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FULL PAPER

Utilization of κ-carrageenan as stabilizer and thickener of honey pineapple (*Ananas comosus* [L. Merr]) jam

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Abstract

Honey pineapple jam is an intermediate moisture food that often has low stability; hence it is not strong enough to hold the fruit tissue sugar in position during storage. Therefore, it is necessary to add hydrocolloid in fruit jam processing to increase stability and consistency, one of which is κ-carrageenan. The purpose of this study was to determine the effect of adding κ-carrageenan towards stability and preference for honey pineapple jam. The κ-carrageenan concentrations used were 0%, 0.5%, 1%, and 1.5% (w/w) of total ingredients. The ratio of honey pineapple pulp and sugar was 4:1 (w/w). The results showed that the addition of κ-carrageenan had a significant effect ($p<0.05$) on the hedonic evaluation of colour, smearing ability, and texture; moisture content, water activity (Aw), syneresis and texture (hardness, cohesiveness, and adhesiveness). The addition of κ-carrageenan had no significant effect ($p>0.05$) on the hedonic evaluation (preference) of aroma and taste. Increasing the κ-carrageenan concentration can increase the hedonic value for colour and decrease the hedonic value for smearing ability and texture. Increasing the concentration of κ-carrageenan can also increase the value of hardness and cohesiveness but decrease water activity, syneresis, and adhesiveness. The addition of κ-carrageenan 0.5% was more efficient in shortening the cooking time until 25%, inhibiting syneresis by 30%, and improving the colour of honey pineapple jam.

1. Introduction

Pineapple fruit is the primary commodity in Pemalang Regency, Central Java Province, Indonesia, with 139,281 tons in 2015 (Statistic Indonesia, 2021). However, pineapple has high moisture content and includes perishable food. Santos *et al*. (2020) confirmed that pineapples' moisture content reaches 85.4% of the sample. Therefore, it is necessary to carry out further processing to extend the shelf life.

Jam is a familiar and popular processed fruit product. Fruit jam is made by boiling fruit pulp with sugar and flavouring agents, consequently, that consistency is vital to hold the fruit tissue in position (Basu *et al.*, 2011). Fruit jam is an intermediate moisture food that often has low stability, hence it is not strong enough to hold the fruit tissue sugar in position during storage. Therefore, it is necessary to add food additives to fruit jam production to increase stability and consistency, one of which is hydrocolloids. Pereira *et al*. (2017) stated that hydrocolloids could enhance and maintain fruit jam's rheological properties.

Carrageenan as a hydrocolloid is often used in the food industry as a stabilizer, emulsifier, thickener, gelling agent, and coating material. The addition of carrageenan to the jam also has a positive correlation with improving sensory attributes. Carrageenan influences food textural properties to affect the sensory fruit jam (Selvamuthukumaran and Khanum, 2014; Jancikova *et al*., 2019). Carrageenan, a linear polysaccharide group, was extracted from red algae (Rhodophyceae) (Maleki *et al*., 2019).

Many studies are related to adding carrageenan to improve the quality of fruit jam. Quintana *et al*. (2018) examined the effect of a mixture of hydrocolloids (pectin, carrageenan, guar gum, and xanthan gum) and sugar concentration in soursop jams. Jancikova *et al*. (2019) investigated the effect of adding κ-carrageenan, ι-carrageenan, and pectin on cherry and apricot jams.

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Minh (2020) evaluated gelling agents' impact (guar gum and carrageenan) and sugar on apple jam sensory. Hilal and Obaid (2020) have also researched the effect of various types of carrageenan on the characteristics of strawberry jam. However, there has been no study regarding the addition of κ-carrageenan to honey pineapple jam. This study was aimed to examine the effect of adding carrageenan with different concentrations to the quality of honey pineapple jam and determine the best engagement.

2. Materials and methods

2.1 Materials

Honey pineapples (350 g/fruit) were obtained from Pemalang, Central Java Province, Indonesia. Other ingredients used in this study include κ-carrageenan (Indogum, Jakarta, Indonesia) and sugar (Rose Brand, Jakarta, Indonesia).

2.2 Production of jam

The honey pineapple jam production was done by preparing ingredients in honey pineapple, sugar, and carrageenan. First, the honey pineapple was peeled and blended for 3 mins (it became honey pineapple pulp), then put in the pan and cooked on medium heat (70°C) for 10 mins. Next, sugar was added to the carrageenan according to the treatment (0%; 0.5%; 1.0%; 1.5% (w/w)), stirred until thickened. The ratio of honey pineapple pulp and sugar was 4:1 (w/w).

2.3 Hedonic evaluation

Twenty-five moderately trained panellists carried out the hedonic evaluation with an age range of 20 to 24 years old. Sample testing was done in the colour, aroma, taste, smearing ability, and texture with a hedonic scale of 9 (extremely pleasant) to 1 (extremely unpleasant).

