

## Preliminary study on ginger (*Zingiber officinale*) pulp-fortified squash (*Cucurbita moschata* Duch) and taro (*Colocasia esculenta*) milk jam

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### Abstract

Jams are a popular preserved food, but they commonly have a high sugar content and low fibre levels. This can be addressed by adding ginger pulp as a source of fiber while minimizing sugar during production without sacrificing its quality. Thus, this study evaluated the effects of ginger pulp and sugar on the water activity, pH, and sensory properties of squash-taro milk jam using response surface methodology to optimize its formulation. Results showed that ginger pulp significantly influenced the taste and sweetness of the jam, while sugar content affected its water activity ( $p < 0.05$ ). Other parameters remained unchanged across different formulations. Microbial analysis indicated no detectable growth at a  $10^1$  dilution factor for 6 months, confirming the product's safety for consumption. Based on the findings, an optimal formulation of 3.76 g of ginger pulp and 363.14 g of sugar can be used to improve the jam's quality and acceptability.

## 1. Introduction

Fruits and vegetables are preserved through various methods. One of these methods is processing them into jam by concentrating and adding sugar. Jams are popular food products due to their low cost of production, year-round accessibility, ease of processing, transport, and storage, and high acceptance. Commercial jams have become increasingly popular due to consumers' modern lifestyles; they are employed to process fresh crops into various products for long-term preservation (Gałkowska *et al.*, 2010; Poiana *et al.*, 2013; Teixeira *et al.*, 2020).

However, jams are commonly produced with high sugar to prolong their shelf life, which can significantly impact human health. Despite the known health risks associated with such jams, their popularity has remained high among consumers. However, excessive sugar consumption is linked to a high rate of chronic diseases such as diabetes, obesity, and cardiovascular diseases. Another one is the low fiber content of most sugar-preserved jams; based on the United States Department of Agriculture (USDA) National Nutrient Database for Standard Reference Legacy (2018) and Philippine Food Composition Table Online Database (PhilFCT) (2020), some jams only have around 0.3 to 1.2% total dietary fiber per 100 g. The lack of fiber in a jam can be rectified by using products with a good source of fiber.

Intake of high fiber has many health benefits, like maintaining body weight by promoting weight loss, preventing obesity and reducing appetite, lowering the risk of diabetes by reducing glucose absorption and improving insulin sensitivity, lowering blood sugar levels, promoting heart health, and reducing the risk of heart diseases, minimize the risk of cancer by binding carcinogens, balancing intestinal pH, and enhancing fermentation in the intestine; maintaining normal gastrointestinal function; relieving constipation by improving the movement of food in the digestive system; and lowering blood pressure (Dhingra *et al.*, 2012; Farooqui, 2015; Norris, 2023). Moreover, fiber-fortified products have the following properties: reduce calorie intake, control moisture migration, retard staling, prevent clumping and improve flowability, stabilize the structure of the food to minimize shrinkage or improve product density, and act as a texturizing agent and thickener (Gelroth and Ranhotra, 2001).

Ginger is commonly processed to extract high-value oleoresins and volatile oils (Palatty *et al.*, 2013; Lai *et al.*, 2016; Makanjuola, 2017; Kou *et al.*, 2018; Inthalaeng *et al.*, 2023). Therefore, a significant amount (by weight) of spent ginger waste was produced from industries such as herbal medicine or beverages (Wiastuti *et al.*, 2016). This waste is typically disposed of in landfills, burned (Konar *et al.*, 2013), or processed

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into low-value animal feed (Omage *et al.*, 2007; Eltazi, 2014).

Fiber is one of ginger's most essential quality parameters, which can be recovered from its waste. Ginger has 23.5% and 25.5% insoluble and soluble fiber, respectively (Shirin and Jamuna, 2010; Jayashree *et al.*, 2014). Ginger pulp has already been studied by the author and has optimized its process parameters to have around 69% fiber content from its initial value of 1.46% for fresh ginger and 3.08% for its pulp (Miranda, 2024).

In addition to ginger pulp, taro (*Colocasia esculenta*) will also be added as another source of nutrients and as a replacement for pectin to improve the consistency of the jam mixture. Taro is a good source of thiamine, riboflavin, iron, phosphorus, zinc, vitamins B6 and C, niacin, copper, and manganese. Foods made from taro can be consumed by people allergic to cereals and by infants/children who are sensitive to milk (Huang *et al.*, 2000; Rashmi *et al.*, 2018). Taro is also a source of potassium (Chandrasekara and Kumar, 2016). Potassium has important biological functions in neural transmission, vascular tone, and muscle contraction (Nascimento *et al.*, 2021). Banana, which is a well-known source of potassium, has an average amount of 326 mg per 100 g of potassium based on the FoodData Central of the USDA (USDA, 2020). Comparing this with taro having 591 mg of potassium in 100 g, taro has 81% more potassium than a banana. Moreover, according to the Philippine Statistics Authority (PSA), taro placed 3<sup>rd</sup> in the highest volume of production after cassava and sweet potato among the root crops in Bulacan, with 530.52 metric tons produced in 2020 (PSA, 2020).

As the Bulacan Agricultural State College of the Philippines, through its Food Innovation Center, has developed a squash-taro milk jam, it is strongly recommended to optimize its formulation to create a product that solves the major problems in commercial jams, as the product will be proceeding to its commercialization phase. This study provides insights into the influence of ginger pulp as fortification, along with its sugar level, on the properties of similar jams. Also, there hasn't been much research done on the application of this waste as an additive in the food industry.

## 2. Materials and methods

### 2.1 Jam production

Mashed squash, mashed taro, milk, sugar, dried ginger pulp powder, and unsalted butter were mixed in a bowl and then homogenized using a blender (Osterizer®, Model: 4172, 375W, China) to disperse the pulp in the

mixture. The formulation of the squash milk jam is shown in Table 1. The mixture was cooked at  $98\pm 2^\circ\text{C}$  in a double boiler with continuous stirring until it reached  $65\pm 3^\circ\text{Bx}$  measured using a refractometer (Baroni *et al.*, 2018; Teixeira *et al.*, 2020).

Table 1. Base formulation of the squash-taro milk jam.

Items	Quantity (g)
Mashed squash	200
Dried ginger pulp powder	5
Sugar	350
Taro	200
Milk	200
Unsalted butter	0.50

### 2.2 Sterilization and storage

The mixture was hot-filled in sterilized glass bottles and then capped. The samples were processed in a pressure canner (ALL AMERICAN, 25 Quartz, Non-electric, USA) at 15 psi for 15 minutes and cooled at room temperature. The products were stored in a cool, dry place before sensory evaluation (Department of Science and Technology (DOST) - Industrial Technology Development Institute (ITDI), 2013).

