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Original Research Article

Development of Antioxidant Jelly Using Tropical Fruits

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ABSTRACT

The demand for food products packed with antioxidants has greatly increased in recent years due to the alarming statistics on free radical diseases Therefore, antioxidant jelly was formulated in this study using mango (MJ1), passion fruit (PAJ2) and pineapple (PIJ3) juices as base ingredients. The formulated jellies were evaluated for their phytochemical, physicochemical, sensory and nutritional properties. Initially, a survey to 112 respondents was carried out to determine consumer acceptance on antioxidant jelly. Out of the respondents, 63.4% prefer antioxidant jelly products with multiple fruits. The formulated jellies showed significant difference ($p<0.05$) in moisture content and pH with the highest moisture content was recorded for PAJ2 at 86.03% while MJ1 recorded the highest pH at 3.86 have sour taste that may not be desirable for all consumers. Antioxidant analysis revealed high levels of DPPH, ABTS, and TPC in MJ1, with 82.78%, 76.95%, and 0.07 mg GAE/g, respectively. Color showed a positive value of L*, a*, b* scale, indicating yellowish red colors of MJ1, PAJ2 and PIJ3 due to the β-carotene pigment found in yellow mango, pineapple, and passion fruit. Sensory evaluation using a 9-point hedonic scale demonstrated that MJ1 jelly has the highest overall acceptance. Nutritionally, MJ1 contained 65 kcal/100g of energy, 15.47% carbohydrate, 0.57% protein, 1.40% total sugar, and 4.63 mg/100g vitamin C. Findings from this study indicates that tropical fruits can be used in the development of a low-calorie dessert with great nutritive value and consumer preferences.

***Keywords*:** Antioxidant jelly, tropical fruit, nutritional value, DPPH, ABTS

Introduction

Malaysia is a country that is rich in tropical fruits. Tropical fruits in Malaysia are known for their strong flavour and vibrant colours, which can be linked to their chemical composition, including antioxidants. Tropical fruits are a good source of vitamins, carotenoids, and other bioactive compounds that are believed to have antioxidant properties. Bioactive compounds in tropical fruit can minimize harmful effects of oxidative stress to human cell.[1] These compounds are recommended to reduce the risk of cardiovascular disease, aging, and various types of cancer.[2,3,4,5]
Mango, passion fruit and pineapple are popular tropical fruits that are known for their bright yellowish-orange colour. These tropical fruits often consumed fresh and processed into juices, pulps, and jams.[6] Nutritionally, these fruits have been analyzed to be rich in β-carotene, total phenolic compounds, dietary fiber, total carotenoid, total ascorbic acid, vitamins and minerals.[7,8,9] The antioxidant content and bioactive compounds in these tropical fruits have attracted the interest of food researchers to explore the effects of these fruits individually in food products formulation such as yogurt, ice cream and toffees.[10, 11, 12,13]
Previous study reported that when fruits are consumed together, their total antioxidant capacity be significantly changed due to additive, synergistic, or antagonistic interactions between these constituents, which may alter their phytochemical and physicochemical effects.[14] The combination of different fruits in one formulation have been studied and showed positive effects on antioxidant properties and nutritional composition.[14]

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Orange extract and melon extract are suggested to be included with mango, passion fruit and pineapples as active ingredients that may increase the effectiveness of other bioactive components in fruit jelly minimizing human body from the risk of civilisation diseases.[15, 16, 17]
Recently, food formulated with natural antioxidants as functional ingredient has been increasing in the market as people tend to seek health through the food they consume. Moreover, the fruit jelly is one of the most consumed desserts enjoyed by pleasant texture and ease of digestion.[18] Traditionally, various types of fruits in different forms, such as juice, puree, and concentrate have been used in the formulation of jelly products to produce dessert with health benefits.[19, 20, 21] The use of fruits in formulation of jelly has been correlated with development of pleasant flavour and color.[22] Besides, gelling agents, sweeteners, colouring, and flavourings are commonly used in the preparation of jelly to enhance the sensorial characteristics.[23] To increase consumer acceptance on jelly with excellent nutritional value without affecting taste and texture of the end product, tropical fruits that naturally contain antioxidants have recently been used as functional ingredients in jelly formulation.[24] This previous study has shown positive finding in bioactive compound and sensorial acceptance of product
Therefore, in this study, antioxidant jelly was formulated using mango, passion fruit and pineapple juice as base ingredients and analysed for their nutritional composition, physicochemical, phytochemical, and sensory properties.