2.4 Cooking time

The cooking time of honey pineapple jam is the time (minutes) when the dough melted not long after the spoon was removed (spoon test), indicating the cooking process was sufficient.

2.5 Moisture content and water activity

Moisture content was determined by the gravimetric method (AOAC, 2005). The water activity test (Aw) was measured by the Aw meter (Rotronic higropalm-27479, U.K.).

2.6 Syneresis

Syneresis is an evaluation to determine the stability of honey pineapple jam during storage. The assessment of syneresis referred to the method of Maleki *et al*. (2019), namely on the principle of weighing fruit jam was separated from water during cold storage. A sample of 40 g was placed in a plastic cup coated with filter paper. Furthermore, the weight of the jam is weighed after being stored at 4°C for 24 hrs. Syneresis is expressed as the percentage difference in the sample's weight before and after storage to the sample's importance before storage.

2.7 Texture

A texture analyser (T.A. Plus Ametek Lloyd Instruments Ltd, Hampshire, UK) was used to measure the hardness, cohesiveness, and adhesiveness of honey pineapple jam. The cylinder probe (L 35 mm, D 12.7 mm), trigger 4.5 g, deformation 5 mm, and speed one mm/s) was used for texture evaluation.

2.8 Statistical analysis

All data were analysed using SPSS 25 (IBM SPSS Statistics 25.0, N.Y., USA). Parametric testing determines normality and homogeneity of data, then analyses data using ANOVA and continues with the Honest Significant Difference (HSD) test. Non-parametric testing using the Kruskal-Wallis method followed by the Mann Whitney test.

3. Results and discussion

3.1 Hedonic

The hedonic results presented in Table 1 show that the addition of carrageenan with different concentrations has significantly different on the preference of panellist for colour, smearing ability, and texture of honey pineapple jam ($p<0.05$). However, the difference in carrageenan concentrations did not significantly differ from the panellist's preference for the aroma and taste of honey pineapple jam ($p<0.05$).

Based on the results of the hedonic test, it can be seen that the panellists gave the lowest hedonic value ($p<0.05$) for the colour of honey pineapple jam without the addition of carrageenan, namely 5.40. However, carrageenan added to a concentration of 1.5% did not significantly differ from the hedonic value of the colour parameter. This study indicates that the addition of carrageenan can increase the preference of panellists for honey pineapple jam colour because it has a brighter colour. However, honey pineapple jam without the addition of carrageenan is brownish yellow and darker in colour. This is closely related to the cooking time of honey pineapple jam; namely, carrageenan's addition caused the cooking time of jam to be longer. The cooking process's length, the more non-enzymatic

browning (caramelization) reactions are formed, therefore the colour of the jam will turn dark brown. Cano-Lamadrid *et al*. (2020) stated that the jelly candies made from gelatin and apple puree have a dark colour caused by non-enzymatic browning reactions during cooking Maillard and caramelization reaction. The longer the cooking process and the higher the temperature used, the more it encourages the browning response. These reactions cause changes in the aroma, taste, and colour of the food.

Table 1 shows that the addition of carrageenan with different concentrations did not significantly differ ($p>0.05$) on the preference of panellists for the taste parameters of honey pineapple jam. Other results were shown by Lima *et al*. (2019); namely, the type and concentration of gelling agents used can affect the gel's mechanical properties and the perception of sweet aromatized in orange jellies. The type of gelling agent used is low methoxyl pectin, guar gum, and carrageenan gum at a concentration of 0 to 1%. A different result was shown by Akesowan and Choonhahirun (2019), namely that the addition of hydrocolloids (konjac and xanthan gum) increased the preference of panellists for the taste of pineapple jam. This can be closely related to the gel that forms in pineapple jam. Mosca *et al*. (2012) stated that the gel that is softer and easier to chew could increase the surface area contact between the sweetener and the tongue's taste receptors.

Honey pineapple jam in this study has a sweet taste that can be influenced by the type and concentration of sugar used and the pH and temperature of the fruit jam (Souza *et al*., 2013). Meanwhile, the types and concentrations of sugar used in this study were the same. The addition of carrageenan to a concentration of 1.5% doesn't cause a change in the jam's taste because it has no taste.