### 2.3 Physical analysis

#### 2.3.1 Water activity

The water activity of the jam was measured using a water activity meter (BIOBASE, BWA-3A, China). Two (2) grams of sample were placed inside the water activity chamber to start the measurement. Analysis was carried out in triplicate.

#### 2.3.2 pH

The pH level of the jam was measured using a pH meter (Lutron, BPH-231, Taiwan). Before analysis, the pH meter was calibrated using the provided buffering solution. A 10 g sample was used for the measurement and was carried out in triplicate (Wasihun *et al.*, 2023).

#### 2.3.3 Total soluble solids

The total soluble solids of the jam were measured using a digital refractometer (SNDWAY, SW-593, China). The refractometer was first set to  $0^\circ\text{Bx}$  using 1 ml distilled water before analysis. A 1 mL sample was placed onto the prism of the refractometer, and a reading was taken after 20 to 25 seconds. Values were expressed in  $^\circ\text{Bx}$ . Analysis was carried out in triplicate (Nduko *et al.*, 2018; Wasihun *et al.*, 2023).

### 2.4 Sensory evaluation

The sensory evaluation determined consumer acceptability and sensory parameters of the squash-taro

milk jam. One hundred (100) panelists (ages 18 to 55) evaluated the jams, and the sensory attributes of the samples to be tested were the following: color, smell, taste, sweetness, texture, and overall acceptability. The product was graded on a 9-point hedonic scale from the least to the most desirable in all sensory parameters (1 - 1.89 = Dislike extremely, 1.90 - 2.78 = Dislike very much, 2.79 - 3.67 = Dislike moderately, 3.68 - 4.56 = Dislike slightly, 4.57 - 5.44 = Neither like or dislike, 5.45 - 6.33 = Like slightly, 6.34 - 7.22 = Like moderately, 7.23 - 8.11 = Like very much, 8.12 - 9.00 = Like extremely).

### 2.5 Microbial analysis

Microbial load was evaluated to ensure the optimized product was safe for consumption. The total plate count in CFU/g was analyzed using AOAC Official Method 986.33 and 989.10 by Petrifilm, while yeast and mold count were analyzed using AOAC Official Method 997.02 by Petrifilm. Changes in the microbial count were monitored every month for six months.

### 2.6 Statistical analysis

Ginger pulp and sugar concentration were the two factors to be considered in the study. Central Composite Design under the Response Surface Methodology was used. Analysis of variance (ANOVA) was used to determine if there was a significant difference among treatments. Software used for the experimental design, visualization, and evaluation of results was Design-Expert (Version 13). The two coded independent variables to be used that correspond to the amount of ginger pulp and sugar are shown in Table 2.

## 3. Results and discussion

### 3.1 Fitting the models

The observed values of all dependent variables (water activity, pH, color, smell, taste, sweetness,

Table 2. Coded and uncoded values of the independent variables.

Run order	A	B	Sugar (g)	Ginger pulp (g)
1	0	0	350	5
2	-1	-1	300	3
3	1	-1	300	7
4	0	1.41	421	5
5	-1	1	400	3
6	1	1	400	7
7	0	0	350	5
8	0	0	350	5
9	0	0	350	5
10	1.41	0	350	8
11	-1.41	0	350	2
12	0	0	350	5
13	0	-1.41	279	5

texture, and overall acceptability) with the level of two independent variables (amount of ginger pulp and sugar) for all samples of the jam are given in Table 3, while the ANOVA results are presented in Table 4. The observed water activity and pH values for all different samples range from 0.82 to 0.87 and 5.67 to 5.79, respectively. The values for the sensory properties of the jam, such as color (6.97 to 8.00), smell (6.70 to 7.55), taste (6.42 to 7.64), sweetness (6.31 to 7.50), texture (6.52 to 7.70), and overall acceptability (6.70 to 7.73), are also indicated in Table 3. The lower (-1) and upper (+1) limits for the amount of ginger pulp were 3 g and 7 g, whereas for sugar, they were 300 g and 400 g. The minimum  $R^2$  was 0.80, which indicated that the data fit the statistical model (Zhao *et al.*, 2017).

### 3.2 Water activity

The lowest water activity was observed at the lowest ginger pulp and the highest sugar content. The analysis of variance results for the response surface model of water activity showed that sugar had a significant quadratic effect on the water activity of the jam ( $p < 0.05$ ). However, low correlation was observed with 0.72

Table 3. Values of the physicochemical and sensory quality of the squash taro milk jams.

Run order	Water activity	pH	Color	Smell	Taste	Sweetness	Texture	Overall acceptability
1	0.86	5.75	7.10	7.25	6.65	7.10	6.75	6.70
2	0.85	5.71	7.25	6.96	7.05	6.89	7.32	7.17
3	0.84	5.67	7.17	7.03	6.55	6.51	6.83	6.89
4	0.83	5.70	7.18	7.11	6.88	6.81	6.83	7.12
5	0.82	5.72	7.51	7.25	7.28	7.13	7.03	7.49
6	0.84	5.69	6.97	6.75	6.42	6.31	6.52	6.88
7	0.87	5.73	7.00	6.70	6.45	6.70	6.80	6.94
8	0.87	5.75	7.19	7.13	7.23	7.29	7.35	7.14
9	0.87	5.73	8.00	7.55	7.60	7.50	7.70	7.70
10	0.86	5.72	7.19	7.12	6.69	6.60	6.93	7.06
11	0.84	5.75	7.36	7.36	7.64	7.45	7.27	7.73
12	0.84	5.79	7.35	7.35	7.45	7.00	7.40	7.20
13	0.87	5.73	7.11	6.94	6.96	7.13	7.09	7.07

Table 4. ANOVA table of the dependent variables.

