International Journal of Nutrition and Food Sciences
2022; 11(6): 187-192
http://www.sciencepublishinggroup.com/j/ijnfs
doi: 10.11648/j.ijnfs.20221106.12
ISSN: 2327-2694 (Print); ISSN: 2327-2716 (Online)

Exploring the Optimal Ratio of Pitaya Puree in Egg Rolls

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To cite this article:

Hung Ju Tsai, Chan Chiung Liu. Exploring the Optimal Ratio of Pitaya Puree in Egg Rolls. *International Journal of Nutrition and Food Sciences*. Vol. 11, No. 6, 2022, pp. 187-192. doi: 10.11648/j.ijnfs.20221106.12

Received: October 26, 2022; **Accepted**: November 15, 2022; **Published**: November 30, 2022

Abstract: Pitayas are highly nutritious fruits. Currently, the pitaya-planted area in Taiwan has continued to expand. To assist farmers in the disposal of substandard pitayas and in overcoming potential problems caused by an imbalance between production and consumption, this study incorporated pitaya puree into egg rolls to produce pitaya egg rolls and explored the color, water content, texture, and sensory evaluation of the rolls. The pitaya egg rolls with higher pitaya juice contents had higher *a* values (which represent redness) and lower water contents. Sensory evaluations revealed that among the five groups of pitaya egg rolls produced, the group with a pitaya juice content of 24% had the highest mean appearance score. The mean texture and flavor scores of the five groups did not differ significantly ($P > 0.05$). In terms of overall acceptance by tasters, the control group and the group with a pitaya juice content of 32% differed significantly ($P < 0.05$). Furthermore, the tasters were less accepting of the group with a pitaya juice content of 32%. The results of this study revealed that the produced pitaya egg rolls made from substandard or overly produced pitayas are feasible for commercialization. The pitaya egg roll production process proposed in this paper provides egg roll manufactures and consumers with a new product to produce and consume, respectively. The proportion of chicken eggs substituted with pitaya in egg rolls should be maintained at 16%–24%.

Keywords: Pitaya, Egg Rolls, Pitaya Egg Rolls, Texture, Sensory Evaluation

1. Introduction

Barquillos, hereafter referred to as egg rolls, are a popular snack among the general public and are often gifted as souvenirs. The snack has a soft and crunchy texture and a low water content and is small and easy to preserve. The main ingredients in egg rolls are eggs, flour, sugar, and oil. In the production of egg rolls, the necessary ingredients are first combined and creamed into batter. The batter is then flattened and fried using a egg roll machine and rolled into a cylindrical shape with a stainless-steel tube while still hot. In recent years, some manufacturers have started repeatedly folding the batter into itself to create square egg rolls; others have added flavored stuffing into egg rolls and made high-calcium egg rolls [1]. These innovative changes to egg rolls have become new directions for research and development. Pitaya puree is a rich source of nutrients, including vitamins, dietary fiber, betaine, organic acids, amino acid, and carbohydrates, which has prompted food manufacturers to take an interest in developing pitaya-based products [2-4]. Given that contemporary consumers remain concerned regarding the health and safety risks of artificial food coloring, the use of natural food coloring is expected to become increasingly common in the future [5, 6]. Studies on the applications of pitayas have reported that adding acid to pitaya juice can adjust the pH level of the juice and increase the stability of the anthocyanin therein [7]. Pitaya puree has considerable potential for applications in the production of soft candy; in addition to possessing a naturally bright red color, pitaya puree is highly nutritious. Accordingly, pitaya puree is considered a safe prospective functional food additive [8]. In one study, researchers performed an experiment that involved adding pitaya peel flour into cookies; the experimental results revealed that the addition increased the crude fiber content of the cookies and colored the cookies red [9]. In another study, researchers incorporated pitaya peel powder into Chinese steamed bread to enhance the nutritional value of the bread and to color it red. However, the study reported that steaming the bread caused the red coloring to fade. This can be attributed to the thermal decomposition of anthocyanin compounds, which produce chalcone structures that sink into deeper layers of the steamed bread and cause the color to fade. In addition, the researcher reported that the pitaya peel powder affected the fermentation of the flour but had the ability to remove free radicals [10].

