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The potential of alginate and modified tapioca starch as pectin substitutes in strawberry-flavored jam

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Abstract

Jam production commonly relies on pectin as the primary thickening and gelling agent; however, pectin is relatively expensive and not easily accessible, creating a need for alternative materials that are more economical and readily available. Alginate and modified tapioca starch have potential to be used as pectin substitutes due to their gelling and water-binding properties. This study aimed to determine the appropriate concentrations of alginate and modified tapioca starch for the production of strawberry jam with acceptable physicochemical and sensory characteristics. The experiment was conducted using a Randomized Block Design with six treatments and three replications, consisting of alginate concentrations of 1.5% and 3% combined with modified tapioca starch concentrations of 5%, 6%, and 7%. The parameters evaluated included viscosity, pH, spreadability, and sensory acceptance using a hedonic test. The results showed that variations in alginate and modified tapioca starch concentrations significantly affected the quality characteristics of strawberry jam. The best formulation was M2A1, containing 1.5% alginate and 6% modified tapioca starch. This formulation exhibited a viscosity of 13.567 cP, a pH value of 3.61, and a spreadability of 16.45 cm. Sensory evaluation indicated that this formulation was preferred by panelists, with hedonic scores of 4.4 for spreadability, 4.0 for taste, 4.6 for texture, and 4.2 for overall acceptance. These findings indicate that the combination of 1.5% alginate and 6% modified tapioca starch have strong potential as a substitute for pectin in the production of strawberry-flavored jam.

INTRODUCTION

Jam is a widely used food product commonly applied as a filling or spread for bakery items. According to the Indonesian National Standard (SNI 01-3746-2008), fruit jam is defined as a semi-moist, spreadable product made from fruit and sugar, with or without the addition of other permitted food ingredients and additives. The texture of jam is strongly influenced by the type of gelling agent used. As reported by Ardiansyah and Hintono (2019), gel formation in jam is affected by several factors, including heating temperature and duration, sugar concentration, stirring process, and the balance between sugar and the gelling agent. In most cases, pectin—either naturally derived from fruit or added during processing—is the primary gelling agent used. Jam texture is formed through the interaction of pectin with sugar and acid at high temperatures, allowing the gel to set upon cooling (Sitorus et al., 2022). Higher pectin concentrations generally result in firmer gel structures (Atviolani et al., 2016).

Over time, jam products have undergone various innovations, ranging from flavor diversification to the application of more advanced processing techniques. Traditionally, jam is prepared using fruit or fruit extract as a natural source of pectin to achieve the desired texture (Siagian et al., 2019). However, increasing industrial competition has prompted the search for more economical and accessible gelling agents that could replace fruit-derived pectin while still producing desirable textural characteristics.

Currently, in the food industry, the use of natural pectin as a gelling agent in jam products has begun to be combined with or replaced by other hydrocolloids, such as alginate, to improve processing efficiency and reduce production costs. Alginate is a hydrocolloid widely used as a stabilizer, emulsifier, and viscosity enhancer in various food products, including sauces, fruit-based products, gel desserts, and thick beverages (Setyoaji et al., 2019). Several studies have reported that alginate application in sauces and desserts improves system stability, produces a more homogeneous texture, and reduces syneresis during storage (Ariani et al., 2023). In fruit-based and semi-solid foods, alginate has also been shown to form stable and elastic gel structures (Bi et al., 2022). Timbalo (2020) reported that alginate application in pineapple jam resulted in good texture, optimal spreadability, and improved product stability during storage. These findings indicate that alginate possesses suitable functional properties as a gelling agent and therefore has potential for application in strawberry-flavored jam as an alternative to natural pectin.

In addition to alginate, modified tapioca starch is another potential substitute for pectin. Modified tapioca starch has been widely applied in various food products, such as sauces, thick soups, bakery products, and semi-solid foods, due to its effective water-binding and viscosity-enhancing properties (Lekahena, 2016). Starch modification alters functional characteristics, including improved stability during heating, stirring, and storage, making it more suitable for processed foods than native starch. Although pectin is commonly used in jam due to its excellent gel-forming ability through enzymatic or thermal degradation (Kiyat et al., 2019), its relatively high cost and limited availability (Dipowaseso et al., 2018) present economic constraints. Therefore, the use of modified tapioca starch, particularly in combination with alginate, is expected to provide a more economical and readily available alternative while maintaining desirable texture and spreadability in strawberry-flavored jam.