	Source	Sum of squares	df	Mean square	F-value	p-value	
pH	Model	0.0064	5	0.0013	1.7100	0.2499	not significant
	A-Ginger pulp	0.0017	1	0.0017	2.3300	0.1707	
	B-Sugar	2.40E-06	1	0.0000	0.0032	0.9563	
	AB	0	1	0.0000	0.0150	0.9061	
	A <sup>2</sup>	0.0013	1	0.0013	1.7100	0.2327	
	B <sup>2</sup>	0.0038	1	0.0038	5.1700	0.0572	
	Lack of Fit	0.0027	3	0.0009	1.3900	0.3676	not significant
Water activity	Model	0.0024	5	0.0005	3.6600	0.0600	not significant
	A-Ginger pulp	0.0001	1	0.0001	0.4619	0.5186	
	B-Sugar	0.0011	1	0.0011	8.2400	0.0240	
	AB	0.0002	1	0.0002	1.8000	0.2217	
	A <sup>2</sup>	0.0006	1	0.0006	4.4200	0.0736	
	B <sup>2</sup>	0.0006	1	0.0006	4.4200	0.0736	
	Lack of Fit	0.0004	3	0.0001	0.8273	0.5438	not significant
Color	Model	0.2028	5	0.0406	0.4384	0.8095	not significant
	A-Ginger pulp	0.0917	1	0.0917	0.9912	0.3526	
	B-Sugar	0.0031	1	0.0031	0.0340	0.8589	
	AB	0.0522	1	0.0522	0.5646	0.4769	
	A <sup>2</sup>	0.0034	1	0.0034	0.0371	0.8527	
	B <sup>2</sup>	0.0549	1	0.0549	0.5939	0.4661	
	Lack of Fit	0.0179	3	0.0060	0.0378	0.9887	not significant
Smell	Model	0.2628	5	0.0526	0.8220	0.5709	not significant
	A-Ginger pulp	0.0762	1	0.0762	1.1900	0.3112	
	B-Sugar	0.0073	1	0.0073	0.1149	0.7446	
	AB	0.0819	1	0.0819	1.2800	0.2950	
	A <sup>2</sup>	0.0008	1	0.0008	0.0129	0.9128	
	B <sup>2</sup>	0.0972	1	0.0972	1.5200	0.2574	
	Lack of Fit	0.0451	3	0.0150	0.1494	0.9249	not significant
Taste	Model	1.07	5	0.2135	1.3500	0.3468	not significant
	A-Ginger pulp	0.9177	1	0.9177	5.7900	0.0470	
	B-Sugar	0	1	0.0000	0.0001	0.9912	
	AB	0.0307	1	0.0307	0.1938	0.6731	
	A <sup>2</sup>	0.0008	1	0.0008	0.0049	0.9463	
	B <sup>2</sup>	0.1186	1	0.1186	0.7484	0.4156	
	Lack of Fit	0.0991	3	0.0330	0.1308	0.9368	not significant
Sweetness	Model	1.02	5	0.2036	2.5500	0.1268	not significant
	A-Ginger pulp	0.7322	1	0.7322	9.1900	0.0191	
	B-Sugar	0.0202	1	0.0202	0.2530	0.6304	
	AB	0.0463	1	0.0463	0.5809	0.4709	
	A <sup>2</sup>	0.0964	1	0.0964	1.2100	0.3078	
	B <sup>2</sup>	0.1505	1	0.1505	1.8900	0.2118	
	Lack of Fit	0.1934	3	0.0645	0.7073	0.5959	not significant
Texture	Model	0.5723	5	0.1145	1.0800	0.4447	not significant
	A-Ginger pulp	0.279	1	0.2790	2.6400	0.1483	
	B-Sugar	0.1184	1	0.1184	1.1200	0.3250	
	AB	0.0001	1	0.0001	0.0011	0.9739	
	A <sup>2</sup>	0.0407	1	0.0407	0.3851	0.5545	
	B <sup>2</sup>	0.1516	1	0.1516	1.4300	0.2701	
	Lack of Fit	0.0636	3	0.0212	0.1253	0.9403	not significant
Overall acceptability	Model	0.5564	5	0.1113	1.3100	0.3592	not significant
	A-Ginger pulp	0.4154	1	0.4154	4.8900	0.0627	
	B-Sugar	0.0171	1	0.0171	0.2006	0.6678	
	AB	0.0287	1	0.0287	0.3373	0.5796	
	A <sup>2</sup>	0.0627	1	0.0627	0.7376	0.4189	
	B <sup>2</sup>	0.0213	1	0.0213	0.2511	0.6317	
	Lack of Fit	0.0461	3	0.0154	0.1120	0.9486	not significant

( $R^2 < 0.80$ ).

The 3D surface and contour plots show how the interaction of variables affected the dependent variable's response (Figure 1). The different colors on the contour plot graph represent response values. The blue color represents the lowest water activity response, while the red color represents the highest water activity level. Based on the graphs, water activity showed a decreasing value with an increase in sugar. The linear effect of sugar in Table 5 was negative, indicating that the water activity of the jam decreased with increasing sugar content.

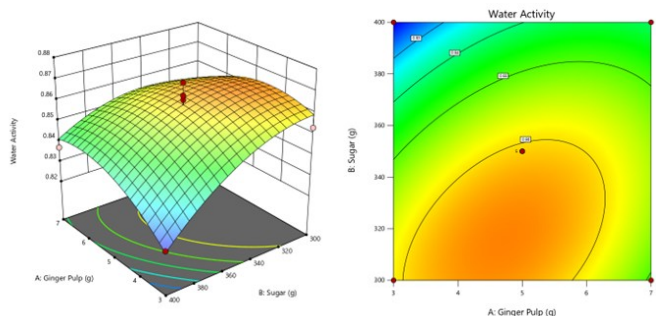


Figure 1. Response surface and contour plots for the combined effect of ginger pulp and sugar on the water activity of the jam.

The amount of accessible water in a dried product can immediately and favorably impact microbiological stability. Microorganisms thrive best between water activity (aw) levels of 0.98 to 0.99, while most germs stop growing at aw 0.90. Some fungi cease to develop with Aw values as low as 0.62 (Zhao *et al.*, 2017; Tapia *et al.*, 2020). Thus, water activity is the critical parameter affecting microbiological spoilage. In this study, the water activity ranged from 0.82 to 0.87 after the jam production, indicating that most microbes ceased to grow. This value is also around the typical range of water activity for jam, which is 0.60 to 0.85 (Ray, 2004). However, this is still not enough, and sterilization is still needed to ensure the safety of the product, as fungal spoilage of foods occurs at 0.61 to 0.85 aw levels. The decrease in the water activity in the jam was due to the osmotic effect of the sugar, as sugar creates a high concentration of solute in the jam that allows the movement of water out of the mixture to evaporate during concentration. With this mechanism, water activity can be lowered or controlled by adding solutes like sugar (Rahman and Labuza, 2007).

### 3.3 pH

The lowest pH was observed at the highest ginger pulp and the lowest sugar content. A low correlation was observed with 0.55 ( $R^2 < 0.80$ ). Figure 2 presents the surface and contour plots for pH and shows the effect of ginger pulp and sugar on the jam. Based on the graphs, the highest pH value was found around the center within the average level of ginger pulp and sugar. The linear effect in Table 5 of both sugar and pulp was negative, indicating that the pH of the jam decreased with increasing ginger pulp and sugar content.

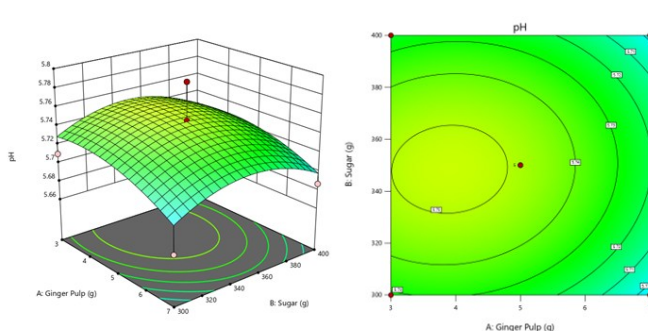


Figure 2. Response surface and contour plots for the combined effect of ginger pulp and sugar on the pH of the jam.

