CHEMICAL ENGINEERING TRANSACTIONS
VOL. 113, 2024
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Jeng Shiun Lim, Bohong Wang, Guo Ren Mong, Petar S. Varbanov

ISBN 979-12-81206-14-4; **ISSN** 2283-9216
DOI: 10.3303/CET24113068

Effects of Pectin and Modified Starch on the Properties of Gummy Candy from Pineapple Eye Juice

Nguyet T. M. Nguyen*, Ngoc H. Han, Nhu T.H. Le, Oanh H.T. Le

Department of Nutrition and Food Science, Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, 12 Nguyen Van Bao Street, Ward 4, Go Vap District, Ho Chi Minh City, Vietnam
nguyenthiminhnguyet@iuh.edu.vn

In this work, pineapple eye juice (PEJ) was utilized to produce gummy candies (GC) to promote the development of a circular economy. The objective was to investigate the effects of pectin and modified starch (MS) on the structural properties and sensory qualities of GC made from PEJ. The method involved formulating GC with varying concentrations of pectin (0.05, 0.1, and 0.15 %) and MS (0.5, 1.0, and 1.5 %) alongside a constant 9 % gelatin concentration. Texture Profile Analysis (TPA) was employed to assess the textural properties, and the antioxidant activity was measured using the 2,2-diphenyl-1-picryhydrazyl (DPPH) radical scavenging method. The results demonstrated that a combination of 0.05 % pectin and 1.5 % MS yielded GC with a more stable structure, harmonious flavour, and better colour compared to formulations using fewer polymers. The antioxidant activity of these GC was determined to be 79.95 ± 0.2 %. The conclusion of this study highlights the potential for using PEJ by-products in GC production, offering a sustainable solution for the food system.

1. Introduction

Pineapples are mainly distributed in tropical and subtropical regions on all continents. Vietnam is a country with suitable land conditions for growing pineapples for year-round harvest. Pineapple has the second highest production volume of all tropical fruits in the world so the production of processed items results in massive waste generation, estimated at 40 - 50 % from fresh fruit such as pineapple peel and core. Pineapple co-products have been made to utilize pineapple waste, which has been used as a substrate for the production of bromelain and organic acids, fibre and phenolic antioxidants, ethanol and biogas. Efficient and thoughtful use of by-products from the food industry will minimize the impact on the environment and bring high profits thanks to the nutritional and functional properties of these by-products. Small and micro food processing facilities generate a negligible amount of this type of waste but do not treat the resulting residue. These by-products are rich in moisture and contain many microorganisms. When not handled properly, they will cause environmental pollution (Roda et al., 2014). Pratiwi et al. (2023) extracted paste from pineapple peel then added to GC from red guava as a gelling agent. However, currently, there are not many studies interested in taking advantage of this by-product. This study took advantage of the juice from pineapple eye by-products combined with pectin and MS, and fixed gelatin to produce GC with the following research contents: 1/ Investigating the effects of mixing pectin and MS to improve the physicochemical properties of GC; 2/ Sensory evaluation all the GC from eight mixing formulas; 3/ Survey some quality properties of the final GC.

2. Materials and Methods

2.1 Raw materials

Pineapple was collected in Tien Giang province, Viet Nam and was in season from January to June 2024. Pineapple eyes were separated (Figure 1b) and collected from traditional pineapple vending carts (Figure 1a) in Ho Chi Minh City. After being transported to the laboratory, pineapple eyes (Figure 1c) were pressed with a slow juicer to collect the liquid (Figure 1d). PEJ was stored in the refrigerator (10-12 °C) and used within the

Paper Received: 13 April 2024; Revised: 4 August 2024; Accepted: 16 October 2024
Please cite this article as: Nguyen N.T.M., Han N.H., Le N.T., Le O.H., 2024, Effects of Pectin and Modified Starch on the Properties of Gummy Candy from Pineapple Eye Juice, Chemical Engineering Transactions, 113, 403-408 DOI:10.3303/CET24113068

day. The materials employed in this study were as follows: modified starch (MS1414, sourced from China), pectin (Ceampectin ESS 4410, a product of Spain), and gelatin powder (Bloom 250, sourced from Germany). Malt (DE 42-Br ≥ 80), sugar (Bien Hoa) and lime (Citrus latifolia, 250 g, approximately 4-5 fruits) were products of Vietnam. The control GC utilized for comparative analysis was a commercially available product, Chupa Chups (5 Mixed, 90 g pack, made in Vietnam).