Based on Table 1 and Figure 1, it can be seen that the increase in carrageenan concentration has caused a decrease in the hedonic value of honey pineapple jam. The use of 1% carrageenan caused honey pineapple jam to be unpleasant by the panellist in terms of smearing ability and texture; even at a concentration of 1.5%, it was very unpleasant ($p<0.05$). The higher the carrageenan concentration, the honey pineapple jam is more challenging to spread jam on bread and mastication. Broomes and Badrie (2010) stated that hydrocolloids are often used to improve fruit jams' texture. The addition of hydrocolloids can affect the mouth-feel (texture) of the jam by thickening the product through a gel-forming process. Javanmard *et al*. (2012) added that the characteristic texture of fruit jam needs to be a concern because it relates to the balance between mechanical stability during handling and storage and instability to obtain a semi-soft texture, because of this it is accessible to mastication and spread on bread. Thus, the texture of fruit jam can also affect the acceptance of fruit jam.

3.2 Cooking time

The addition of carrageenan helped shorten the cooking time of honey pineapple jam (Table 2). However, the concentration of 0.5% to 1.5% was not significantly different ($p<0.05$). This phenomenon can be caused by a reaction between κ-carrageenan and sugar to form a more stable network. The addition of hydrocolloids can increase the gel formation viscoelastic system (Quintana *et al*., 2018). The appearance of an elastic carrageenan gel can cause a shorter cooking time for honey pineapple jam, which is indicated by the fact that honey pineapple jam is no longer sticky to the cooking equipment.

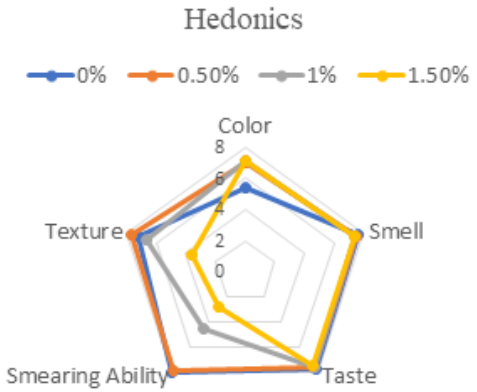

Figure 1. Hedonic of honey pineapple jam with the addition of different carrageenan concentrations

Table 1. Hedonic of honey pineapple jam with the addition of different carrageenan concentrations

Parameters	Carrageenan			
	0%	0.50%	1%	1.50%
Colour	5.40±0.96^{a}	7.00±0.87^{b}	7.08±0.76^{b}	7.16±1.03^{b}
Aroma	7.6±0.96^{a}	7.52±0.65^{a}	7.44±1.09^{a}	7.36±1.25^{a}
Taste	7.72±0.89^{a}	7.60±0.76^{a}	7.52±0.59^{a}	7.48±0.94^{a}
Smearing ability	8.00±0.70^{a}	7.80±0.87^{b}	4.52±1.19^{c}	2.84±0.66^{d}
Texture	7.24±0.78^{a}	7.68±0.69^{a}	6.68±0.99^{a}	3.56±1.44^{b}

Values are presented as mean±SD, n = 25. Values with the different superscript within the same column are significantly different between treatments ($p<0.05$).

3.3 Moisture content

The results showed that the addition of carrageenan was able to increase the moisture content of honey pineapple jam ($p<0.05$) (Table 2). Razak *et al*. (2018) and Setiaboma *et al*. (2019) explained that hydrocolloids could bind large amounts of water. Carrageenan, as a hydrocolloid, has free O.H.- ions, which can bind with H_2O (water), consequently that the bond becomes strong. Carrageenan is more optimum in trapping water within the gel formation. However, different results were shown by other types of hydrocolloids, namely high methoxyl pectin (0.1%, 0.7%, 1.2%), carboxymethyl cellulose (0.5%, 1.25%, 2.50%), and sago starch (2%, 6%, 10%). The addition of this type of hydrocolloid can decrease the moisture content of mango jam. This is because hydrocolloids can increase the solid fraction, reducing the amount of water that is evaporated during the cooking process (Javanmard *et al*., 2012).

The moisture content of honey pineapple jam from this study ranged from 38.08 to 50.93%, which is higher than the result of research by Santos *et al*. (2020), namely pineapple's moisture content jam using pectin as hydrocolloid is 20.9%. Pineapple jam is made from 65% pineapple pulp, sugar 34.4%, pectin 0.4%, and citric acid 0.2%.

3.4 Water activity

The water activity value of honey pineapple jam is shown in Table 2, ranging from 0.80 to 0.87. This value is higher than Ismail *et al*. (2017); namely, the water activity value of honey pineapple jam produced using microwave 800 W for 10 mins is 0.7. Water activity significantly affects the physical properties and shelf life of fruit jam. Moulds can optimally grow and spoil the fruit jam in the water activity range of 0.60 to 0.85.

Based on Table 2, it is also known that the addition of carrageenan to a concentration of 1% can increase the water activity of honey pineapple jam. However, at higher carrageenan concentrations (1.5%), honey pineapple jam's water activity was lower. This study's results have the same trend as the research of Broomes and Badrie (2010), namely that the higher concentration of pectin can decrease the water activity value of roselle jam. This is closely related to pectin's ability as a hydrocolloid to trap water in its three-dimensional network. In this case, carrageenan and pectin are types of hydrocolloids.