Materials and Methods

Materials
Ripe Manila mango (*Mangifera indica*), yellow passion fruit (*Passiflora flavicarpa*) and Moris pineapple fruit (*Ananas comosus*) were bought in August 2022 from local supplier in Pagoh, Malaysia and the fruits were identified by plant botanists TB/RD/LOC/172/0922. Ingredients such as orange powder, melon powder, acesulfame K, sodium benzoate, potassium sorbate, carrageenan, Konjac Glucomannan, citric acid and sodium citrate were bought from online shopping platform.

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Online survey
An online survey through the Google Form application was conducted to evaluate public acceptance on high antioxidant jelly made with various tropical fruits.[25] The questionnaire consists of 26 questions and 5 sections: (1) demographic, (2) jelly product consumption habits, (3) consumption of vegetables (4) health consciousness and (5) of product features.

Jelly production
Mango, pineapple and passion fruit pulp were blended separately using Panasonic MX-800S blender to extract the juice. Then, the juice extract was filtered using cheesecloth. The juice was pasteurized for nearly 1 hour until it reached 50°C and then immediately chilled to 9°C.[15] The formulation of jelly is shown in Table 1. The production of jellies was based on a previous method with some modifications.[26] The jelly was produced using different base fruit juice namely mango (MJ1), pineapple (PIJ3) and passion fruit (PAJ2). Carrageenan and Konjac Glucomannan were dissolved separately in water while heating at 70°C for 2 minutes. The fruit juice, sodium citrate, potassium sorbate, orange powder, melon powder, sodium benzoate and citric acid were put after the acesulfame K completely dissolved in the gelling solution for 2 minutes. Citric acid was placed into the mixture and cooked to thicken it. [27] Then, the mixture was boiled for 3 minutes at 90°C. The mixture was immediately filled in aluminum sachet and stored for 24 hours at room temperature prior to the analysis.

Physicochemical analysis.
Determination of moisture content and pH
The moisture content of the jellies was determined using rapid moisture analyser (A&D Company, Weighing MX-50, Japan) by drying at 140°C until completely dry and expressed in percentage (%).[28] The pH value of the jellies was determined using a digital pH meter (EUTECH Instrumentals, Singapore) calibrated according to the AOAC standard modification method by Sun *et al*.[29]

Determination of texture properties
The hardness, chewiness, cohesiveness, springiness and gumminess of the jellies were measured using texture analyzer (Stable Micro System TA. XT, United Kingdom) based on the method described by Renaldi *et al*.[28] 15g of sample was placed in an aluminium petri dish and equipped with can SMS cylinder probe (35mm, P/36). The analysis was conducted with pre-test speed (1 mm/s), distance (4 mm), test speed (5 mm/s), post-test speed (1 mm/s), and trigger force (5g) at room temperature.
Texture parameters can be extracted from each force against time curve of the TPA test.[30] Hardness was calculated as the maximum peak force during the first compression cycle (H = *f*max). Cohesiveness was determined by comparing the amount of positive force area during the second compression cycle (a_2) to that during the first compression cycle (a_1) using equation (1). Springiness was defined as the ratio of time elapsed during positive forces at the second compression (t_2) to that of the first compression (t_1) using equation (2). The chewiness and gumminess of jelly was calculated using equation (3) and (4) respectively.

$$\text{Cohesiveness} = a_2/a_1 \quad (1)$$
$$\text{Springiness} = t_2/t_1 \quad (2)$$
$$\text{Chewiness} = \textit{Hardness x Cohesiveness x Springiness} \quad (3)$$
$$\text{Gumminess} = \textit{Hardness x Cohesiveness} \quad (4)$$

Determination of color properties
MiniScan EZ Hunter Lab 4500 was used to analyze colour properties of the jelly. Colour measured was expressed as L*, a* and b* value with the L* is lightness range from white (100) to black (0), +a represented red or -a represented green and +b is value of yellow or -b is value of blue.[16]

Determination of antioxidant properties
Antioxidant properties of the jelly was determined using 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid (ABTS) Scavenging Activity, DPPH Radical Scavenging Activity and total phenolic content (TPC).[31, 32,33,34]

Jelly extraction
The sample extraction for antioxidant assay was done according to previous study.[31] 5 g of jelly was extracted in 80% aqueous methanol (25 ml) with 1% concentrated HCl. The extract was heated for 30 minutes at 55°C on a hot plate and mixed with magnetic stirrer before being filtered through Smith filter papers.