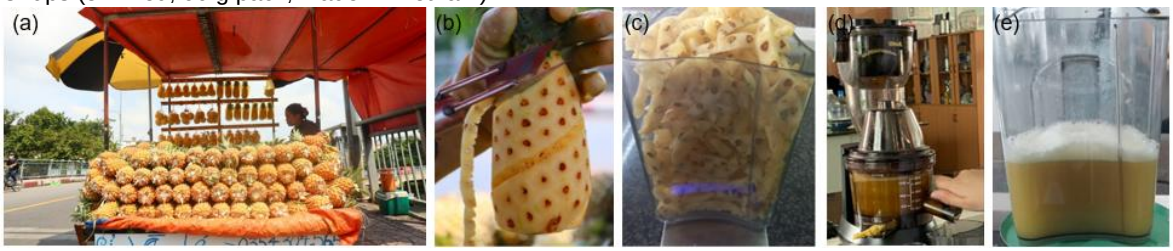

Figure 1: Illustrating images (a) Pineapple truck; (b) Separate pineapple eyes; (c) Collect pineapple eyes; (d) Collect juice with a slow juicer; and (e) juice from pineapple eye for making GC

2.2 The preparation of the GC

Measured 500 g of pre-treated pineapple eyes and processed them in a slow juicer (Hafele HS-J42S, Germany) to obtain PEJ. The mixing ingredients were prepared according to Table 1. The mixture, consisting of PEJ, malt, and sugar, was concentrated at 70 – 80 °C to dissolve the ingredients and increase the concentration of soluble solids to 60 – 65 °C for better mixing. Mixed the MS one by one and cooked until the starch dissolved. Gelatin was added and gently stirred for 2 min, followed by pouring lemon juice, thoroughly stirring, and turning off the stove. Pectin was added and stirred until dissolved. The foam on the candy liquid's surface was skimmed off, then the mixture was poured into molds and allowed to cool at room temperature (30 – 35 °C) to shape each candy for enhanced aesthetics. The molds were placed in a 32 x 18 cm zip bag and cooled in a refrigerator at 4 – 5 °C for 24 h. Finally, the GC was separated from the molds and stored in 8 x 5 cm zip bags.

Table 1: The formulation for the mixture of GC from PEJ

Ingredients	Control 1	Control 2	Control 3	Sample A	Sample B	Sample C	Sample D	Sample E
PEJ	35 %	35 %	35 %	35 %	35 %	35 %	35 %	35 %
Malt	21 %	21 %	21 %	21 %	21 %	21 %	21 %	21 %
Sugar	9 %	9 %	9 %	9 %	9 %	9 %	9 %	9 %
Lime juice	0.3 %	0.3 %	0.3 %	0.3 %	0.3 %	0.3 %	0.3 %	0.3 %
Gelatin	9 %	9 %	9 %	9 %	9 %	9 %	9 %	9 %
Pectin	0.1 %	-	-	0.15 %	0.1 %	0.1 %	0.05 %	0.05 %
MS	-	1 %	-	0.5 %	1 %	0.5 %	1 %	1.5 %
Water	25.6 %	24.7 %	25.7 %	25.05 %	24.6 %	25.1 %	24.65 %	24.15 %

Note: % of weight total mixture volume (100 %), (-): no added

2.3 Determination of the textural properties, colour, total aerobic microorganism, antioxidant activity and nutritional ingredients of the GC

