4):299-306.

[14] Wickramarachchi KS, Ranamukhaarachchi SL. Preservation of fiber-rich banana blossom as a dehydrated vegetable. ScienceAsia. 2005;31:265-271.

[15] Sikora M, Swieca M, Franczyk M, Jakubczyk A, Bochnak J, Zlotek U. Biochemical properties of polyphenol oxidases from ready-to-eat lentil (*Lens culinaris* Medik.) sprouts and factors affecting their activities: a search for potent tools limiting enzymatic browning. Foods. 2019;8(154):1-10.

[16] Guven RG, Guven K, Bekler FM, Acer O, Dogru M. Purification and characterization of polyphenol oxidase from purslane. Food Sci Technol. 2017;37(3):356-362.

[17] Shrestha L, Kulig B, Moscetti R, Massantini R, Pawelzik E, Hensel O, et al. Optimisation of physical and chemical treatments to control browning development and enzymatic activity on fresh-cut apple slices. Foods. 2020;9(76):1-21.

[18] Schweiggert U, Schieber A, Carle R. Inactivation of peroxidase, polyphenoloxidase, and lipoxygenase in paprika and chili powder after immediate thermal treatment of the plant material. Inno Food Sci Emerg Technol. 2005;6(4):403-411.

[19] Arumuganathan T, Manikantan MR, Indurani C, Rai RD, Kamal S. Texture and quality parameters of oyster mushroom as influenced by drying methods. Int Agrophys. 2010;24:339-342.

[20] Arya KS, Sinija VR. Proximate composition and antioxidant activity of banana blossom of two cultivars in India. Int J Res Agric Food Sci. 2016;7(1):13-22.

[21] Mu T, Sun H, Zhang M, Wang C. Sweet potato processing technology. 1st ed. Academic Press;2017.

[22] Jing-jun Y, Jian-rong L, Xiao-xiang H, Lei Z, Tian-jia J, Miao X. Effects of active modified atmosphere packaging on postharvest quality of Shiitake mushrooms (*Lentinula edodes*) stored at cold storage. J Integr Agric. 2012;11(3):474-482.

[23] Devece C, Rodrigues-Lopes JN, Fennol LG, Tudela J, Catala JM, de los Reys E, et al. Enzyme inactivation analysis for industrial blanching application: comparison of microwave, conventional and combination heat treatments on mushroom polyphenoloxidase activity. J Agri Food Chem. 1999;47(11):4506-4511.

[24] Changchai S, Varith J, Jaturonglumlert S, Narkprasom K, Theanworrakant N, Klinlajorn P. Application of ozone gas to disinfest fruit fly (*Actrocera latifrons*) in chilli. J Agr Res Ext. 2016;33(2):13-23.

[25] Kurihara K. Umami the fifth basic taste: history of studies on receptor mechanisms and role as a food flavor. BioMed Res Int. 2015;1-10.

[26] Eriksson E, Koch K, Tortoe C, Akonor PT, Baidoo E. Physicochemical, functional and pasting characteristics of three varieties of cassava in wheat composite flours. Br J Appl Sci Technol. 2014;4(11): 1609-1621.

[27] Karakelle B, Kian-Pour N, Toker OS, Palabiyik I. Effect of process conditions and amylose/amylopectin ratio on the pasting behavior of maize starch: a modeling approach. J Cereal Sci. 2020;94:1-9.

[28] Zhang H, Zhang W, Xu C, Zhou X. Morphological features and physicochemical properties of waxy wheat starch. Int J Biol Macromol. 2013;62(0):304-309.

[29] Kröncke N, Grebenteuch S, Keil C. Effect of different drying methods on nutrient quality of the yellow mealworm. Insects. 2019;10(4):1-13.

[30] Dzhivoderova M, Nikovska K, Hadjikinov D, Hadjikinova R. Evaluation of reduced-fat food emulsions with cassava starch. Int J Res Agric Sci. 2015;2(6):2348-3997.

[31] Paes SS, Akimets I, Mitchell JR. Influence of gelatinization process on functional properties of cassava starch films. Food Hydrocoll. 2008;22(5):788-797.

[32] Savadkoohi S, Hoogenkamp H, Shamsi K, Farahnaky A. Color, sensory and textural attributes of beef frankfurter, beef ham and meat-free sausage containing tomato pomace. Meat Sci. 2014;97(4):410-418.

[33] Songdach C, Riebroy S, Pasakawee K, Banjongsinsiri P, Ruangthamsing R, Siriwong N. Texture and color characteristics of crispy healthy snack produced from shiitake, straw and Indian oyster mushrooms. In: 12th ASEAN Food Conference; 2011 June 16-18, Bangkok;2011. p.722-725.

[34] Reis FS, Barros L, Martins A, Ferrreia ICFR. Chemical composition and nutritional value of the most widely appreciated cultivated mushrooms: an inter-species comparative study. Food Chem Toxicol. 2012; 50(2):191-197.

[35] Tabata T, Tomioka K, Iwasaka Y, Shinohara H, Ogura T. Comparison of chemical compositions of shiitake (*Lentinus edodes* (Berk.) Sing) cultivated on logs and sawdust substrate. Food Sci Technol Res. 2006; 12(4):252-255.

[36] Mau J. The umami taste of edible and medicinal mushrooms. Int J Med Mushrooms. 2005;7:119-125.