This study aimed to evaluate the effects of different concentrations of alginate and modified tapioca starch on the quality characteristics of strawberry-flavored jam. The findings are expected to determine the most appropriate formulation that is acceptable to panelists.

METHOD

Materials

The equipment used for strawberry jam production included an overhead stirrer, beaker glass, spatula, analytical balance, watch glass, volumetric pipette, and spoon. Instruments used for analysis consisted of a viscometer (Brookfield DV-I Prime), a Brix refractometer (Atago), and standard laboratory glassware (Pyrex).

The materials used in this study were granulated sugar (Gulaku), sodium alginate (Multi Jaya Kimia), potassium sorbate (Multi Jaya Kimia), salt (Refina), rose food coloring (Koepoe-Koepoe), modified tapioca starch (Subur Kimia Jaya), liquid glucose (Chef Daniel), sodium citrate (Multi Jaya Kimia), malic acid (Gratama Bumi Indonesia), citric acid (Koepoe-koepoe), strawberry flavoring (Chemnovatic), and water (Flow).

Methods

The strawberry jam was prepared using formulations as presented in Table 1. A total of six formulations were developed with different concentrations of alginate and modified tapioca starch.

Table 1. Strawberry jam formulation.

Ingredients	Formula (g)					
	M1A1	M1A2	M2A1	M2A2	M3A1	M3A2
Powdered Sugar	20	20	20	20	20	20
Sucralose	1	1	1	1	1	1
Sodium alginate	3	1.5	3	1.5	3	1.5
Potassium sorbate	0.05	0.05	0.05	0.05	0.05	0.05
Salt	0.2	0.2	0.2	0.2	0.2	0.2
Food coloring	0.2	0.2	0.2	0.2	0.2	0.2
Modified tapioca starch	5	5	6	6	7	7
Water	55.35	56.85	54.35	55.85	53.35	54.85
Liquid glucose	12	12	12	12	12	12
Sodium citrate	0.2	0.2	0.2	0.2	0.2	0.2
Citric acid	2	2	2	2	2	2
Strawberry flavor	1	1	1	1	1	1

The jam production process followed modified methods based on Syaifuddin, Ridho, and Harsanti (2019) and Misnawati et al. (2022). The procedure began with weighing all ingredients according to the formulations listed in Table 1. The weighed dry ingredients were first homogenized using an overhead stirrer, after which the liquid ingredients were gradually added to prevent lump formation. Once a homogeneous mixture was obtained, the mixture was heated at approximately 80°C for 13 minutes. Strawberry flavoring was then added, followed by further heating for 2 minutes until a homogeneous jam texture was achieved. The resulting strawberry jam was allowed to cool to room temperature and then stored in tightly closed containers at room temperature (±27°C) for 24 hours prior to further analysis.

Data Analysis

This study was conducted experimentally using a Randomized Block Design. The blocking was based on differences in the strawberry jam production time, where each block represented a production batch prepared at different times. The use of this design aimed to minimize the influence of process variability during jam production on the experimental results, allowing the effects of the treatments to be evaluated more accurately. The treatments consisted of variations in alginate and modified tapioca starch concentrations, resulting in six treatment combinations as presented in Table 1.

The parameters evaluated in this study included viscosity, pH, and jam spreadability. Viscosity was measured using a Brookfield viscometer (DV-I Prime) following the method described by Špeťuch et al. (2015). pH measurement was conducted using a calibrated pH meter according to the procedure reported by Syaifuddin et al. (2019). Spreadability was evaluated by measuring the spreading distance of jam on the surface of bread in accordance with the method described by Harto et al. (2016). Sensory evaluation was subsequently performed using a hedonic test with 20 semi-trained panelists to assess spreadability, taste, texture, and overall acceptance.

All experimental data were statistically analyzed using Analysis of Variance to determine the effects of the treatments. Significant differences among treatments were further analyzed using Tukey's post-hoc test at a 95% confidence level with the assistance of Minitab 18 software.