TPA was performed according to the method of Delgado and Bañón (2015) using a Brookfield texture analyzer (CT3 4500, USA). The sample was prepared in a bear mold (Figure 2a) with dimensions of length × width × depth (20 cm × 11 cm × 8 cm) and stabled for 24 h at a temperature of 4 - 5 °C before measuring. Samples were measured with TA44 cylindrical probe (diameter 4 mm, Figure 2b); probe speed 1 mm/s compressed twice with 50 % deformation, compression force 0.05 N (the graph with 2 peaks as Figure 2c). Perform TPA was analysed at room temperature 25 °C and recorded the parameters of hardness, adhesion, cohesion, springiness, gumminess, and chewiness. The colour of GC was determined using a colourimeter (CR-400 Konica Minolta, Japan) recorded L*, a* and b* values of GC. The total aerobic microorganisms was determine according to the ISO 4833-1:2013 standard on microorganisms in food and animal feed, which outlines the method for quantifying microorganisms using the Colony counting technique at 30 °C. To determine the antioxidant activity of GC, sample extraction was performed according to the study of Mahmood et al. (2021): 5 g of sample was extracted in 25 mL of methanol solution 80 % with 1 % concentrated HCl. The extract was heated for 30 min at 55 ºC on an electric stove and mixed with a magnetic stirrer. Then filter and collect the filtrate. Weigh 5.8 mg of DPPH dissolved in 100 mL of methanol. Mixed 0.15 mL of sample extract with 3 mL of DPPH solution in each test tube, shaken well and then incubated for 30 min in the dark at room temperature.

Absorbance was measured using a spectrophotometer (Genesys 20 Visible, USA) at a wavelength of 517 nm. Do the same with the juice. For nutritional ingredients of the GC, analysis included ash content (TCVN 4070:2009), fibre (TCVN 4998:1989), protein (TCVN 10791:2015), and lipid (TCVN 8103:2009), following the guidelines of TCVN 4335:1986. Carbohydrate content was determined according to FAO guidelines as Eq(1):

$$\text{Carbohydrate (\%)} = 100\ \% - (\%\ \text{Moisture} + \%\ \text{Lipid} + \%\ \text{Protein} + \%\ \text{Ash} + \%\ \text{Fiber}) \quad (1)$$

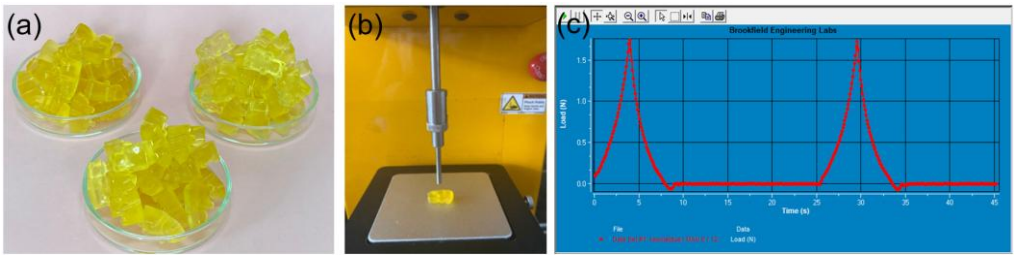

Figure 2: Illustration of the process of measuring the TPA measurement. From Left to Right (a) Sample prepared for measurement, (b) Probe operation on the sample, (c) Typical graph of measurement

2.4 Sensory evaluation technique: by QDA (Quantitative Descriptive Analysis) method

Sensory characteristics (colour, smell, taste, hardness, plasticity, toughness, elasticity and liking) were evaluated by 9 members. Each participant received training before the assessment to become familiar with the sensory technique, samples and assessment methods. The evaluators were asked to rate from 1 to 5 according to the descriptive criteria of colour, smell, taste, hardness, plasticity, toughness, elasticity and liking with a scale of 1 - 9. The sensory evaluation session was conducted in the sensory evaluation rooms (F 7.1 and F 7.2) at Industry University of Ho Chi Minh City. Data from the sensory evaluation results of the expert panel using the flash profile method were processed by principal component analysis (PCA) using the R2.15.1 program.