Determination of 2,2-diphenyl-1-picrylhydrazyl Radical Scavenging Activity (DPPH)
5.8 mg of DPPH was dissolved in 100 ml of methanol. Then, 0.150 ml of sample extract was mixed with 3.0 ml of DPPH solution in each test tube, vigorously shook, and incubated in the dark at room temperature for 30 minutes. Absorbance was measured using a spectrophotometer (Brand/Model, country of origin) at a wavelength of 517 nm. Ascorbic acid was used as the positive control while DPPH solution and methanol as the negative control. The percentage of antioxidant activity was calculated using Equation 5.

Table 1: Ingredients used in the development of antioxidant jelly

Ingredients (%)	MJ1	PAJ2	PIJ3
Mango juice	50.0	-	-
Passion juice	-	50.0	-
Pineapple juice	-	-	50.0
Water	25	25	25
Carrageenan	1.0	1.0	1.0
Konjac Glucomannan	1.0	1.0	1.0
Potassium Sorbate	0.5	0.5	0.5
Acesulfame K	10.0	10.0	10.0
Citric Acid	1.5	1.5	1.5
Melon powder	5.0	5.0	5.0
Orange powder	5.0	5.0	5.0
Sodium Benzoate	0.5	0.5	0.5
Sodium Citrate	0.5	0.5	0.5

* MJ1: Mango jelly flavour; PAJ2: Passion jelly flavour; PIJ3: Pineapple jelly flavour

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$$\text{Percentage of radical scavenging activity} = \frac{A_{DPPH} - A_S}{A_{DPPH}} \times 100 \quad (5)$$

where A_S is absorbance of the solution added with jelly extract and A_{DPPH} is absorbance of DPPH solution with methanol.

Measurement of 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS+)
The ABTS solution was prepared mixing 2.45 mM potassium persulfate and 7mM ABTS+ solutions at 1 to 1 ration. The mixture was incubated at dark for 14-16 hours. ABTS+ solution (1 ml) was diluted with methanol (60 ml) to obtain an absorbance of 0.7 units at 734 nm. The scavenging activity was determined by mixing l00 µl of jelly extract with the ABTS+ solution (3.9 ml) for 10 minutes in dark room temperature. The absorbance was then determined at 734 nm using a spectrophotometer. ABTS+ solution and methanol were used as the negative control while ascorbic acid was used as the positive control. The $ABTS^+$ radical scavenging activity was then calculated using Equation 6.

$$\text{Percentage of radical scavenging activity} = \frac{A_{ABTS} - A_S}{A_{ABTS}} \times 100 \quad (6)$$

where A_S is absorbance of the sample and A_{ABTS} is absorbance of A_{BTS} solution with methanol.

Determination of total phenolic content (TPC)
Jelly extract was mixed with 200 µl of Folin-Ciocalteu reagent and 7.5% (w/v) sodium carbonate (0.6 ml) before being placed in a test tube filled with 3.16 ml of distilled water. Then, the mixture was incubated in the dark room temperature for 90 minutes prior to measure the absorbance at 765 nm. A gallic acid standard curve (0.00, 0.05, 0.1, 0.25, and 0.5 mg/ml, R2 = 0.99) was produced and TPC was measured as mg of gallic acid equivalent (GAE)/g sample.

Sensory evaluation
Sensory properties of MJ1, PAJ2 and PIJ3 were evaluated using 9-point hedonic scale by 30 untrained panellists. The scoring scale was from 1 to 9 with indication as 1 represent as dislike extremely and 9 represent like extremely. The jellies were evaluated in terms of taste, color, texture and overall acceptability.

Determination of nutritional composition
Jelly was analyzed for the presence of carbohydrate, protein, fat, total sugar and Vitamin C.[35,36,37, 38] The energy content was measured using conversion ratio of 4 cal/g of carbohydrates, 4 cal/g of protein, and 9 cal/g of fat.[39]

Statistical analysis
All analyses were conducted in triplicate. The data was expressed in mean of three replicates and standard deviation. Analysis of Variance (ANOVA) of the data obtained were conducted using the Statistical Package for Social Sciences (SPSS) to measure the significant differences ($p < 0.05$) between the formulation of antioxidant jelly and Tukey's test on all analysis.