RESULTS AND DISCUSSION

Physical and Chemical Characteristics

The physical characteristics of the strawberry jam were visually observed to provide an initial overview of the product appearance resulting from the formulations containing alginate and modified tapioca starch. The strawberry jam produced exhibited a characteristic bright red color, a strong strawberry aroma, and textures ranging from relatively fluid to thick, depending on the formulation used, as shown in Figure 1. These differences in physical characteristics indicate that variations in alginate and modified tapioca starch concentrations influenced the structural formation and consistency of the jam.

Figure 1. Strawberry jam.

Furthermore, to support the visual observations, analyses of the physical and chemical characteristics were conducted, including viscosity, pH, and jam spreadability. The results of the physical and chemical analyses of strawberry jam from all treatments are presented in Table 2.

Table 2. Strawberry jam characteristics.

Formulation	Viscocity (cP)	pH	Spreadability (cm)
M1A1	11.668±0,96^{c}	3.56±0,01^{c}	10.1±0,14^{d}
M2A1	13.567±0,09^{c}	3.61±0,01^{bc}	16.45±0,21^{a}
M3A1	17.737±0,40^{b}	3.77±0,01^{a}	7.30±0,42^{e}
M1A2	12.195±0,17^{c}	3.55±0,01^{c}	14.95±0,21^{b}
M2A2	16.035±0,23^{b}	3.61±0,01^{bc}	12.45±0,21^{c}
M3A2	20.394±0,83^{a}	3.64±0,03^{b}	7.65±0,49^{e}

Note: Values represent the mean of three replications ± standard deviation. Different superscript letters within the same column indicate significant differences.

a. Viscocity

Viscosity is defined as the resistance of a fluid to flow due to intermolecular friction between particles when they are in contact (Špeťuch et al., 2015). It is also an important physical parameter used to evaluate jam quality (Dwiloka et al., 2024). In general, higher jam viscosity results in lower spreadability (Tuhumury et al., 2023). As shown in Table 2, the viscosity of strawberry jam was influenced by variations in alginate and modified tapioca starch concentrations. The highest viscosity in this study was observed in treatment M3A2, with a value of 20.394 cP.

The results indicate that increasing the concentration of modified tapioca starch significantly increased the viscosity of strawberry jam. This effect occurs because higher starch content enhances water binding, leading to the formation of a greater amount of starch gel, which in turn increases viscosity (Bulkaini et al., 2020). Similarly, higher alginate concentration resulted in increased viscosity, as all treatments containing 3% alginate exhibited higher viscosity values compared to those containing 1.5% alginate. This is attributed to the increased ability of alginate to form gel structures at higher concentrations. Sinurat (2017) reported that increasing the concentration of gelling ions leads to stronger gel formation. When a greater amount of Ca^{2+} ions is released during gel formation, more cross-linking between alginate molecules occurs, resulting in a stronger gel network.

Overall, the combination of alginate and modified tapioca starch exhibited an interaction effect on jam viscosity. Alginate contributed to the formation of an ionic gel network, while modified tapioca starch enhanced water-binding capacity and filled the gel matrix. The interaction between these two hydrocolloids produced a more compact and stable gel system, thereby synergistically increasing the viscosity of strawberry jam.

b. pH

Jam products have different optimum pH values depending on the raw materials used in their formulation (Syaifuddin et al., 2019). In this study, citric acid was used as an acidifying agent at the same concentration across all treatments to control the pH of the system. pH control is essential because hydrocolloid gel formation occurs optimally within a specific acidic range. The addition of citric acid enhances the water-binding capacity of the system, resulting in the formation of a stronger and more stable gel structure (Fajarwati et al., 2017).

The results showed that pH values significantly influenced the quality characteristics of strawberry jam; however, no significant differences were observed among treatments. This outcome is attributed to the use of the same concentration of acidifying agent in all formulations. The pH values obtained in this study ranged from 3.56 to 3.77. These values are slightly lower than those reported by Adji (2022), who observed pH values between 3.80 and 4.40, but are comparable to the findings of Christianto (2022), who reported pH values ranging from 3.09 to 3.59 for strawberry jam.