3. Results and Discussions

3.1 Effect of mixing pectin and MS on physical properties

The average recovery efficiency of PEJ 67.0 ± 0.8 %, pH 3.81 ± 0.11 and Bx 13.0 ± 0.5 with the following ingredients (% wt.) such as 86.67 ± 2.48 % of moisture, 0.79 ± 0.60 % of protein, 0.17 ± 0.13 % of lipid, 12.06 ± 3.51 % of carbohydrate, 0.31 ± 0.30 % of ash and 0.28 ± 0.16 % of fibre. This data when compared to the USDA database shows that PEJ had higher moisture, protein, and fiber content than pineapple juice (*Pineapple Juice, Canned or Bottled, Unsweetened, with Added Ascorbic Acid*, 2019). Hemalatha and Anbuselvi (2013) acknowledged that pineapple by-products contain higher nutritional content. Mixing PEJ with other ingredients according to Table 1, GC samples were obtained as illustrated in Figure 3.

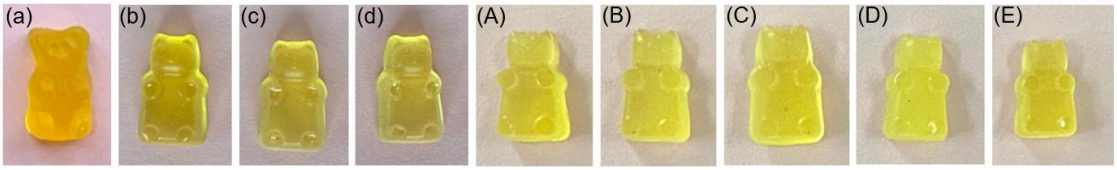

Figure 3: Images of candies made from mixing recipes according to Table 1. From Left to Right (a) Control (Chupa Chups); (b), (c), (d) control samples; and (A), (B), (C), (D), (E): examined samples (see Table 1)

The hardness values of controls 1, 2, and 3 were different from 5 Samples (A) to (E). The ratio of control samples with only one or two polymers added, while 3 types of biological polymers were added, obtained a structure closer to Control. This pointed out that adding pectin and MS improved gel formation ability and created a more stable texture (Schrieber and Gareis, 2007). Although there was a statistically significant difference between the samples when using the TPA method, visually it was very difficult to notice this difference. However, the structure of the 5 mixed formulas was still lower than that of the Control sample (2.43 N). The Control sample did have differences in processing processes or the addition of many other additives. Besides, DeMars and Ziegler (2024) admitted that gelatin-pectin combinations at different levels can significantly affect the texture of GC (Tarahi et al., 2024). Samples A, C and E had no difference in hardness because they were proportional to each other. When A and C increased the pectin ratio by 0.1 - 0.15 %, the MS decreased by 0.05 %, while in sample E, the pectin ratio decreased by 0.05 % and the MS was 1.5 %. It could be explained by the fact that pectin and starch both have quite similar hardness (Hartel et al., 2018). Different from D and B samples with an MS ratio of 1 % and a pectin ratio of 0.05 - 0.1 %, the hardness value did not have a significant difference, this proved that the

pectin concentration was high when combined with gelatin could create a stronger gel network lead increasing cross-linking between polymers. Regarding the adhesiveness value, the highest value was B (0.2 mJ) and the lowest was Control 2 (0.05 mJ). These two samples had the same ratio of 1 % MS and B only added pectin (0.1 %) proving that pectin could increase the adhesiveness (Bagal-Kestwal et al., 2019).