Results and Discussion

Online survey
There were 112 respondents participated in the market survey consisted of both females and males age between 18-54 with 80.4% and 19.6% respectively. Majority of the respondents with 68.8% like to eat jelly's product whereas 46.4% respondents whose age between 18-24 consume jelly products less than once a month. 83% of the respondents can accept an idea of antioxidant jelly product and only 0.9% of respondents cannot accept the idea of jelly from multiple fruits. Consuming fruits together can increase the total antioxidant capacity in the food product since each of fruits contain individually bioactive compounds.[14] Lastly, the majority of respondents prefer mango fruit, followed by passion fruit and pineapple with 30.8%, 25.5% and 24.1% respectively. Therefore, mango, pineapple and passion fruit are chosen as main flavour in the formulation of antioxidant jelly to meet consumer preferrence.

Physicochemical properties
Moisture content and pH
Table 2 shows that MJ1, PAJ2 and PIJ3 have significant difference ($p < 0.05$) in moisture content. PAJ2 has the highest moisture content with 86.03% as compared to PIJ3 and MJ1. The range of moisture content was comparable to the moisture content reported for mango-pineapple and lychee jelly.[39,40] The previous studies recorded moisture content between 81.11% and 86.07%. The high moisture content implies that the fruit jelly has a short shelf life and that refrigeration is necessary to prevent microbial spoilage in the sample.[41] Therefore, the food conditioner and preservatives such as citric acid, sodium citrate, sodium benzoate, and potassium sorbate are utilized to slow yeast spoilage in acidic beverages and foods due to its high-water solubility and stability.[42, 43]
pH of the antioxidant jelly was recorded between 3.86 to 3.40 and showed significant difference ($p < 0.05$) between formulation (Table 2). The high pH in jelly was due to the low acidity level in product.[44] The passion fruit contains high level of acidity compared to pineapple and mango fruit with 2.02, 1.90 and 1.36g citric acid/g respectively.[6] As a result, the jelly formulation that incorporated passion fruit as the main flavour had the lowest pH value consider as high in acidity compared to jelly containing pineapple and mango fruit.

Texture properties
Texture analysis of the jelly sample (MJ1, PAJ2, PIJ3) revealed there were no significant difference ($p > 0.05$) between formulations for attributes such as hardness (0.65-0.63 N), cohesiveness (0.50-0.48), chewiness (0.30-0.29 N), springiness (0.92-0.93 mm) and gumminess (0.33-0.31 N). However, the hardness of the jelly is directly related to the moisture content as reported in Table 2. The high moisture value can increase the softness of jelly.[45] Moreover, foods with a small-scale firmness and high springiness have a good chewiness propert.[46] Previous research found that the springiness of lychee jelly is 0.92-0.93,[40] and the value obtained in this study is within the same range (Table 2).
In terms of cohesiveness, when the jelly has a low cohesiveness value, it is easy to swallow and chew.[40] Since MJ1. PAJ2 and PIJ3 possess a similar and low cohesiveness value (0.48 to 0.50), the jelly will be preferred by consumers as cohesiveness is the most important parameter for the acceptance factors for all ages.[47] All of the three jelly formulations have soft texture of gels due to low chewiness and hardness values. The chewiness and gumminess of jelly is directly proportional to the hardness value which indicate minimal energy needed to disintegrate a semi-solid food product.[48] This finding was similar to previous study that investigated the production of apple jelly with soft texture of gels as chewiness and hardness decreased in the jelly product.[49]

Color properties
The L*, a* and b* value presented in Table 3 showed a significant difference ($p < 0.05$) between samples. The +a and +b values present that the jelly were redness yellowish colored. MJ1 has a higher value of (b*) at 26.47 than PAJ2 and PIJ3. MJ1 was brighter while PAJ2 and PAJ3 were darker which was attributed to the more yellowness colour of the mango as compared to pineapple and passion. This is due to β-carotene pigment found in yellow mango is high compared to pineapple, and passion fruit.[39] This is similar with the study conducted on the development of mango-pineapple jelly whereby the yellow mango and pineapple contributed to the yellowness color of the fruit jelly.[39]