Few studies have incorporated pitaya puree into baked foods. The objectives of the present study were as follows: (1) to help fruit farmers manage products deemed unmarketable because of excessive production or poor product quality; (2) to provide food product manufacturers with a new ingredient that can be used to increase product diversity; and (3) to help provide consumers with more nutritious and healthy egg rolls for consumption. In addition, this study explored (1) whether adding pitaya puree to egg rolls influenced the texture of the rolls; (2) whether pitaya puree content affected the color of the rolls; and (3) whether the recruited tasters were accepting of the rolls. The quality of the pitaya egg rolls was evaluated on the basis of color, texture, and sensory evaluation variables, and the relationships between the quality and the color, hardness, and water content of the rolls were examined.

2. Literature Review

2.1. Pitayas

Pitayas originated in the tropical rainforests of Central and South America and belongs to the genus *Hylocereus* of the botanical family Cactaceae. They are perennial succulent epiphytes commonly grown in tropical and subtropical regions. Pitaya species can be classified according to puree color and peel color; *Hylocereus undatus*, *Hylocereus polyrhizus*, and *Hylocereus megulanthus* have red peels with white puree, red peels with red puree, and yellow peels with white puree, respectively. Pitayas are egg-shaped, 300–600 g in mass, 32–35 cm in diameter, and 13–15 cm in length [11-13]. According to statistics published by the Agriculture and Food Agency of the Council of Agriculture of the Executive Yuan, the pitaya-planted area in Taiwan in 2017 comprised 2,846 hectares, accounting for a production capacity of 66,126 tons of pitayas. In recent years, Taiwan's pitaya production capacity has reached a balance between production and consumption. Pitaya production in Taiwan is concentrated in the central and southern counties, including Changhua, Nantou, Tainan, and Pingtung. At present, well-known varieties of red-peel pitayas in Taiwan include the *Shi-huo-quan*, *Wu-pei-lan*, *Mi-bao*, and *Mi-long* varieties.

2.2. Egg Rolls

Egg rolls are sweet, tasty, and crunchy cookies. They are usually golden and cylindrical porous surfaces. Their unique scent comes from the combination of ingredients used in the batter, which is baked using a egg roll machine [14]. The main ingredients in egg rolls are eggs, flour, oil, and sugar. The ingredients are creamed into batter, which is then fried and shaped into a cylinder with a stainless-steel tube to create a traditional egg roll. Some manufacturers have also produced new types of egg rolls by folding the batter into itself or adding fillings. The wheat flour used to prepare egg rolls is low in amylose, which contributes to the crunchy texture of egg rolls. Scholars have experimented with sage starch to produce egg rolls [15]. One study on pumpkin egg rolls reported that egg rolls made using batters with pumpkin powder contents of no more than 50% received the highest level of acceptance among tasters. A higher pumpkin powder content resulted in less crunchy egg rolls as well as a higher carotene content but lower protein and carbohydrate contents [16].

2.3. Sensory Evaluation

Sensory evaluation is a crucial experimental technique in the food product research and development and generally involves tasters using their senses of sight, smell, touch, taste, and hearing to evaluate and provide key information regarding the sensory characteristics of food. Sensory evaluations are the main qualitative and quantitative methods used to investigate consumers' opinions and attitudes toward food products. By reviewing information collected on the sensory characteristics of food products, manufacturers can assess the overall consumer acceptance of such products [17, 18]. Through this process, manufacturers can reduce the uncertainty and risks associated with product evaluation and identify factors that influence consumer acceptance and, in turn, determine the success of new products. Sensory evaluation is key to product success and the release of new products on the market [19]. Sensory evaluation is often performed by teams of human tasters. During the sensory evaluation process, the results of each team's evaluation are compared, and the data are analyzed. Food product researchers and developers then use the insights extracted from the data to create new products that align with consumer interests, thus enabling manufacturers to reduce development costs and increase profits. Because pastry products are assuming a more prominent role in the diets of contemporary consumers, pastry products can serve as a key source of nutrients and must be able to be accepted by consumers [20].