Fruit products are well-kept at low pH levels, and the pH level is the most critical aspect that should be checked and managed during jam production (Awad and Shokry, 2018). pH values of the squash-taro milk jam with different combinations of ginger pulp and sugar are presented in Table 3. Based on the table, the pH ranged from 5.67 to 5.79 after jam production. With this, the produced jam is grouped under low-acid foods with a pH of 4.6 and above. The pH value of the jam shows that molds, yeast, and bacteria will grow, and thermal treatment is required (Ray, 2004). The decrease in pH may be caused by sugar undergoing a Maillard reaction during heating as more hydrogen ions become more available (Wen *et al.*, 2023).

### 3.4 Color

Based on Table 3, the color ranged from 6.97 (like moderately) to 8 (like very much) after the sensory evaluation of the jam. The highest color rating was observed at the median ginger pulp and sugar content. A low correlation was observed with 0.24 ( $R^2 < 0.80$ ).

Table 5. Regression equations of analyzed dependent variables.

Water activity = 0.8608 + 0.0028A - 0.0117B + 0.0078AB - 0.0092A <sup>2</sup> - 0.0092B <sup>2</sup>
pH = 5.75 - 0.0147A - 0.0005B + 0.0017AB - 0.0135A <sup>2</sup> - 0.0235B <sup>2</sup>
Color = 7.33 - 0.1071A + 0.0198B - 0.1143AB - 0.0222A <sup>2</sup> - 0.0889B <sup>2</sup>
Smell = 7.20 - 0.0976A + 0.0303B - 0.1431AB - 0.0109A <sup>2</sup> - 0.1182B <sup>2</sup>
Taste = 7.08 - 0.3387A - 0.0016B - 0.0876AB - 0.0105A <sup>2</sup> - 0.1306B <sup>2</sup>
Sweetness = 7.12 - 0.3025A - 0.0502B - 0.1076AB - 0.1177A <sup>2</sup> - 0.1471B <sup>2</sup>
Texture = 7.20 - 0.1867A - 0.1217B - 0.0055AB - 0.0765A <sup>2</sup> - 0.1476B <sup>2</sup>

A: ginger pulp level, B: sugar level.

Figure 3 presents the surface and contour plots for color rating and shows the effect of ginger pulp and sugar on the jam. Based on the graphs, the highest color rating value was found at the highest sugar and lowest ginger pulp level. The linear effect of ginger pulp in Table 5 was negative. At the same time, sugar was positive, indicating that the color rating of the jam decreased with increasing ginger pulp and increased with increasing sugar content.

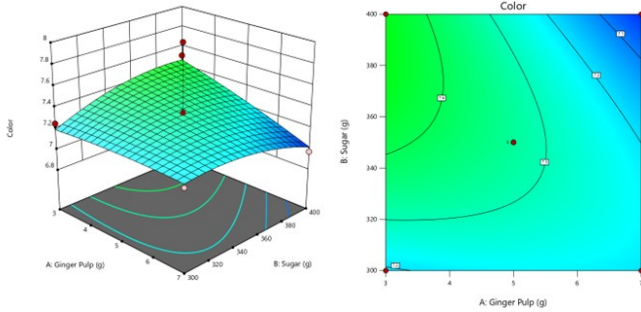


Figure 3. Response surface and contour plots for the combined effect of ginger pulp and sugar on the color rating of the jam.

Color is essential in purchasing and selecting food products (Calvo *et al.*, 2001; AL-Ansi *et al.*, 2018). The decrease in color rating in the jam may be caused by the dark hues contributed by the addition of the dried ginger pulp, while sugar may have helped preserve the vibrant color of the squash by preventing oxidation and enzymatic browning (Kaur *et al.*, 2019).

### 3.5 Smell

Smell rating values of the squash-taro milk jam with different combinations of ginger pulp and sugar are presented in Table 3. Based on the table, the smell ranged from 6.7 (like moderately) to 7.55 (like very much) after the sensory evaluation of the jam. The highest smell rating was observed at the median ginger pulp and sugar content. However, low correlation was observed with 0.37 ( $R^2 < 0.80$ ).

Figure 4 presents the surface and contour plots for smell rating and shows the effect of ginger pulp and sugar on the jam. The graphs revealed that the highest smell rating was found around the highest sugar level and the lowest ginger pulp. The linear effect of ginger pulp in Table 5 was negative. At the same time, sugar was positive, indicating that the smell rating parameter of the jam decreased with increasing ginger pulp and increased with increasing sugar content. The increase in smell rating may be related to the perceived sweetness of the panelists. A study by Wang *et al.*, (2019) reveals that added aroma significantly enhanced sweetness; therefore, the high smell rating may be associated with the added sugar that directly affects consumer perception.

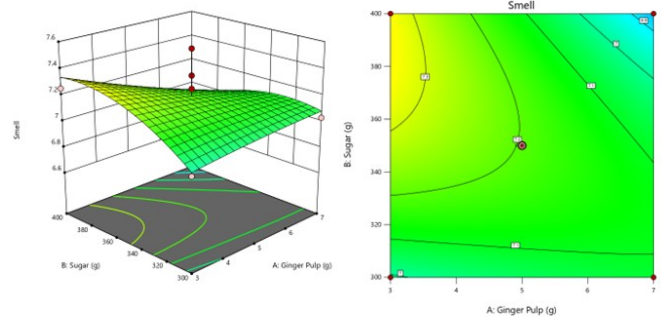


Figure 4. Response surface and contour plots for the combined effect of ginger pulp and sugar on the smell rating of jam.

### 3.6 Taste

Based on Table 3, the pH ranged from 6.42 (like moderately) to 7.63 (like very much) after the sensory evaluation of the jam. The analysis of variance results for the response surface model of taste showed that ginger pulp had a significant linear effect on the taste of the jam ( $p < 0.05$ ). However, low correlation was observed with 0.49 ( $R^2 < 0.80$ ).

Figure 5 presents the surface and contour plots for taste rating and shows the effect of ginger pulp and sugar on the jam. The graphs showed that the highest taste rating is produced at low ginger pulp and average sugar value. The linear effect in Table 5 of both ginger pulp and sugar was negative, indicating that the taste rating of the jam decreased with increasing ginger pulp and sugar values. The taste of the ginger pulp may influence the decrease, as ginger is innately spicy, earthy, and woody, which some consumers may not like. The pungency may be a result of the bioactive component of ginger shogaols, whose concentration increases by thermal processing (Ali *et al.*, 2008; Balestra *et al.*, 2018). Also, adding fiber causes a similar trend in jams where taste rating lowers as the addition of using chia seeds and peel powders increases (Younis *et al.*, 2015; Nduko *et al.*, 2018; Teixeira *et al.*, 2020).