Antioxidant activities
Data on DPPH, ABTS assay and TPC presented in Table 4 differs significantly ($p > 0.05$) between samples. TPC values calculated for the samples ranged from 0.07-0.04 mg GAE/g with antioxidant activities which are DPPH and ABTS found between 82.78 to 70.24% and 76.95 to 72.74% respectively. The high DPPH scavenging is correlated with the high antioxidant activity in the sample.[50] Among all three samples, MJ1 showed the highest percentage of inhibition toward DPPH followed by PAJ2 and PIJ3. This trend corraborated with the

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antioxidant activity reported by Martínez *et al*., who recorded highest DPPH value in mango pulp (47.1 .8 µM TE/g) followed by passion fruit (5.1 µM TE/g) and pineapple (4.8 µM TE/g). [51] Meanwhile, the data obtained was higher by almost 45% as compared to study by Molla *et al*. on jelly containing pineapple and guava with 40.08-41.44% DPPH radical scavenging activity.[52] MJ1 also showed the highest value of ABTS scavenging activity with 76.95% which is high compared to ABTS values reported for blood orange jelly (807.70 µmol/g), grapefruit jelly (314.90 µmol/ g) and beetroot jelly (6.39-13.94%)[17, 27]. The higher DPPH and ABTS values of MJ1 might be attributed by the combination of others fruits which are melon and orange whereby each contains high amount of antioxidant.[53,54]

The total phenolic content showed a proportional correlation with antioxidant activitiy.[23] The higher TPC of the MJ1 sample may be due to higher amount of total polyphenols in mango pulp as compared to passion fruit and pineapple. Previous study has reported TPC ranged from 129 mg GAE/g for pineapple to 546 mg GAE/g for mango in the methanol extractions.[51] Fruthermore, previous studies reported that jellies prepared with plant-derived extracts or polyphenolic-rich fruit powders were found to exhibit high antioxidant efficiency.[18,24,55,56] However, citric acid content can minimize polyphenol oxidase activity by reducing non-enzymatic oxidation of phenolic compounds affected by temperature damage during making the jelly[27].

Table 2: Physiochemical properties of antioxidant jelly

Sample	MJ1	PAJ2	PIJ3
Moisture content (%)	83.62 ± 0.26^{b}	86.03 ± 0.62^{a}	84.39 ± 0.71^{b}
pH	3.86 ± 0.02^{a}	3.40 ± 0.04^{b}	3.49 + 0.01^{c}
Hardness (N)	0.65 ± 0.03^{a}	0.65 ± 0.02^{a}	0.63 ± 0.06^{a}
Cohesiveness (ratio)	0.50 ± 0.01^{a}	0.50 ± 0.04^{a}	0.48 ± 0.05^{a}
Springiness (mm)	0.92 ± 0.01^{a}	0.93 ± 0.04^{a}	0.92 ± 0.00^{a}
Chewiness (N)	0.30 ± 0.00^{a}	0.30 ± 0.02^{a}	0.29 ± 0.05^{a}
Gumminess (N)	0.33 ± 0.01^{a}	0.33 ± 0.03^{a}	0.31 ± 0.06^{a}

Remark: Each value is given as a mean value with a standard deviation (n = 3). Means in the same row that are followed by a different superscript letter differ significantly (p < 0.05)

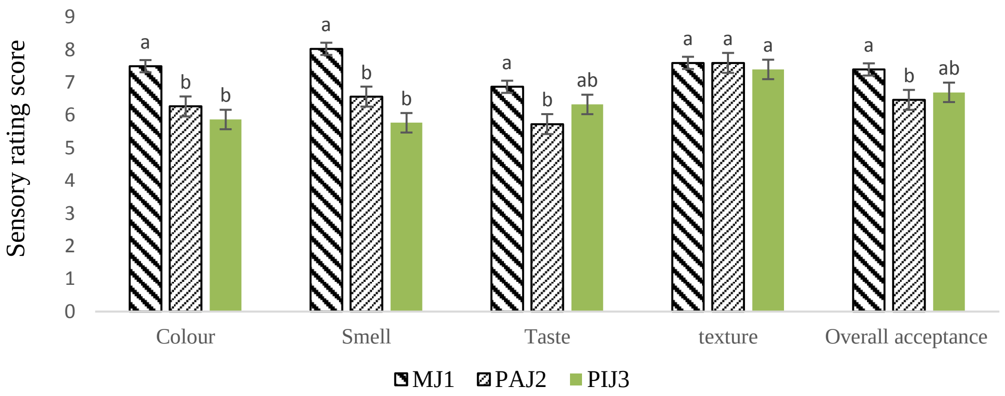

Figure 1: Mean scores for sensory evaluation of antioxidant jelly.

