

Effect of Microwave-Assisted Processing on Quality Characteristics of Pineapple Jam

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ABSTRACT

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Traditional heating method of pineapple puree during the production of pineapple jam can cause over degradation of quality of the fresh pineapple. Thus, the objective of this study was to determine optimum microwave-assisted processing conditions for producing pineapple jam which could reduce water activity, and meets minimum requirement for pH and total soluble solids contents of fruit jam. The experiment was designed using full-factorial experimental design, which the power and time of the microwave processing were chosen as the independent variables, while the water activity, pH and total soluble solids (TSS) content of the pineapple jam were determined as dependent variables. The microwave treatment was optimised to achieve ideal properties of pineapple jam. The optimum microwave processing of pineapple jam was obtained at 800 Watts of power for 8 minutes. The usage of domestic microwave oven for the pineapple jam production also results in acceptable pineapple jam with 62% of consumers' preference compared to conventional fruit jam sold in the marketplace.

Keywords:

Fruit jam, microwave, optimization, pineapple

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1. Introduction

Pineapple is one of the unseasonal tropical fruits, which its continuous supply in Malaysia causing the farmers and retailers to face problems in treating the disposition of unsuccessfully sold pineapples. The freshness of freshly cut pineapple takes about only five days when stored at 4°C [1]. If they are treated with anti-browning agent, the shelf life of the fruits can be extended until seven days before the microorganisms start to spoil the fruits [2]. Montero-Calderon *et al.*, [3] found that modified atmosphere packaging condition can only preserve the fresh cut pineapple for 14 days before mesophilic bacteria starts to grow even though when stored in refrigerated conditions. Therefore, in order to preserve the pineapples for months and years, they are processed into low-moisture food products such as candy, jam and sauce.

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Jam is a sweet spread prepared by boiling crushed fruit with sugar, pectin, acid, and other ingredients such as preservatives, colouring, and flavouring material to a reasonably thick consistency, which is firm enough to hold the fruit tissues in position [4]. According to Bureau of Indian Standard (BIS) and Prevention of Food Adulteration (PFA) specifications, jam should contain at least 0.75 of water activity, pH of 3.0-3.3, more than 68% of total soluble solids (TSS) and at least 45% of fruit.

Conventional method in jam processing includes direct and long heating of the crushed pineapple. The extreme heat exposure for long time can cause degradation of nutrients of the pineapple fruits since more volatile compounds and attributes are loss throughout the process. Moreover, the traditional method can also cause low rate of heat penetration, long processing time and destruction of sensorial properties of the pineapple jam.

Microwave processing involves the usage of electromagnetic waves at certain frequency. Since the heating process occurs through oscillations of the water molecules inside the food, there are rapid heating of the food products. Therefore, less time is required to heat the products to targeted temperature. Microwave processing food products can produce a high quality product with a minimum structural, nutritional or organoleptic changes in short operating time [5]. In addition, there is more uniform heating as compared to the conventional heating method. The microwave heating has higher heating rates and it does not involve direct contact between heating source and the heated material. Furthermore, there will be greater control of dehydration process in microwave processing in comparison to conventional method.

Experimental design is an excellent tool to be used to study the interaction between individuals and many parameters simultaneously [6]. Full factorial design is applied in this study as the power variable used was fixed and not adjustable due to the limitation of the instrument specification. These factorial design is used to investigate the effects of experimental factors and the interactions between those factors and how the effect of one factor relates with the level of other factor in response [7]. This is a low-cost technique and it minimises and reduces the number of experiments and also increases the possibilities to evaluate possible interactions between the variables. The aim of this work was to determine optimum microwave-assisted processing conditions for producing pineapple jam which meets minimum requirement for water activity level, pH and TSS content of fruit jam.