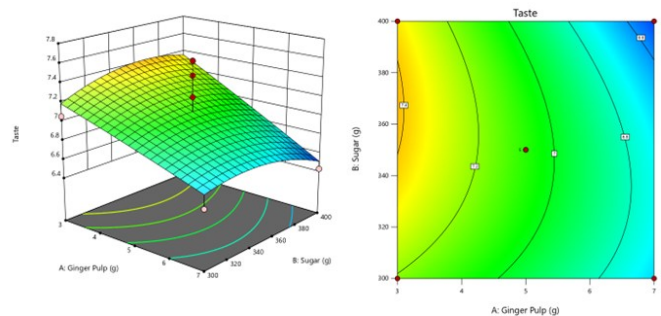


Figure 5. Response surface and contour plots for the combined effect of ginger pulp and sugar on the taste rating of the jam.

### 3.7 Sweetness

Sweetness rating values of the squash-taro milk jam with different combinations of ginger pulp and sugar are presented in Table 3. Based on the table, the sweetness rating ranged from 6.31 (like slightly) to 7.5 (like very

much) after the sensory evaluation of the jam. The highest sweetness rating was observed at the median ginger pulp and sugar content. The analysis of variance results for the response surface model of sweetness showed that ginger pulp had a significant linear effect on the sweetness of the jam ( $p < 0.05$ ). A low correlation was observed with 0.65 ( $R^2 < 0.80$ ).

Figure 6 presents the surface and contour plots for sweetness rating and shows the effect of ginger pulp and sugar on the jam. Based on the graphs, the highest sweetness rating is found at lower ginger pulp and average sugar levels. The linear effect in Table 5 of both ginger pulp and sugar was negative, indicating that the sweetness rating of the jam decreased with increasing ginger pulp and sugar values. The contrasting effect of sugar on sweetness may be part of consumers' dietary decisions to seek foods with lower sugar content, as most panelists are adults. Though preference for sweets is universal, adults generally prefer less sweet foods than children and adolescents (Pepino, 2005; Drewnowski *et al.*, 2012). Less sweet products may be viewed as healthier choices, and foods with less sweetness have fewer calories and better meet the overall wellness goals.

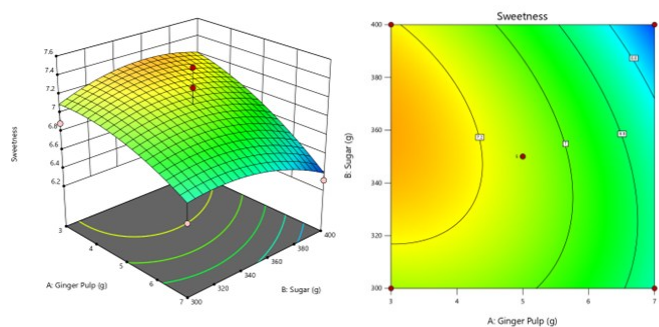


Figure 6. Response surface and contour plots for the combined effect of ginger pulp and sugar on the sweetness rating of jam.

### 3.8 Texture

The texture rating ranged from 6.52 (like moderately) to 7.7 (like very much) after the sensory evaluation of the jam. The highest texture rating was observed at median ginger pulp and sugar content. A low correlation was observed with 0.44 ( $R^2 < 0.80$ ).

Figure 7 presents the surface and contour plots for texture rating and shows the effect of ginger pulp and sugar on the jam. The graphs reveal that the highest texture rating was found around lower values of sugar and ginger pulp. The linear effect in Table 5 of both ginger pulp and sugar was negative, indicating that the texture rating of the jam decreased with increasing ginger pulp and sugar values.

The decrease in the texture rating may be caused by the rough consistency of the jam associated with the increase in ginger pulp. Also, the addition of fibers may

have increased the liquid retention capacity of the jam and affected its texture. The finding is comparable to the study about jams with orange peels, where the fiber of the orange peel is the primary reason for the change in the texture of the jam (Teixeira *et al.*, 2020). A similar result is also reported as the addition of chia seeds and pineapple peels lowers the texture rating of pineapple jam (Nduko *et al.*, 2018; Santos *et al.*, 2020).

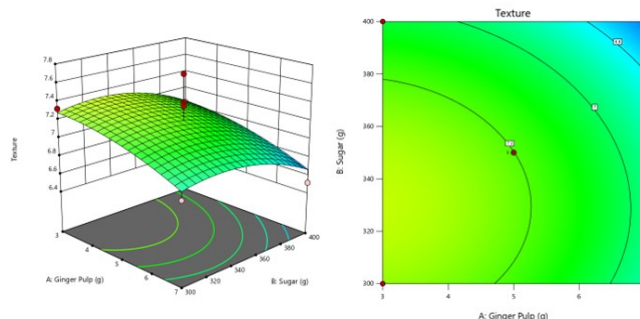


Figure 7. Response surface and contour plots for the combined effect of ginger pulp and sugar on the texture rating of the jam.

### 3.9 Overall acceptability

Overall acceptability values of the squash-taro milk jam with different combinations of ginger pulp and sugar are presented in Table 3. Based on the results, the maximum overall acceptability was 7.73 (like very much), while the minimum was 6.7 (like moderately). A low correlation was observed with 0.48 ( $R^2 < 0.80$ ).

Figure 8 presents the surface and contour plots for overall acceptability and shows the effect of ginger pulp and sugar on the jam. Based on the graphs, the overall acceptability decreased with an increase in ginger pulp, while there was an increase with the increase in sugar. The linear effect of ginger pulp in Table 5 was negative, while the sugar was positive, indicating that a decrease in ginger pulp and an increase in sugar increased overall acceptability. This is similar to the findings of Younis *et al.* (2015), Nduko *et al.* (2018), and Teixeira *et al.* (2020), indicating that the addition of fiber in jams generally lowers acceptability, which can be a result of unfamiliarity, textural changes and bitterness to the product.

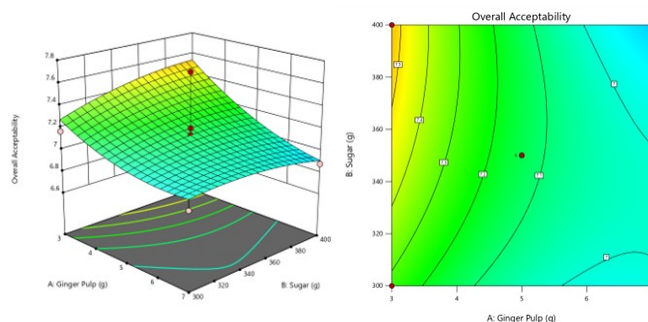


Figure 8. Response surface and contour plots for the combined effect of ginger pulp and sugar on the overall acceptability of the jam.