Table 3: Colour parameter of MJ1, PAJ2 and PIJ3

Sample	MJ1	PAJ2	PIJ3
Lightness (L*)	40.46 ± 0.45^{a}	25.45 ± 0.10^{b}	25.27 ± 0.51^{b}
Redness (a*)	17.80 ± 0.45^{a}	6.53 ± 0.31^{b}	3.73 ± 0.31^{c}
Yellowness (b*)	26.47 ± 0.29^{a}	10.58 ± 0.41^{c}	12.58 ± 0.41^{b}

Remark: Each value is given as a mean value with a standard deviation (n = 3). Means in the same row that are followed by a different superscript letter differ significantly (p < 0.05)

Table 4: Antioxidant properties of antioxidant jelly

Sample	MJ1	PAJ2	PIJ3
DPPH (%)	82.78 ± 0.55^{a}	72.47 ± 0.62^{b}	70.24 ± 0.66^{c}
ABTS^{+} (%)	76.95 ± 0.84^{a}	72.74 ± 0.76^{b}	73.15 ± 0.41^{b}
TPC (mg GAE/g)	0.07 ± 0.01^{a}	0.06 ± 0.01^{ab}	0.04 ± 0.01^{b}

Remark: Each value is given as a mean value with a standard deviation (n = 3). Means in the same row that are followed by a different superscript letter differ significantly (p < 0.05)

Table 5: Nutritional value of mango jelly (MJ1)

Component	Percentage
Energy (kcal/100g)	65.00 ± 1.00
Carbohydrate (%w/w)	15.47 ± 0.31
Protein (%w/w)	0.57 ± 0.06
Total sugar (%w/w)	1.40 ± 0.00
Total fat (%w/w)	0.00 ± 0.00
Vitamin C (mg/100g)	4.63 ± 0.06

Sensory properties

Sensory evaluation among 30 untrained panelists revealed that the smell, colour, taste and overall acceptance of the formulated jellies were significantly difference (p < 0.05) between samples as presented in Figure 1. However, no significant difference (p > 0.05) was shown for texture with mean scores between 7.6 to 7.40 indicating moderately liked which corroborated with the results obtained in the texture analysis. Overall, MJ1 scored the highest value for all attributes compared to PAJ2 and PIJ2. The high preference for MJ1 could be driven by the distinct and pleasant aroma of mango that enhances the overall eating experience. Previous studies have also reported that that jelly formulations containing mango were highly preferred by consumers[39,57] Therefore, it is fair to justify that adding mango fruit with other ingredients enhanced the taste, colour, texture and smell of the jelly.

Nutritional composition

In this study, MJ1 was analysed for nutritional composition as it was the most preferred jelly among the sensory panelists (Figure 1). Table 5 shows that MJ1 can be considered as low-calorie product as the energy content was 65 kcal/g which is lower than the 80 kcal/g recommended by the Food and Drug Administration (FDA)[58]. In general, the protein (0.57%), fat (0.00%) and carbohydrate (17.35%) content of MJ1 are within the range of values reported in optimized mango-pineapple jelly sphere[39] with only 0.1-2% differences. As predicted, MJ1 contained zero fat, which was below the 0.5g/100g maximum recommended by the FDA[58] necessary to claim it as a fat-free food. Moreover, MJ1 contains 1.40% total sugar which is much lower than the total sugar (9.20-16.90%) found in mango-pineapple jelly[39]. Meanwhile, 4.63 mg/100g of vitamin C was found in MJ1 that is around 3.69 mg higher than the vitamin C reported in guava jelly 0.74-0.94 mg/100g.[52] This higher value shows that the combination tropical fruits in jelly formulation can help to increase the nutritional value of the dessert.

Conclusion

The present study showed that the use of multiple tropical fruits in a jelly formulation can enhance the nutritional benefits of jelly. Overall, mango-based jelly (MJ1) exhibited the highest antioxidant properties and sensory preference with low amount of energy and zero fat. This fruit jelly generally showed 4-8% higher antioxidant activity than passion fruit and pineapple-based jelly. Further research should concentrate on combination of mango, pineapple and passion fruit in a jelly formulation to enhance its antioxidant activity.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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