2. Materials and Methods

Pineapple (*Ananas comosus L. Merr*) fruits from the Josapine variety were purchased from the street market in Ayer Hitam, Johor, Malaysia. Pineapples with the maturity of three days after harvesting were peeled. The pineapple flesh and refined, castor sugar were blended using a food processor (Philips HR7761, Australia) to get homogenised mixture. The mixture was allowed to be heated in the domestic microwave oven (NN-ST342M, Panasonic, Japan). The experiment was designed using Minitab® 17.1.0 (Minitab Inc. US) with full-factorial experimental design for a total number of 12 treatments (Table 1). The microwave power and processing time were selected as independent variables, while the water activity, pH and TSS content were taken as response parameters. The power and time combinations of the pineapple puree heating were set in the range of 550-800 Watt and 5-10 minutes, respectively. These ranges were chosen due to the limitation of power setting of the microwave, and the adequacy of processing time based on the preliminary study.

The water activity content was measured using a water activity metre (AL1823, AquaLab, USA) [8]. The pH was determined using a pH metre (pH700, Eutech Instruments, UK) [9]. The TSS content

was determined using a refractometer (PAL-BX/RI, Atago, Japan) [10]. All analyses were done in triplicate.

After the experiments were performed, the interaction and relationship among the independent factors and responses were studied using analysis of variance (ANOVA). Both the independent and dependent variables were fitted into one-way and two-way interactions to compare the fitness of the data in each of the models and to determine the best fitted model for the data prior to the optimisation and prediction for the variables. The optimisation was done after the ideal ranges for each response were set according to the commercial pineapple jam. After the optimum jam processing conditions were obtained, another experiment to validate the outcome of the optimisation was done. The validity of the optimisation result was determined by the percentage errors, where less than 10% error is considered as a valid result.

Table 1

Full factorial design matrix, and average value of water activity, pH and TSS of pineapple jam

Number of treatment	Power (Watt)	Time (min)	Water activity	pH	TSS (%)
1	550	10	0.8	3.31	56.3
2	800	8	0.8	3.45	64.8
3	550	9	0.8	3.52	55.1
4	800	5	0.8	3.43	52.3
5	800	6	1.0	3.51	56.1
6	800	7	0.9	3.52	65.5
7	550	7	0.8	3.50	48.7
8	800	10	0.7	3.44	76.5
9	550	6	0.9	3.58	44.5
10	550	8	1.0	3.53	51.6
11	550	5	0.9	3.59	44.0

Descriptive and affective tests were used to determine the sensory attributes of the optimised pineapple jams. The descriptive test involved 8 panellists meanwhile the affective test involved 100 respondents with different races and ages [11]. The panellists were served with coded pineapple jam samples at room temperature ($25\pm 1^\circ\text{C}$). The evaluation of appearance, sweetness, mouthfeel, and overall acceptability of the pineapple jam was done based on hedonic ratings at 5-point scale (1=dislike very much and 5=like very much). The higher rating reflected good quality attribute. The panellists were also required to choose either the optimised pineapple jam or commercial pineapple jam.

3. Results and Discussions

A. Characterisation Study of Pineapple Jam

The value of water activity, pH and TSS content of the pineapple jam are shown in Table 1. The pineapple jam treated with power of 800 Watt for 10 minutes microwave processing time has the lowest water activity, which is 0.7. The water activity of the pineapple jam is important to be determined for optimising the physical properties of the pineapple jam such as viscosity and its shelf life. Most jams are preserved by their high sugar content [12]. The large amount of sugar presents in the jams reduce the moisture that promoting microbial growth. The sugar molecules act as dehydrating agent for the pectin molecules, which allowing closer contact between the chain molecules [13]. Addition of sucrose into jams could reduce the water activity to below 0.8.

Therefore, it is a requisite to ensure the amount of sugars inside jams are ranging around 40-75% in order to forestall microbial spoilage. The optimum water activity at which most food spoilage bacteria can grow is at 0.90 [14]. Bacteria require higher water activity values for their growth rather than fungi, whereas gram-negative bacteria have higher requirements for water activity than gram-positive bacteria [15]. The lowest limit of growth for yeasts and moulds is a water activity of 0.60 [16]. Since the water activity of fruit jam is ranging from 0.60 to 0.85, it most likely to be spoiled by growth of yeasts and moulds rather than growth of bacteria. If the value of water activity is below 0.60, the spoilage of foods cannot occur as the environment of low water activity is not favourable for most microorganisms to live [17].