Table 2: Effect of mixing pectin and MS on textural properties

Samples	Hardness (N)	Adhesiveness (mJ)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (mJ)
Control	2.43 ± 0.20 ^{e}	0.09 ± 0.10 ^{ab}	0.87 ± 0.04 ^{ab}	3.77 ± 0.10 ^{ab}	2.11 ± 0.10 ^{c}	7.95 ± 0.32 ^{d}
Control 1	1.40 ± 0.04 ^{ab}	0.09 ± 0.04 ^{ab}	1.11 ± 0.34 ^{b}	3.53 ± 0.45 ^{a}	1.56 ± 0.53 ^{b}	5.35 ± 1.06 ^{ab}
Control 2	1.43 ± 0.04 ^{b}	0.05 ± 0.03 ^{a}	0.96 ± 0.10 ^{ab}	3.88 ± 0.02 ^{b}	1.38 ± 0.17 ^{ab}	5.34 ± 0.69 ^{ab}
Control 3	1.28 ± 0.02 ^{a}	0.08 ± 0.03 ^{ab}	0.90 ± 0.07 ^{ab}	3.80 ± 0.03^{ab}	1.16 ± 0.11 ^{a}	4.42 ± 0.42 ^{a}
Sample A	1.63 ± 0.10 ^{c}	0.15 ± 0.03 ^{bc}	0.93 ± 0.02 ^{ab}	3.89 ± 0.07 ^{b}	1.51 ± 0.10 ^{ab}	5.88 ± 0.32 ^{bc}
Sample B	1.89 ± 0.02 ^{d}	0.20 ± 0.08 ^{c}	0.90 ± 0.01 ^{ab}	3.82 ± 0.1 ^{ab}	1.70 ± 0.04 ^{b}	6.48 ± 0.30 ^{c}
Sample C	1.58 ± 0.12 ^{c}	0.16 ± 0.06 ^{bc}	0.89 ± 0.08 ^{ab}	3.77 ± 0.15 ^{ab}	1.41 ± 0.17 ^{ab}	5.34 ± 0.85 ^{ab}
Sample D	1.88 ± 0.04 ^{d}	0.12 ± 0.01 ^{ab}	0.67 ± 0.48 ^{a}	3.87 ± 0.17 ^{b}	1.71 ± 0.16 ^{b}	6.65 ± 0.92 ^{c}
Sample E	1.71 ± 0.04 ^{c}	0.11 ± 0.06 ^{ab}	0.91 ± 0.04 ^{ab}	3.90 ± 0.05 ^{b}	1.55 ± 0.10 ^{b}	6.03 ± 0.40 ^{bc}

Different letters in the same column represent a statistically significant difference according to ANOVA analysis (α = 0.05)

The gumminess and chewiness value of sample D reached the highest value (1.71 N; 6.65 N) and the lowest value of Control 3 (1.16 N; 4.42 N) because sample D was supplemented with MS and pectin, while control sample 3 only added gelatin. This experiment showed that MS and pectin significantly influence the gumminess and chewiness of the sample (Haug and Draget, 2009). Table 2 also indicated that the values of adhesiveness, gumminess and chewiness have differences ($p < 0.05$) but were not significant when changing the mixing ratio of pectin and MS. In general, the structure of the 5 samples was higher than that of the controls (Control, Control 1, 2 and 3). These experimental results can be explained based on the network connection ability of three types of biopolymers when mixed to create a better structure (Venkataramappa and Aswathnaryan, 2014). However, for springiness and cohesiveness, there was no difference ($p > 0.05$), which can be based on the comments of Hartel et al. (2018) acknowledged that the use of mixed polymers was still complex and the ability to predict structural properties was limited.

Table 3: Effect of mixing pectin and MS on moisture, ash content and colour parameters