3. Methods

In this study, pitaya juice was employed as the base ingredient in the pitaya egg rolls. Pitayas were washed, peeled, diced, juiced, and sieved, and the pitaya juice was added to egg roll batter. Thereafter, the quality of the pitaya egg rolls was evaluated.

3.1. Ingredients

The egg rolls were produced using low-gluten flour (Uni-President, Tainan, Taiwan), powdered sugar (Wang Lai, Tainan, Taiwan), chicken eggs (PX Mart, Pingtung, Taiwan), butter (Fonterra, Taipei, Taiwan), and pitayas (*Hylocereus poltrhizus*) provided by farmers (Mingjian, Nantou, Taiwan).

3.2. Methodology

3.2.1. Production of Pitaya Egg Rolls

Table 1 lists the five recipes used to produce the pitaya egg rolls. The pitaya juice contents in recipes A, B, C, D, and E were 0%, 8%, 16%, 24%, and 32%, respectively. In the preparation of each pitaya egg roll batter, cream and sugar were first blended with a mixer (KitchenAid 3KSM150PSTER, USA). Then, eggs and pitaya juice were added and stirred evenly. Finally, low-gluten flour was added, and the mixture was stirred evenly. The batter was subsequently poured into a pastry bag, piped onto the egg roll machine (Huangta Industrial, Taichung, Taiwan), fried, rolled using a stainless-steel tube. After the egg rolls cooled and the tube was extracted, the rolls were complete.

Table 1. *Ingredient proportions.*

Ingredient	A (0%)	B (8%)	C (16%)	D (24%)	E (32%)
Butter	180	180	180	180	180
Sugar	150	150	150	150	150
Salt	1	1	1	1	1
Egg	244	183	122	61	0
Pitaya	0	61	122	183	244
Cake flour	200	200	200	200	200
Total	774	774	774	774	774

3.2.2. Analysis Methods

1) Texture analysis

Texture analysis testing was performed 1 hr after the pitaya egg rolls had finished cooling down. The samples were analyzed using a modified version of the method proposed by Gostin [21]. The texture analysis was performed using a CT3 Texture Analyzer (Brookfield Engineering Laboratories, Middleboro, MA, USA) and a 38.1-mm acrylic cylinder. The probe was inserted 10 mm into each egg roll to obtain a compression rate of 40%, and the hardness of each sample was tested. Three samples from each egg roll were analyzed.

2) Color analysis

The colors of the egg roll batters and final products were analyzed using a colorimeter (CR-10 Konica Minolta Sensing, Osaka, Japan). Samples of the batters were directly placed in a plastic bag for analysis; samples of the final products were acquired by grinding 10 g of the egg rolls and placing the grounds into a plastic bag for analysis. The indices used for color analysis were luminance (L), red content (a), yellow content (b), and whiteness index (WI). The equation used to calculate the whiteness index is as follows:

$$(WI) = 100- [(100-L)2+(a)2+(b)2]1/2 \quad (1)$$

3) Water content analysis

Water content analysis was performed on 2-g samples of the rolls with an infrared moisture meter (MF-50, A&D, Japan). The masses of the samples before and after the water in each sample evaporated were measured and recorded.