Besides that, the water activity also interacts with other factors such as pH and other nutrients in order to inhibit or promote bacterial growth. The pineapple jam treated with power of 550 Watt for 10 minutes microwave processing time has the lowest value of pH, which is 3.31. The pH is a function of the hydrogen ion concentration in the food. Foods with pH below than 4.6 are known as high acid foods and foods with pH greater than 4.6 are known as low acid foods. Therefore, pineapple jam is categorised as high acid food. Determination of the pH value of the pineapple jam is important to ensure that there are no microorganisms can spoil the pineapple jam and subsequently decrease the quality of the pineapple jam. Bacteria are more critical in their relationship to pH than moulds and yeasts as they are quite sensitive to pH level of foods [15]. In general, the optimum pH range for bacteria is 6.0 to 8.0, yeasts is 4.5 to 6.0, and filamentous fungi is 3.5 to 4.0 [17]. The most common pH level of fruit jams is ranging from 3.0 to 3.9.

The TSS of the pineapple jam is closely related to the viscosity of the jam. The higher the value of TSS, the less water content in the jam, thus increase its viscosity. Based on the result, the pineapple jam with the highest power, which is 800 Watt and longer processing time, which is 10 minutes has the highest TSS content, which is 76.5%. Contrary, Tomruk *et al.*, [18] found that TSS of 65.8% and 59.0% can only be achieved by heating strawberry jam for 20 and 25 minutes, respectively. This shows that pineapple jam processing time could be reduced by heating using microwave. The pineapple jam treated with power of 550 Watt for 5 minutes microwave processing time has the lowest TSS, which is 44%, where it still contains high moisture. The water activity of the pineapple jam decreased as the TSS increased and vice versa.

B. Optimisation Study

Table 2 shows the statistical results of data fitted into one-way and two-way interactions (Table 2). The two-way interaction was chosen for each parameter since it has the lowest standard deviation (S), the highest value of regression (R²) and p-value of less than 0.05 [19].

Table 2

Comparison between two-way interaction and one-way interaction between each parameter

Dependent variable	Two-way interaction					One-way interaction				
	S	R ² (%)	R ² (adj) (%)	R ² (pred) (%)	p-value	S	R ² (%)	R ² (adj) (%)	R ² (pred) (%)	p-value
pH	0.0594	70.65	57.20	33.96	0.001	0.0761	41.73	29.68	10.21	0.011
TSS	0.5855	99.77	99.66	99.47	0.000	2.2322	95.89	95.04	93.67	0.000
Water activity	0.0163	94.69	92.26	88.05	0.000	0.0486	43.05	31.27	12.24	0.008

The predicted power and processing time generated by Minitab software are 800 Watt and 8 minutes, respectively. In order to confirm the predicted optimum microwave processing conditions,

the pineapple jam underwent microwave processing again under the optimum conditions. The result of the validation is simplified in Table 3. The predicted values of water activity, pH and TSS of the pineapple jam are close to the experimental values with less than 10% error, which relatively desirable.

Table 3
 Differences between predicted value and experimental value

Parameters	Predicted Value	Experimental Value	Percentage of Error (%)
Water Activity	0.80	0.735	7.5
pH	3.45	3.55	2.8
TSS (%)	65	68.38	4.4

Table 4 shows the comparison of water activity, pH and TSS between fresh pineapple pulp, optimised microwaved as well as commercial pineapple jam. Microwave treatment is able to reduce water activity from 1.0 to 0.74. Since the commercial pineapple jam has water activity close to 1, it is at risk of getting spoiled by microbial growth. The pH of fresh pineapple pulp, as well as optimised microwaved and commercial pineapple jam is in the range of low acidic food, which indicates that they are not get spoiled easily. The optimised microwaved pineapple jam may have longer shelf life than the commercial pineapple jam because of the lower pH value. Based on the result of TSS, both values for optimised microwaved and commercial pineapple jam are comparable.