Although no significant differences in pH were observed among treatments, pH plays an important role in supporting optimal gel structure formation under acidic conditions. Controlled pH contributes to increased viscosity, reduced spreadability, and balanced flavor, all of which influence panelist acceptance. Overall, alginate and modified tapioca starch did not directly affect pH; however, they indirectly interacted through the formation of a more stable gel network under controlled pH conditions. Consequently, the physical and sensory characteristics of strawberry jam are closely interrelated and collectively contribute to overall product quality.

c. Spreadability

Spreadability testing was conducted to evaluate the consistency and texture of strawberry jam when applied to the surface of bread (Handoyo & Suseno, 2021). Consistency and texture are important indicators of jam quality, as better consistency and texture reflect higher product quality (Jabar et al., 2020). In this study, the spreadability values of strawberry jam ranged from 7.30 cm to 16.40 cm. The highest spreadability was observed in treatment M2A1, while the lowest was found in treatment M3A1.

Differences in spreadability among treatments were influenced by the moisture content of each formulation. Lower moisture content resulted in reduced spreadability (Thio & Djarkasi, 2018). Statistical analysis showed significant differences among treatments ($p < 0.05$), indicating that variations in alginate and modified tapioca starch concentrations significantly affected jam spreadability. Higher concentrations of alginate and modified tapioca starch increased water-binding capacity, leading to higher viscosity and making the jam more difficult to spread on bread. Conversely, lower concentrations resulted in lower viscosity, causing the jam to break more easily during spreading.

The interaction between alginate as a gel network–forming agent and modified tapioca starch as a water-binding component played a crucial role in determining the balance between viscosity and spreadability. According to Lapamona et al. (2023), jam with good spreadability should be easy to apply and evenly distributed on the bread surface. The spreadability values obtained in this study are consistent with those reported in the literature, ranging from 11.46 cm to 16.80 cm (Nafi' et al., 2018)

Sensory Characteristics

The sensory characteristics of strawberry jam were evaluated to determine panelist acceptance of the product based on spreadability, taste, texture, and overall acceptance. Sensory evaluation was conducted using a hedonic test with a preference scale of 1–5 to describe panelist preferences for each strawberry jam formulation. The results of the sensory quality evaluation of strawberry jam are presented graphically in Figure 2.

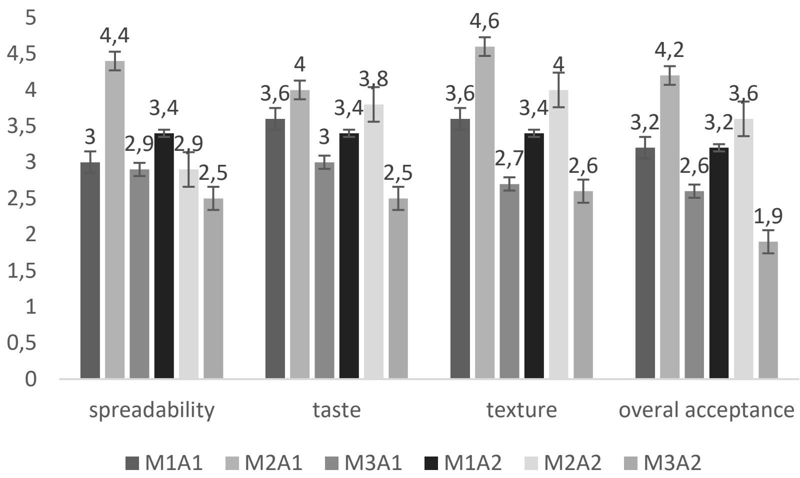

Figure 2. Sensory quality evaluation of strawberry jam.