4) Sensory evaluation

The sensory evaluation method employed in this study was a modified version of the method proposed by Ulziijargal et al. [22]. Sensory evaluation was conducted 1 day after the pitaya egg rolls were completed. Each sample was 30 mm in length. A total of 60 students from departments of hospitality management between 18–24 years old were recruited as tasters. Each taster rated the color, scent, texture, and taste as well as their overall acceptance of the pitaya egg rolls on a 9-point scale. Score of 1, 6, and 9 corresponded to responses of *strongly dislike*, *acceptable*, and *strongly like*, respectively. Each sample was coded using a three-digit code. The mean scores assigned by the 60 tasters were obtained.

5) Statistical analysis

SPSS Statistics v 24.0 (IBM, USA) was used to statistically analyze the experimental data. With reference to the method proposed by Vasaf et al. [23], a statistical analysis was performed for a post hoc analysis of the experimental data to compare the least significant differences in the variables of interest. The level of significance was set at 5%.

4. Results and Discussion

4.1. Comparison of the Colors of Pitaya Egg Roll Batter and Final Products

The red color of the pitaya egg rolls originated from the natural color of the betaine in the pitayas [24]. The colorimeter was used to determine the a values of the pitaya egg rolls, with a higher a value indicating a redder color. Table 2 presents the results of the color analysis of the egg roll batters prepared using each recipe. The a values of the Group A and E batter samples were the lowest and highest, respectively, and the a values of all the groups differed significantly ($P < 0.05$). Pitaya juice content was positively correlated with a value (redness) but negatively correlated with L value (luminance).

Table 2. *Colors of batter samples.*

Group	L	a	b	WI
A	88.25 ± 0.08^a	3.17 ± 0.08^e	49.1 ± 0.26^a	50.29 ± 1.99^a
B	65.01 ± 0.44^b	35.8 ± 0.68^d	8.96 ± 0.20^b	49.14 ± 0.58^a
C	57.12 ± 0.24^c	46.17 ± 0.39^c	0.85 ± 0.13^c	36.98 ± 0.33^b
D	55.62 ± 0.43^d	47.19 ± 0.81^b	-6.96 ± 0.25^d	34.84 ± 0.42^c
E	48.89 ± 0.31^e	51.64 ± 1.19^a	-8.85 ± 0.21^e	26.80 ± 0.88^d

Mean values in the same column followed by different superscript letters are significantly different ($p < 0.05$).

Table 3 compares the colors of the final products. The Group A samples had the highest mean L value and the lightest colors. The samples with higher pitaya juice content had lower L values and, in turn, darker colors. Significant differences were observed among various groups ($P < 0.05$). The mean a value of Group C differed significantly from those of the other groups ($P < 0.05$; Figure 1), indicating that pitaya egg rolls made with a pitaya juice content of approximately 15% were the brightest shade of red. Therefore, a higher pitaya juice content does not necessarily result in a redder final product. Group C had the highest *a* value, followed by Groups D, E, B, and A. This finding is similar to those of a previous study on green tea cake, in which a higher content of additive was determined to result in an obvious color [25]. Because pitaya puree contains sugar, a high pitaya juice content may result in a final product appearing brown or darker colored. The color of the Group A final product (Figure 1) was the result of caramelization and a Maillard reaction [26]. The Group C final product was the brightest shade of red and was therefore selected as the optimal result. The Group D and E final products were darker shades of red because they had higher pitaya juice contents. The experimental results were similar to those obtained in a previous study, in which chicken eggs were replaced with rice hydrolysate in the production of egg rolls [27].

Table 3. *Colors of final products.*

Group	L	a	b	WI
A	63.98±1.16^{a}	10.55±1.16^{d}	30.41±1.08^{a}	51.48±0.38^{a}
B	58.54±1.01^{b}	17.00±0.78^{c}	23.05±0.84^{b}	49.39±0.50^{b}
C	58.36±0.78^{b}	24.65±0.74^{a}	16.89±0.43^{c}	48.35±0.56^{c}
D	51.18±0.95^{c}	22.45±0.30^{b}	16.67±0.48^{c}	44.58±0.64^{d}
E	47.56±0.42^{d}	23.03±0.97^{b}	15.73±0.50^{d}	41.45±0.50^{e}

Mean values in the same column followed by different superscript letters are significantly different ($p < 0.05$).