Table 6. Result of the microbiological tests.

Parameters	Month						
	0 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>
Total plate count, (CFU/g)	<10	<10	<10	<10	<10	<10	<10
Yeast and mold count, (CFU/g)	<10	<10	<10	<10	<10	<10	<10

Note: Count of <10 CFU/g is synonymous with negative detection at 10<sup>1</sup> dilution factor.

### 3.10 Microbial load

After processing, the samples were tested for total plate count and yeast and mold count. The result of the microbial analysis presented in Table 6 shows <10 CFU/g, synonymous with negative detection at a 10<sup>1</sup> dilution factor for a six-month duration. This means that the thermal processing employed was sufficient in preventing the growth of microorganisms in the produced jam since 15 psi or 121°C is the recommended condition for effective sterilization for low-acid foods and similar jam (pH>4.6) (DOST-ITDI, 2013; Charoen and Phungamgoen, 2016).

### 3.11 Optimal formulation

During optimization, the amount of ginger pulp was maximized, and the sugar level was maximized while the described targets for each response were optimized. Based on the analysis, the optimal formulation of 3.76 grams of ginger pulp and 363.14 grams of sugar was obtained, with a predicted value of 7.34 for the overall acceptability. The pH, water activity, color, smell, taste, sweetness, and texture of the jam under optimized formulation are presented in Table 7.

Table 7. Simultaneously optimized formulation with target and experimental values of investigated responses.

Responses	Target	Predicted mean±SD	Remark/s*
pH	Minimized	5.75±0.03	
Water activity	Minimized	0.85±0.01	
Color	Maximized	7.40±0.30	Like very much
Smell	Maximized	7.28±0.25	Like very much
Taste	Maximized	7.29±0.40	Like very much
Sweetness	Maximized	7.25±0.28	Like very much
Texture	Maximized	7.25±0.33	Like very much
Overall acceptability	Maximized	7.34±0.29	Like very much

\* 1 - 1.89 = Dislike extremely, 1.90 - 2.78 = Dislike very much, 2.79 - 3.67 = Dislike moderately, 3.68 - 4.56 = Dislike slightly, 4.57 - 5.44 = Neither like or dislike, 5.45 - 6.33 = Like slightly, 6.34 - 7.22 = Like moderately, 7.23 - 8.11 = Like very much, 8.12 - 9.00 = Like extremely.

## 4. Conclusion

Using response surface methodology, the optimization of ginger pulp and sugar levels for the formulation of squash-taro milk jam was predicted based

on the water activity, pH, color, smell, taste, sweetness, texture, and overall acceptability. After analysis, it was found that sugar significantly affects the water activity of the squash-taro milk jam. Also, adding ginger pulp significantly affects its taste and sweetness. This research was limited to the parameters mentioned above, and further evaluation of storage stability, nutritional content, and other physicochemical properties was not conducted.

### Conflict of interest

The author declares no conflict of interest.

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### References

- AL-Ansi, W., Ali Mahdi, A., Li, Y., Qian, H. and Wang, L. (2018). Optimization and acceptability evaluation of Shapporah biscuits formulated by different ingredients: Using response surface methodology (RSM). *Journal of Food and Nutrition Research*, 6 (3), 192–199. <https://doi.org/10.12691/jfnr-6-3-9>
- Ali, B.H., Blunden, G., Tanira, M.O. and Nemmar, A. (2008). Some phytochemical, pharmacological, and toxicological properties of ginger (*Zingiber officinale* Roscoe): A review of recent research. *Food and Chemical Toxicology*, 46(2), 409–420. <https://doi.org/10.1016/j.fct.2007.09.085>.
- AOAC INTERNATIONAL. (2005). Bacterial and Coliform Counts in Dairy Products - Dry Rehydratable Film Methods (Petrifilm™ Aerobic Count Plate™ and Petrifilm™ Coliform Count Plate™) (AOAC Official Method 989.10). Retrieved from website: [https://epraise.com.tw/wp-content/uploads/2024/06/Petrifilm\\_ACCC\\_AOAC-OMA-989.10.pdf](https://epraise.com.tw/wp-content/uploads/2024/06/Petrifilm_ACCC_AOAC-OMA-989.10.pdf)
- AOAC INTERNATIONAL. (2005). Bacterial and Coliform Counts in Milk - Dry Rehydratable Film Methods (Petrifilm™ Aerobic Count Plate™ and Petrifilm™ Coliform Count Plate™) Methods (AOAC Official Method 986.33). Retrieved from website: [https://epraise.com.tw/wp-content/uploads/2024/06/Petrifilm-ACCC\\_AOAC-OMA-](https://epraise.com.tw/wp-content/uploads/2024/06/Petrifilm-ACCC_AOAC-OMA-)