Table 4
 Comparison between pineapple jam products

Parameters	Fresh pineapple pulp	Optimised microwaved pineapple jam	Commercial pineapple jam
Water Activity	1.00	0.74	0.94
pH	3.71	3.55	4.10
TSS (%)	23.30	68.38	63.70

C. Sensory Evaluation of Pineapple Jam

The result of the descriptive test is illustrated in Figure 1, while the result of affective test is shown in Figure 2. The descriptive test result shows that for each attributes the mean score higher for the optimised microwave processing pineapple jam compared to the commercial pineapple jam except for the appearance attribute.

For the appearance attribute, some panellists might want a lighter yellow colour of pineapple jam, some might also prefer a brown colour of pineapple jam. The amount of sugar added into the pineapple jam was half of the weight of the pineapple puree. The amount of sugar added is necessary to ensure the total soluble solids of the pineapple jam able to achieve 68%. Moreover, the sugar is able to provide acceptable texture to the pineapple jam, which influences the mouthfeel of the product. The consumer usually judges the quality when the food produces a physical sensation such as hard, soft, moist and dry in the mouth [20, 21]. For the affective test, a total of 62% of the respondents preferred the optimised microwaved pineapple jam compared to the commercial product sold in the market.

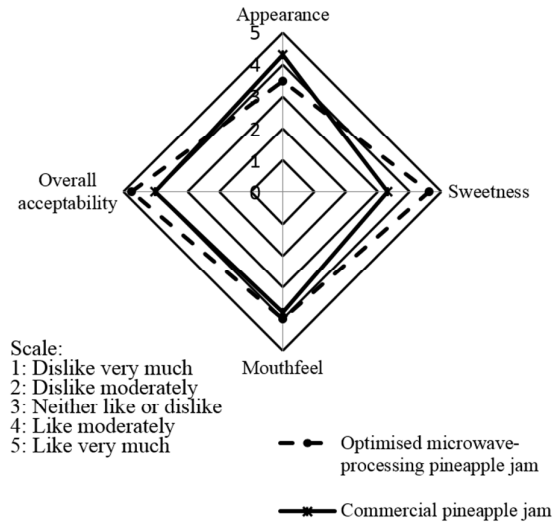


Fig. 1. Sensorial profile

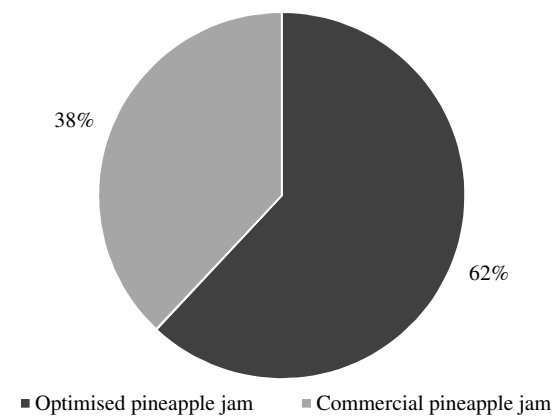


Fig. 2. Preference of pineapple jam

3. Conclusion

The microwave-assisted processing conditions for producing pineapple jam which meets minimum requirement for water activity, pH and TSS content of the pineapple jam is by processing the jam at power of 800 Watt for 8 minutes. The power and processing time of the processed pineapple jam were important in determining the overall quality and outcome of the microwave processed pineapple jam. The microwave processing time is very short compared to the traditional fruit jam processing which requires longer time to get the required specifications. Besides that, 62% of the consumers preferred microwaved pineapple jam compared to the commercial pineapple jam. Overall, the microwave is able to aid in producing acceptable quality and taste of pineapple jam.

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