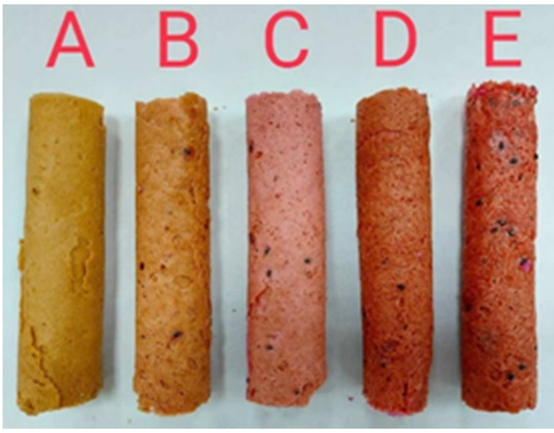

Figure 1. *Final products (pitaya egg rolls).*

4.2. Comparison of the Water Contents and Hardness of the Pitaya Egg Rolls

Table 4 compares the water contents and hardness of the pitaya egg rolls. The control group, namely Group A, had the highest water content. The pitaya juice content of the control group differed significantly from those of the other groups ($P < 0.05$), and the mean water contents of all the groups differed significantly ($P < 0.05$). Pitaya juice content affects the water content of a pitaya egg roll; a higher pitaya juice content results in lower water content. This may be attributed to the presence of pectin in pitaya puree and the high water content of chicken eggs, which were present in the highest concentration in recipe A.

When the texture analyzer was used to measure the hardness of the pitaya egg rolls, the Group E egg rolls were the hardest and were significantly harder than the egg rolls in the other groups ($P < 0.05$). A higher gel content results in a harder final product [28]. In the present study, egg rolls with a higher hardness value had lower water content [29].

Table 4. *Pitaya Egg Rolls Water content and hardness.*

Group	Water content	Hardness
A	2.32±0.18^{a}	1226.31±463.47^{c}
B	1.77±0.06^{b}	1901.15±625.47^{bc}
C	1.38±0.08^{c}	2005.73±686.54^{b}
D	1.17±0.12^{d}	1920.77±401.55^{bc}
E	0.92±0.05^{e}	2954.65±308.62^{a}

Mean values in the same column followed by different superscript letters are significantly different ($P < 0.05$).

4.3. Sensory Evaluation of the Pitaya Egg Rolls and Correlation Analysis of Sensory Evaluation Variables

Table 5 presents the mean scores assigned by the 60 tasters during the sensory evaluation process. The purpose of the evaluation was to determine whether the color and texture of the pitaya egg rolls would be appealing to consumers. The mean appearance scores of Groups A, C, D, and E did not differ significantly ($P > 0.05$); that of Group B was the lowest and was significantly lower than those of the other groups ($P < 0.05$). The tasters were accepting of the textures and flavors of all the rolls, and the groups' mean texture and flavor scores did not differ significantly. The sweetness of the Group A, B, C, and D rolls did not differ significantly; however, the sweetness of the Group E roll differed significantly from that of the Group A and C rolls. The mean overall acceptance scores of the rolls were all ≥6, and the tasters' overall acceptance of the Group A, B, C, and D rolls did not differ significantly ($P > 0.05$). However, the overall acceptance score of Group E was significantly lower than those of the other groups, which may be because the Group E roll had a higher betaine content, which negatively affected the flavor and the tasters' acceptance of the roll [30]. Group D had the highest mean appearance score, followed by Groups C, A, E, and B. Accordingly, the proportion of chicken eggs substituted with pitaya juice should remain at 16%–24%; completely substituting chicken eggs with pitaya puree results in egg rolls that are less acceptable to consumers.