- 986.33.pdf
- AOAC INTERNATIONAL. (2005). Yeast and Mold Counts in Foods - Dry Rehydratable Film Method (Petrifilm™ Method) (AOAC Official Method 997.02). Retrieved from website: [https://epraise.com.tw/wp-content/uploads/2024/06/Petrifilm-YM\\_AOAC-OMA-997.02.pdf](https://epraise.com.tw/wp-content/uploads/2024/06/Petrifilm-YM_AOAC-OMA-997.02.pdf)
- Awad, S.M.S. and Shokry, A.M. (2018). Evaluation of physical and sensory characteristics of jam and cake processed using pumpkin (*Cucurbita moschata*). *Middle East Journal of Applied Sciences*, 8(2), 295–306.
- Balestra, F., Cocci, E., Pinnavaia, G. and Romani, S. (2011). Evaluation of antioxidant, rheological and sensorial properties of wheat flour dough and bread containing ginger powder. *LWT - Food Science and Technology*, 44(3), 700–705. <https://doi.org/10.1016/j.lwt.2010.10.017>
- Baroni, M.V., Gastaminza, J., Podio, N.S., Lingua, M.S., Wunderlin, D.A., Rovasio, J.L., Dotti, R., Rosso, J.C., Ghione, S. and Ribotta, P.D. (2018). Changes in the antioxidant properties of quince fruit (*Cydonia oblonga* Miller) during jam production at industrial scale. *Journal of Food Quality*, 2018, 1460758. <https://doi.org/10.1155/2018/1460758>
- Calvo, C., Salvador, A. and Fiszman, S. (2001). Influence of colour intensity on the perception of colour and sweetness in various fruit-flavoured yoghurts. *European Food Research and Technology*, 213(2), 99–103. <https://doi.org/10.1007/s002170100359>
- Chandrasekara, A. and Kumar, T.J. (2016). Roots and Tuber Crops as Functional Foods: A Review on Phytochemical Constituents and Their Potential Health Benefits. *International Journal of Food Science*, 2016, 3631647. <https://doi.org/10.1155/2016/3631647>
- Charoen, R. and Phungamngoen, C. (2016). Product development of canned Thai food by thermal processing. *International Food Research Journal*, 23(3), 1320-1326.
- Department of Science and Technology (DOST) - Industrial Technology Development Institute (ITDI). (2013). Ube Processing. Retrieved on October 19, 2021 from ITDI Website: [www.itdi.dost.gov.ph/images/LivelihoodTechnologyBrochures/05-Ube\\_Processing.pdf](http://www.itdi.dost.gov.ph/images/LivelihoodTechnologyBrochures/05-Ube_Processing.pdf)
- Dhingra, D., Michael, M., Rajput, H. and Patil, R.T. (2012). Dietary fibre in foods: A review. *Journal of Food Science and Technology*, 49(3), 255–266. <https://doi.org/10.1007/s13197-011-0365-5>
- Drewnowski, A., Mennella, J.A., Johnson, S.L. and Bellisle, F. (2012). Sweetness and Food Preference. *The Journal of Nutrition*, 142(6), 1142–1148. <https://doi.org/10.3945/jn.111.149575>
- Eltazi, S.M. (2014). Effect of using ginger powder as natural feed additive on performance and carcass quality of broiler chicks. *Assiut Veterinary Medical Journal*, 60(141), 87–95.
- Farooqui, A.A. (2015). Importance and Roles of Fiber in the Diet. In Farooqui, A.A. (Ed.) *High Calorie Diet and the Human Brain*, p. 193–218. Switzerland: Springer International Publishing. [https://doi.org/10.1007/978-3-319-15254-7\\_7](https://doi.org/10.1007/978-3-319-15254-7_7)
- Gałkowska, D., Fortuna, T. and Zagórska, W.P. (2010). Physicochemical quality of selected strawberry jams with fructose. *Potravinarstvo Slovak Journal of Food Sciences*, 4(2), 22–24. <https://doi.org/10.5219/46>
- Gelroth, J. and Ranhotra, G. (2001). Food Uses of Fiber. In Cho. S. and Dreher M. (Eds.). *Handbook of Dietary Fiber*. USA: Marcel Dekker, Inc.
- Huang, A.S., Titchenal, C.A. and Meilleur, B.A. (2000). Nutrient Composition of Taro Corms and Breadfruit. *Journal of Food Composition and Analysis*, 13(5), 859–864. <https://doi.org/10.1006/jfca.2000.0936>
- Inthalaeng, N., Gao, Y., Remón, J., Dugmore, T.I., Ozel, M., Sulaeman, A.P. and Matharu, A.S. (2023). Ginger Waste as a Potential Feedstock for a Zero-Waste Ginger Biorefinery: A Review. *Royal Society of Chemistry Sustainability*, 1(2), 213–223. <https://doi.org/10.1039/D2SU00099G>
- Jayashree, E., Visvanathan, R. and John Zachariah, T. (2014). Quality of dry ginger (*Zingiber officinale*) by different drying methods. *Journal of Food Science and Technology*, 51(11), 3190–3198. <https://doi.org/10.1007/s13197-012-0823-8>
- Kaur, M., Aggarwal, P. and Kaur, S. (2019). Natural colour retention and anthocyanin stability of strawberry jam. *Agricultural Research Journal*, 56(4), 710-716. <https://doi.org/10.5958/2395-146X.2019.00110.8>
- Konar, E.M., Harde, S.M., Kagliwal, L.D. and Singhal, R.S. (2013). Value-added bioethanol from spent ginger obtained after oleoresin extraction. *Industrial Crops and Products*, 42, 299–307. <https://doi.org/10.1016/j.indcrop.2012.05.040>
- Kou, X., Ke, Y., Wang, X., Rahman, M.R.T., Xie, Y., Chen, S. and Wang, H. (2018). Simultaneous extraction of hydrophobic and hydrophilic bioactive compounds from ginger (*Zingiber officinale* Roscoe). *Food Chemistry*, 257, 223–229. <https://doi.org/10.1016/j.foodchem.2018.02.125>