Samples	Moisture (%)	Ash content (%)	Colour parameters		
			L*	a*	b*
Control	0.6 ± 0.11 ^{a}	0.55 ± 0.2 ^{b}	41.49 ± 0.05 ^{g}	17.63 ± 0.03 ^{g}	21.09 ± 0.02 ^{h}
Control 1	14.5 ± 0.83 ^{de}	0.36 ± 0.1 ^{a}	26.77 ± 0.20 ^{a}	14.34 ± 0.22 ^{f}	15.17 ± 0.08 ^{f}
Control 2	5.25 ± 0.76 ^{b}	0.4 ± 0.01 ^{a}	26.82 ± 0.16 ^{a}	12.25 ± 0.07 ^{d}	12.63 ± 0.08 ^{c}
Control 3	13.76 ± 1.4 ^{d}	0.4 ± 0.09 ^{a}	29.30 ± 0.04 ^{b}	13.85 ± 0.02 ^{e}	19.03 ± 0.05 ^{g}
Sample A	13.98 ± 1.07 ^{de}	0.32 ± 0.04 ^{a}	34.42 ± 0.16 ^{d}	-2.04 ± 0.03 ^{c}	10.72 ± 0.03 ^{b}
Sample B	8.22 ± 1.34 ^{c}	0.3 ± 0.06 ^{a}	34.11 ± 0.03 ^{c}	-2.11 ± 0.03 ^{c}	9.23 ± 0.02 ^{a}
Sample C	15.86 ± 1.68 ^{e}	0.36 ± 0.07 ^{a}	42.43 ± 0.09 ^{h}	-2.58 ± 0.02 ^{a}	13.53 ± 0.03 ^{d}
Sample D	9.91 ± 1.38 ^{c}	0.33 ± 0.07 ^{a}	40.94 ± 0.08 ^{f}	-2.43 ± 0.03 ^{b}	12.65 ± 0.04 ^{c}
Sample E	5.95 ± 0.79 ^{b}	0.37 ± 0.05 ^{a}	38.32 ± 0.02 ^{e}	-2.61 ± 0.03 ^{a}	14.47 ± 0.05 ^{e}

Different letters in the same column represent a statistically significant difference according to ANOVA analysis (α = 0.05)

Moisture content was significantly affected by different polymer ratios in the formulations. The difference in moisture content of GC samples can be explained based on the water-holding capacity of each biopolymer, and each formula had a different mixing ratio, which created different structural properties and retained water. According to Renaldi et al. (2022), pectin is hygroscopic because it can bond molecules through hydrogen bonds or the OH group on the pectin molecule with the H atom on the water molecule so that pectin can reduce water content in GC. MS and gelatin have good water-holding capacity (Ergun et al., 2010). The aim of determining the ash content of GC was to represent the total amount of minerals in the GC (Meilianti, 2018). Table 2 showed that the ratio of gelatin, pectin and MS did not have a significant effect on the ash content of the product ($p > 0.05$). However, when the pectin content was high, it bound more minerals from water and dissolved solids, lead increasing the ash content (Anjliany et al., 2022). In addition, the higher the concentration of modified starch, the higher the ash content, because MS was formed gel when combined with water since MS was formed gel when combined water, and often absorbs water to give texture and flexibility (Hari et al., 1989). The brightness (L*) of the 5 samples showed a significant difference ($p < 0.05$) compared to the controls. Sample C had the

highest brightness, followed by A, D, E and B. All samples have L* lower than the Control and higher than the three of the Control. In addition, the brightness of the GC was affected by the polymer ratio in the mixture, in which the higher the pectin concentration, the lower the L* value. Anjliany (2022) pointed out that the more pectin, the lower the L* value because of non-enzymatic browning reactions, specifically the Maillard reaction. Similarly, when the starch content was high, the L* value of the samples was rather high (Roudbari et al., 2024). The a* value proved that mixing 3 types of polymers had a significant effect on the a* value of the product. Besides, for the b* value, the Control had the highest yellow colour and the lowest was the 5 mixed samples. According to Masri et al. (2023), the yellow colour of GC was due to the presence of carotenoid pigments in pineapple juice. The higher the pectin ratio, the lower the b* value. The decrease in the b* value was due to the decomposition of carotenoid pigments during the heating treatment. Adding much pectin can increase acidity, causing carotenoid pigments to be destroyed faster. At the same time, MS had a milky white colour and reflected light, so when the concentration of MS was high, the colour of the samples decreased (Roudbari et al., 2024). In summary, the colour parameters were significantly affected by polymer mixing ratios.