Table 6 lists the results of the correlation analysis of the sensory evaluation variable. A 6 × 6 correlation analysis matrix was constructed. The correlation coefficients on the diagonal are 1, and the matrix is symmetrical about the diagonal. The appearance, color, texture, flavor, sweetness, and overall acceptance scores of the rolls were all significantly and positively correlated ($P < 0.01$). In particular, the coefficient of the correlation between flavor and overall acceptance was the highest (0.873), indicating that a higher level of acceptance of flavor corresponds to a higher level of overall acceptance. The second strongest correlation was that between appearance and color (0.861), suggesting that appearance and color are closely related. Finally, texture was strongly correlated with overall acceptance, and flavor was strongly correlated with both sweetness and overall acceptance.

Table 5. *Pitaya Egg Rolls Sensory evaluation results.*

	Appearance	Color	Texture	Flavor	Sweetness	Overall acceptance
A	7.01±0.38^{a}	7.03±0.40^{a}	7.06±0.35^{a}	7.21±0.38^{a}	7.27±0.39^{a}	7.36±0.34^{a}
B	6.30±0.38^{b}	6.21±0.41^{b}	6.61±0.37^{a}	6.94±0.38^{a}	7.03±0.41^{ab}	6.94±0.34^{ab}
C	7.04±0.35^{a}	6.90±0.39^{a}	6.80±0.42^{a}	7.10±0.39^{a}	7.17±0.35^{a}	7.13±0.33^{ab}
D	7.19±0.33^{a}	7.03±0.33^{a}	6.80±0.40^{a}	6.89±0.43^{a}	7.01±0.43^{ab}	6.84±0.43^{ab}
E	6.79±0.37^{ab}	6.89±0.38^{a}	6.49±0.45^{a}	6.61±0.43^{a}	6.53±0.43^{b}	6.66±0.42^{b}

Mean values in the same column followed by different superscript letters are significantly different ($P < 0.05$).

Table 6. *Correlation analysis of sensory evaluation variables.*

Pearson Correlation	Appearance	Color	Texture	Flavor	Sweetness	Overall acceptance
Appearance	1					
Color	.861 (**)	1				
Texture	.624 (**)	.608 (**)	1			
Flavor	.520 (**)	.555 (**)	.717 (**)	1		
Sweetness	.430 (**)	.475 (**)	.576 (**)	.750 (**)	1	
Overall acceptance	.581 (**)	.585 (**)	.746 (**)	.873 (**)	.787 (**)	1

**Significant correlation ($P \leq 0.01$; two-tailed).

5. Conclusion and Suggestions

5.1. Conclusion

In this study, a new product—namely pitaya egg rolls—were produced through the addition of pitaya puree to egg roll batters. Tasters' acceptance of the egg rolls as related to several sensory evaluation variables, including color, was assessed. The results indicated that the egg roll batters and final products with higher pitaya juice contents were brighter shades of red. Additionally, pitaya juice content was positively correlated with hardness but negatively correlated with water content. The tasters recruited for this study were more accepting of the pitaya egg rolls with pitaya juice contents of 16%–24% and less accepting of those with pitaya juice contents of ≥32%. The experimental results indicate that the pitaya egg rolls developed in this study are suitable for commercialization in the future.

5.2. Suggestions

(1) The pitaya-planted area in Taiwan is increasing. Food product manufacturers can assist farmers in the primary processing of pitayas, thereby preventing farmers from sustaining tremendous losses due to their inability to sell substandard products or an imbalance between production and consumption. Additionally, manufacturers of egg rolls may attempt to develop new pitaya-flavored products and thus diversify pitaya-related food products. (2) The experimental results presented herein indicate that the pitaya egg rolls developed in this study are feasible for commercialization. In the future, researchers should explore whether changes in ingredient composition or the addition of antioxidants would influence consumers' intention to purchase pitaya egg rolls.

Acknowledgements

Not applicable.

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