Figure 2 presents the average hedonic scores for each treatment, with the x-axis representing the different strawberry jam formulations (M1A1, M1A2, M2A1, M2A2, M3A1, and M3A2) and the y-axis representing the panelists' hedonic scores. Sensory data were statistically analyzed using Analysis of Variance (ANOVA) to determine the effect of the treatments on each sensory parameter. When the analysis indicated no significant differences among treatments ($p > 0.05$), Tukey's post-hoc test was applied to support the analysis at a 95% confidence level.

a. Spreadability

The spreadability of strawberry jam showed hedonic scores ranging from 2.5 to 4.4, indicating panelist preferences from "dislike" to "like." The most preferred formulation was M2A1, while the least preferred was M3A2. This result is attributed to the use of the highest concentrations of alginate (3%) and modified tapioca starch (7%) in treatment M3A2, which produced a thick texture that was difficult to spread on the surface of bread. According to Amelia and Astuti (2016), jam with good spreadability is characterized by ease of application and uniform distribution on the bread surface. Therefore, in this study, formulations with thicker textures were less favored by panelists due to their lower spreadability.

b. Taste

The most preferred taste of strawberry jam was observed in treatment M2A1, which received a hedonic score of 4, while the lowest score was recorded for treatment M3A2. However, based on the results of the Analysis of Variance (ANOVA), the taste parameter showed no significant differences among treatments ($p > 0.05$); therefore, no further post-hoc test was performed. The absence of significant differences can be attributed to the use of the same concentration of strawberry flavoring in all formulations, resulting in relatively uniform taste profiles. In addition, taste evaluation may have been influenced by subjective factors related to the panelists, such as smoking habits, sensory adaptation, and fatigue during the evaluation process (Rahayu & Nurosiyah, 2019).

The results of the taste evaluation are in accordance with the Indonesian National Standard No. 01-3746 (2008), which states that jam should have a normal and acceptable taste. The strawberry jam produced in this study was characterized by a sweet taste with a dominant strawberry flavor and slight acidity. The addition of citric acid contributed to increased acidity, enhanced flavor intensity, and supported the formation of a consistent gel structure (Nurani, 2020).

c. Texture

The results showed that the hedonic scores for the texture of strawberry jam ranged from 2.6 to 4.6, indicating panelist preferences from "dislike" to "like." Treatment M2A1 obtained the highest texture score, indicating that the combination of 1.5% alginate and 6% modified tapioca starch produced the most preferred gel structure. In this formulation, the alginate gel network exhibited sufficient elasticity and was supported by modified tapioca starch with optimal water-binding capacity, resulting in a jam texture that was soft, stable, and neither too rigid nor too fluid. This balanced thickening structure produced a texture that did not break easily when spread on the surface of bread. In contrast, higher thickener concentrations tended to form denser and more rigid gel networks, which reduced texture elasticity and spreading comfort. This finding is consistent with the statement of Amelia and Astuti (2016), who reported that excessive increases in viscosity can cause the texture to become stiff and less elastic, thereby reducing jam spreadability.

d. Overall Acceptance

The overall acceptance parameter in this study reflected panelist evaluations of taste, texture, and spreadability to determine the most appropriate and preferred concentrations of alginate and modified tapioca starch. The hedonic test results for overall acceptance showed that treatment M2A1 achieved the highest score of 4.2, indicating that the panelists liked the strawberry jam produced under this formulation. This preference was attributed to the jam's dominant strawberry flavor with slight acidity, soft texture, and consistency that was neither too runny nor too dense, making it easy to spread on bread.

Based on the sensory evaluation results, treatment M2A1 was the most preferred formulation in terms of spreadability, taste, texture, and overall acceptance. However, the determination of the best formulation for strawberry jam production should not rely solely on sensory parameters but should also consider physicochemical properties to ensure overall product quality.

CONCLUSION

Based on the results of this study, variations in alginate concentration and modified tapioca starch concentration significantly affected the quality characteristics of strawberry jam. The M2A1 formulation, containing 1.5% alginate and 6% modified tapioca starch, was identified as the best formulation and was the most preferred by panelists. Strawberry jam produced using this formulation exhibited a viscosity of 13.567 cP, a pH value of 3.61, and a spreadability of 16.45 cm. Sensory evaluation showed hedonic scores of 4.4 for spreadability, 4.0 for taste, 4.6 for texture, and 4.2 for overall acceptance.

These findings indicate that the use of 1.5% alginate combined with 6% modified tapioca starch has strong potential as a substitute for pectin in strawberry jam production. However, further studies focusing on chemical composition analysis and shelf-life evaluation of strawberry jam are recommended to support and strengthen these findings.

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