3.5 Syneresis

The results showed that carrageenan's addition could inhibit the syneresis of honey pineapple jam (Table 2). The higher of carrageenan concentration added, the smaller of syneresis value in the honey pineapple jam ($p<0.05$). Syneresis is a jelly product that consists of various types of homogenous substances, which then separate into solid lumps surrounded by liquid. Jam is considered not experiencing syneresis or syneresis-free if the syneresis level is in the range of 0-5% (Croptova and Popel, 2013).

Hydrocolloid can increase the food system's stability by expanding its viscosity or utilizing colloid interactions such as spatial suppression and electrostatic interactions. Thereby reducing the particle movement and separation speed of two or more phases. The presence of a three-dimensional network formed by carrageenan has resulted in trapping pineapple pulp in this network (Maleki *et al*., 2019).

3.6 Texture

The hardness value and cohesiveness value of honey pineapple jam increased with increasing carrageenan concentration ($p<0.05$) (Table 2). Hardness is the peak force exerted on a product and able to maintain its structure against deformation. The hardness value is closely related to the strength of the gel structure formed by hydrocolloid polymer chains (Javanmard *et al*., 2012). Sensory hardness can be defined as the maximum force required to compress food between the teeth. Meanwhile, cohesiveness shows the consistency value of a product, namely the strength of the internal bonds that compose food and the extent to which food can change shape

Table 2. Property test of honey pineapple jam with the addition of different carrageenan concentrations

Parameters	Carrageenan			
	0%	0.50%	1%	1.50%
Cooking Time (mins)	40.90±2.05^{a}	29.97±1.02^{b}	30.45±1.41^{b}	29.30±0.78^{b}
Moisture content (%)	38.08±0.77^{a}	45.07±0.90^{b}	49.73±0.98^{c}	50.93±1.23^{c}
Water Activity	0.81±0.01^{a}	0.82±0.02^{a}	0.87±0.01^{b}	0.80±0.02^{a}
Syneresis (%)	13.77±0.44^{a}	9.60±0.25^{b}	7.90 ±0.69^{c}	5.69±0.77^{d}
Hardness (kg/mm^2)	17.00±1.80^{a}	67.20±25.30^{a}	224.00±69.30^{b}	244.70±58.50^{b}
Cohesiveness	0.39±0.05^{a}	0.50±0.09^{ab}	0.49±0.08^{ab}	0.63±0.05^{b}
Adhesiveness (mJ)	0.33±0.07^{a}	0.53±0.06^{b}	0.27±0.04^{a}	0.25±0.05^{a}

Values are presented as mean±SD, n = 3. Values with the different superscript within the same column are significantly different between treatments ($p<0.05$).

before the rapture. Cohesiveness is the ratio of the area of positive force during the second compression to the first compression. This can be measured as the rate at which a product is crushed after being subjected to mechanical stress (Chandra and Shamasundar, 2015).

Carrageenan can increase the hardness of the food. At temperatures above 60°C, carrageenan shows a random structure due to electrostatic repulsions between the polymer chains. Then, the network is turned into a helical structure by polymer chains after cooling. A helical aggregation will be formed and form a stable and rigid gel when the temperature decreased again. Intermolecular interactions between carrageenan chains can also increase cohesiveness (Rhein-Knudsen *et al*., 2015; Tavassoli-Kafrani *et al*., 2016).

Adhesiveness is a negative force area for the first bite. It is related to overcoming the attractive force between the surface of the food and the character of other materials that come into contact with food (Chandra and Shamasundar, 2015). This study indicated that the addition of carrageenan at a concentration of 0.5% could increase adhesiveness ($p<0.05$). However, at concentrations greater than 0.5%, honey pineapple jam's adhesiveness decreased (Table 2). This is possible because the increasing hydrocolloid concentration causes more water to be bound and other product components to be placed together as a denser structure in the fruit jam. Thus, the adhesiveness value is lower (Azimi *et al*., 2012). Jain and Babbar (2011) also stated that the decrease in adhesiveness was related to firmer and stronger gel formation.

4. Conclusion

The addition of carrageenan had a significant effect ($p<0.05$) on the hedonic evaluation of colour, smearing ability, and texture; moisture content, water activity (Aw), syneresis and texture (hardness, cohesiveness, and adhesiveness), and had no significant effect ($p>0.05$) on the hedonic evaluation (preference) of aroma and taste. The addition of carrageenan 0.5% was more efficient in shortening the cooking time until 25%, inhibiting syneresis by 30%, and improving the colour of honey pineapple jam.

Conflict of interest

The authors state no conflict of interest.

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