3.2 Effect of mixing pectin and MS on the properties of sensory evaluation

Figure 4a pointed out that panel members have many differences in how they evaluated the sample. This might be due to the testers' ability to recognize different sensory properties. When observing according to Dim 1, it could be seen that member No.1 (P 1) had the most difference compared to the remaining members, followed by member No.9 (P9). Besides, if compared according to the Dim 2 axis, it could be seen that P1 had different results compared to the remaining members of the council. Dim 1 axis (41.95 %) was more significant than Dim 2 axis (23 %). Therefore, the results of the consensus level of the panel members were acceptable and the panel's assessment results could be used to analyse sensory attributes for the PEJ gummy samples. Figure 4b showed the GC samples and their sensory attributes. GC samples that were located close to each other have similar sensory attributes. The dispersion of the samples on the graph proved that changing the ingredients of each product greatly affects the sensory properties of the product.

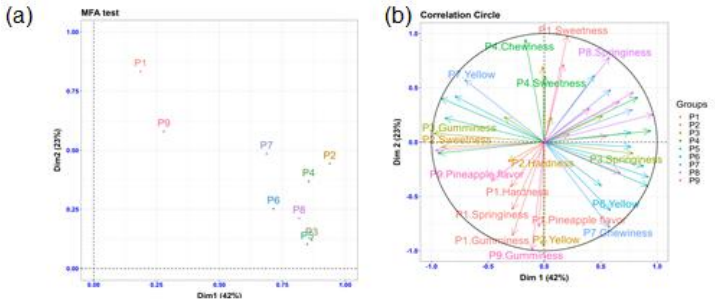

Figure 4: From Left to Right Chart (a) and (b) the correlation in assessments between members of the council

3.3 Determination of the nutrition value and total aerobic microorganisms of the final GC product

Sample E had high texture, colour and sensory properties with nutritional values as determined in Table 4. Table 4 showed that GC had quite a high nutritional value, and the total number of aerobic microorganisms was within the allowable limit. The antioxidant activity of GC can be considered the most controversial factor in this survey.

Table 4: The nutrition value and total aerobic microorganisms of the final GC product

Composition	Antioxidant Activity (%)	Total aerobic microorganisms (CFU/g)	Moisture (%)	Protein (%)	Lipid (%)	Carbohydrate (%)	Energy (Kcal)
Sample E	79.95 ± 0,2	$6.3 \times 10^2 \pm 3.5 \times 10^2$	5.95 ± 0.79	2.27 ± 0.99	0.9 ± 0.0	125.27 ± 4.24	128.43 ± 3.30

After heating, the antioxidant activity of the juice decreased by about 13.78 % compared to the original. According to research by Masri et al. (2023), the antioxidant capacity in pineapple jelly was 70.24 ± 0.66 %. Antioxidant activity in products made from juice was higher than in products made from pineapple juice, and Jovanovic et al. (2018) also showed that the antioxidant activity in pineapple peel extract was higher than that in pineapple juice. This highlights the diversity of pineapple's antioxidant profile, with most of the effectiveness residing in the skin. Leong and Shui (2002) admitted that pineapple waste contained a significant amount of

antioxidants, possibly even greater than the edible part of the fruit. Moreover, the antioxidant activity in chewing gum can be partly explained by the added sugar in the processing process. The sugar content after heating created carbohydrate radicals (CHO-) leading to the formation of the Maillard reaction (interaction of reducing sugars with amino acids) (Karseno et al., 2017). Moreover, on the correlation between brownness and antioxidant activity, DPPH reduction activity increased with increasing browning intensity of the Maillard reaction (Phisut and Jiraporn, 2013).

4. Conclusions

This study has shown that by fixing the gelatin content, changing the mixing ratio of pectin and MS can significantly impact some physicochemical and sensory properties of GC from PEJ. The most preferred GC was made from PEJ with an appropriate ratio of gelatin: pectin: MS of 9: 0.05: 1.5 (% wt.). PEJ had high antioxidant activity. After heat processing, the GC product retained 79.95 ± 0.2 % antioxidant activity. The total number of aerobic microorganisms was within safe limits. Future research needs to focus on the content of reducing sugars, total sugars, phenolic and flavonoid content, and also investigate the effect of temperature on the antioxidant activity of GC made from PEJ.

References

Anjliany M., Nabilah T.A., and Syafutri, M.I., 2022, Variation of Pectin and Sugar Concentration on The Characteristic of Passion Fruit Gummy Candy, Indonesian Food Science and Technology Journal, 6.