- Lai, Y.S., Lee, W.C., Lin, Y.E., Ho, C.T., Lu, K.H., Lin, S.H., Panyod, S., Chu, Y.L. and Sheen, L.Y. (2016). Ginger essential oil ameliorates hepatic injury and lipid accumulation in high fat diet-induced nonalcoholic fatty liver disease. *Journal of Agricultural and Food Chemistry*, 64(10), 2062–2071. <https://doi.org/10.1021/acs.jafc.5b06159>
- Makanjuola, S.A. (2017). Influence of particle size and extraction solvent on antioxidant properties of extracts of tea, ginger, and tea-ginger blend. *Food Science and Nutrition*, 5(6), 1179–1185. <https://doi.org/10.1002/fsn3.509>
- Miranda, F.Z. (2024). Process optimization of dried ginger (*Zingiber officinale*) pulp. *Food Research*, 8 (Suppl. 4), 33–42. [https://doi.org/10.26656/fr.2017.8\(S4\).4](https://doi.org/10.26656/fr.2017.8(S4).4)
- Nascimento, A., Santiago, S., Coelho, I., Ventura, M., Gueifão, S., Santos, M. and Castanheira, I. (2021). Sodium and potassium contents in food samples from the first Portuguese total diet pilot study. *Journal of Food Composition and Analysis*, 104, 104091. <https://doi.org/10.1016/j.jfca.2021.104091>
- Nduko, J.M., Maina, R.W., Muchina, R.K. and Kibitok, S.K. (2018). Application of chia (*Salvia hispanica*) seeds as a functional component in the fortification of pineapple jam. *Food Science and Nutrition*, 6(8), 2344-2349. <https://doi.org/10.1002/fsn3.819>
- Norris, T. (2023). What's the Difference Between Soluble and Insoluble Fiber? Retrieved on February 9, 2024 from Healthline Website: [www.healthline.com/health/soluble-vs-insoluble-fiber](http://www.healthline.com/health/soluble-vs-insoluble-fiber)
- Omage, J., Onimisi, P., Adegbite, E. and Agunbiade, M. (2007). The effect of ginger (*Zingiber officinale* Roscoe) waste meal on growth performance, carcass characteristics, serum lipid and serum cholesterol profiles of rabbit. *Pakistan Journal of Nutrition*, 6 (4), 359–362. <https://doi.org/10.1007/s11250-013-0430-3>
- Palatty, P.L., Haniadka, R., Valder, B., Arora, R. and Baliga, M.S. (2013). Ginger in the prevention of nausea and vomiting: a review. *Critical Reviews in Food Science and Nutrition*, 53(7), 659–669. <https://doi.org/10.1080/10408398.2011.553751>
- Pepino, M.Y. (2005). Factors Contributing to Individual Differences in Sucrose Preference. *Chemical Senses*, 30(Supplement 1), i319–i320. <https://doi.org/10.1093/chemse/bjh243>
- Philippine Food Composition Tables Online Database. (2020). Jam. Retrieved on March 9, 2024 from FNRI Website: [i.fnri.dost.gov.ph/fct/library/starting\\_pg](http://i.fnri.dost.gov.ph/fct/library/starting_pg)
- Philippine Statistics Authority (PSA). (2020). OpenSTAT. Database: Agriculture, Forestry, Fisheries. Retrieved on October 25, 2021 from PSA Website: [openstat.psa.gov.ph/PXWeb/pxweb/en/DB/DB\\_2E\\_CS/0062E4EVCPI.px/table/tableViewLayout1/?rxid=bd9d8da-96f1-4100-ae09-18cb3eae313](http://openstat.psa.gov.ph/PXWeb/pxweb/en/DB/DB_2E_CS/0062E4EVCPI.px/table/tableViewLayout1/?rxid=bd9d8da-96f1-4100-ae09-18cb3eae313)
- Poiana, M.-A., Munteanu, M.-F., Bordean, D.-M., Gligor, R. and Alexa, E. (2013). Assessing the effects of different pectin additions on color quality and antioxidant properties of blackberry jam. *Chemistry Central Journal*, 7, 121. <https://doi.org/10.1186/1752-153X-7-121>
- Rahman, M.S. and Labuza, T. (2007). Water Activity and Food Preservation. In Rahman, M.S. (Ed). *Handbook of food preservation*. 2<sup>nd</sup> ed., p. 447-476. USA: Taylor and Francis Group, LLC.
- Rashmi, D.R., Raghu, N., Gopenath, T.S., Pradeep, P., Pugazhandhi B., Murugesan K., Ashok G., Ranjith, M.S., Chandrashekrappa, G.K. and Kanthesh, M.B. (2018). Taro (*Colocasia esculenta*): An overview. *Journal of Medicinal Plants Studies*, 6(4), 156-161.
- Ray, B. (2004). *Fundamental food microbiology*. 3<sup>rd</sup> ed. USA: CRC Press LLC.
- Santos, B.A.D., Teixeira, F., Soares, J.M., Amaral, L.A.D., De Souza, G.H.O., Da Silva Fleming De Almeida, T., Schiessel, D.L., Santos, E.F.D. and Novello, D. (2020). Pineapple jam physicochemical and sensory evaluation with added pineapple peel. *International Journal of Research-GRANTHAALAYAH*, 8(7), 374–383. <https://doi.org/10.29121/granthaalayah.v8.i7.2020.438>
- Shirin, A.P.R. and Jamuna, P. (2010). Chemical composition and antioxidant properties of ginger root (*Zingiber officinale*). *Journal of Medicinal Plants Research*, 4(24), 2674–2679. <https://doi.org/10.5897/JMPR09.464>
- Tapia, M.S., Alzamora, S.M. and Chirife, J. (2020). Effects of Water Activity (aw) on Microbial Stability as a Hurdle in Food Preservation. In Gustavo, V.B., Anthony, J.F.Jr., Shelly, J.S. and Theodore, P.L. (Eds). *Water Activity in Foods: Fundamentals and Applications*. 2<sup>nd</sup> ed., p. 323–355. USA: John Wiley and Sons, Inc.
- Teixeira, F., Santos, B.A.D., Nunes, G., Soares, J.M., Amaral, L.A.D., De Souza, G.H.O., De Resende, J.T.V., Menegassi, B., Rafacho, B.P.M., Schwarz, K., Santos, E.F.D. and Novello, D. (2020). Addition of orange peel in orange jam: evaluation of sensory, physicochemical, and nutritional characteristics. *Molecules*, 25(7), 1670. <https://doi.org/10.3390/molecules25071670>
- United States Department of Agriculture (USDA).

- (2020). FoodData Central Food Details: Bananas, ripe and slightly ripe, raw. Retrieved on October 25, 2021 from Agricultural Research Service Website: [fdc.nal.usda.gov/food-details/1105314/nutrients](https://fdc.nal.usda.gov/food-details/1105314/nutrients)
- United States Department of Agriculture (USDA). (2018). Nutrient Lists from Standard Reference Legacy. Retrieved on September 17, 2024 from National Agricultural Library Website: [www.nal.usda.gov/sites/default/files/page-files/Total\\_Dietary\\_Fiber.pdf](https://www.nal.usda.gov/sites/default/files/page-files/Total_Dietary_Fiber.pdf)
- Wang, Q.J., Mielby, L.A., Junge, J.Y., Bertelsen, A.S., Kidmose, U., Spence, C. and Byrne, D.V. (2019). The role of intrinsic and extrinsic sensory factors in sweetness perception of food and beverages: A review. *Foods*, 8(6), 211. <https://doi.org/10.3390/foods8060211>
- Wasihun, A.A., Berhe, G.G., Sbhata, D.B., Abay, K.H. and Gebreyohannes, G. (2023). Quality Jam from Baobab (*Adansonia digitata* L.) Fruit Pulp Powder: Formulation and Evaluation of Its Physicochemical and Nutritional Properties. *Journal of Food Quality*, 2023, 8816256. <https://doi.org/10.1155/2023/8816256>
- Wen, F., Zeng, C., Yang, Y., Xu, T., Wang, H. and Wang, S. (2023). Sensory attributes and functional properties of Maillard reaction products derived from the *Crassostrea gigas* (*Ostrea rivularis* Gould) enzymatic hydrolysate and xylose system. *Heliyon*, 9(4), e14774. <https://doi.org/10.1016/j.heliyon.2023.e14774>
- Wiastuti, T., Khasanah, L., Kawiji, W.A., Manuhara, G. and Utami, R. (2016). Characterization of active paper packaging incorporated with ginger pulp oleoresin. *IOP Conference Series: Materials Science and Engineering*, 107, 012057. <https://doi.org/10.1088/1757-899X/107/1/012057>
- Younis, K., Islam, R.U., Jahan, K., Yousuf, B. and Ray, A. (2015). Effect of addition of mosambi (*Citrus limetta*) peel powder on textural and sensory properties of papaya jam. *Cogent Food and Agriculture*, 1(1), 1023675. <https://doi.org/10.1080/23311932.2015.1023675>
- Zhao, C.C., Jiang, G.H. and Eun, J.B. (2017). Optimization of Drying Process for Squid-Laver Snack by a Combined Method of Fuzzy Synthetic and Response Surface Methodology. *Journal of Food Quality*, 2017, 9761356. <https://doi.org/10.1155/2017/9761356>