Bagal-Kestwal D.R., Pan M. h., Chiang B. H., 2019, Properties and Applications of Gelatine, Pectin, and Carrageenan Gels. In Bio Monomers for Green Polymeric Composite Materialsp, 11– 140.

Delgado P., Bañón S., 2015, Determining the minimum drying time of gummy confections based on their mechanical properties, CyTA - Journal of Food, 13(3), 329–335.

Ergun R., Lietha R., Hartel R.W., 2010. Moisture and Shelf Life in Sugar Confections. Critical Reviews in Food Science and Nutrition, 50(2), 162–192.

Hari P.K., Garg S., Garg S.K., 1989, Gelatineization of Starch and Modified Starch, 41(3), 88–91.

Hartel R., Elbe J., Hofberger R., 2018, Jellies, Gummies and Licorices, 329–359.

Haug I.J., Draget K.I., 2009, 6—Gelatine. In G. O. Phillips and P. A. Williams (Eds.), Handbook of Hydrocolloids, SecondEdition, 142–163, Woodhead Publishing.

Hemalatha R., Anbuselvi S., 2013, Physicohemical constituents of pineapple pulp and waste, Journal of Chemical and Pharmaceutical Research, 5, 240–242.

Karseno K., Wuryatmo E., Yanto T., Setyawati R., Haryanti P., 2017. Effect of pH and temperature on browning intensity of coconut sugar and its antioxidant activity, Food Research, 2, 32–38.

Leong L.P., Shui G., 2002, An investigation of antioxidant capacity of fruits in Singapore markets, Food Chemistry, 76(1), 69–75.

Mahmood A.L., Lani M., Hassan Z., Abd Razak S.B., Ahmad F.T., 2021, Antioxidant and antimicrobial properties of Indo-Malayan stingless bee (Heterotrigona itama) honey from different seasons and distribution of flowers, Food Research, 5, 498–507.

Masri A.A., Bakar F.I.A., Abidin M.Z., Malik N.H., 2023, Development of Antioxidant Jelly Using Tropical Fruits, Tropical Journal of Natural Product Research.

Phisut N., Jiraporn B., 2013, Characteristics and antioxidant activity of Maillard reaction products derived from chitosan-sugar solution, International Food Research Journal, 20, 1077–1085.

Pratiwi L. J., Swasti Y. R., Pranata F. S., 2023, The quality of red guava (Psidium guajava L.) gummy candies with variation additions of pineapple peel extract paste (Ananas comoscus L. Merr) as a gelling agent, Food Research, 7(3), 63-70.

Renaldi G., Junsara K., Jannu T., Sirinupong N., Samakradhamrongthai R.S., 2022, Physicochemical, textural, and sensory qualities of pectin/gelatine gummy jelly incorporated with Garcinia atroviridis and its consumer acceptability, International Journal of Gastronomy and Food Science, 28, 100505.

Roda A., Dante Marco D.F., Dordoni R., Lambri M., 2014, Vinegar Production from Pineapple Wastes – Preliminary Saccharification Trials, Chemical Engineering Transactions (CET), 37, 607–612.

Roudbari M., Barzegar M., Sahari M.A., Gavlighi H.A., 2024, Formulation of functional gummy candies containing natural antioxidants and stevia, Heliyon, 10(11).

Schrieber R., Gareis H., 2007, April, Gelatine Handbook: Theory and Industrial Practice, 1807-2007, Knowledge for Generations Title page Copyright page Contents Gelatine - An Element of Our Life.

Tarahi M., Tahmouzi S., Kianiani M.R., Ezzati S., Hedayati, S., Niakousari M., 2024, Current Innovations in the Development of Functional Gummy Candies, Foods, 13(1), Article 1.

Venkataramappa C., Aswathnaryan S., 2014, Texture Profile Analysis and Functional Properties of Gelatine from the Skin of Three Species of Fresh Water Fish, International Journal of Food Properties, 18, 572–584.