Physical and sensory characteristic of cheese whey frozen yogurt with the addition of arrowroot starch (*Marantha arundinacea* L.) as stabilizer

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Abstract

In this research, the effect of arrowroot starch addition as stabilizer on physical and sensory characteristics of cheese whey frozen yogurt was determined. The variations of arrowroot starch concentration were 0%, 2%, 4%, and 6% (w/w) total solid. The results showed that the addition of arrowroot starch affected the physical characteristics of cheese whey frozen yogurt, which increases the total dissolved solids, viscosity, and overrun, which were at 23.000 to 26.667 °Brix, from 350.366 to 567.400 cP, and from 11.178 to 51.385%, respectively. Also, the addition of arrowroot starch decreased the melting rate from 25.109 g/min to 19.480 g/min.

Keywords: Arrowroot starch, Cheese whey, Frozen yogurt, Physical, Sensory.

1. Introduction

Whey is a by-product of cheese manufacture, which is in the form of a clear greenish liquid produced from coagulation and separating casein protein from milk. Whey contains 5% lactose, 93% water, 0.85% protein, 0.53% mineral, 0.36% minimum fat, and 6% total solids [1]. The total world production of whey is 145 million tons/year, with 85 million tons being used by the industry for several products, 50 million tons processed into its powdered form by the drying method, 30 million tons converted into its protein concentrate (WPC) and 60 million tons used as animal feed, fertilizer, and waste [2].

Furthermore, the high lactose content in whey is used as a source of carbon and energy, for bacterial growth [3]. However, whey fermented drinks have lower viscosity, compared to its yogurt products. Whey-based yogurt has lower viscosity, decreased water holding capacity (whey off), and the occurrence of separation in yogurt [4]. Also, frozen yogurt is an alternative to the development of fermented milk products. This combines the physical characteristics of ice cream with the sensory and nutritional properties of fermented milk products, which possess longer storage stability than yogurt [5]. The supplementation of prebiotics has also been developed to provide health benefits [6]. Moreover, *L. acidophilus* FNCC 0051 increases the amount of lactic acid, with *L. plantarum* FNCC 0027 also having high viability to multiply colonies, and attach to the digestive tract of humans or animals [7].
Furthermore, cheese whey frozen yogurt has lower total solids, due to the derivative products possessing lower viscosity than the commercial fermentation commodities [8]. To improve the physical quality, a stabilizer in the form of arrowroot starch (*Marantha arundiaceae* L.) was added due to its easy collection, while also containing a total starch content of 98.10%, amylose and amylopectin ratios of 24.64%:73.46%, and prebiotics in the form of oligosaccharides, consisting of raffinose, lactulose, and stachyose [9]. Also, the arrowroot starch possessed the ability to bind bulk water, increase the amount of fluid absorption into the cell, and minimize the formation of ice crystals during freezing. Therefore, in this study, whey cheese was used as medium for bacterial growth, in order to produce lactic acid, with the arrowroot starch (*Marantha arundiaceae* L.) being added as stabilizer, for the improvement of physical properties, while also maintaining the stability of the emulsion during the yogurt storage.

2. Material and methods

2.1. Materials
Mozzarella whey was collected from CV Indrakila Boyolali (Indonesia), with *L. acidophilus* FNCC 0051 and *L. plantarum* FNCC 0027 obtained from the Centre for Food and Nutrition Studies, Gadjah Mada University, Yogyakarta (Indonesia). Also, the arrowroot starch, skimmed milk (IndoPrima®), whipped cream (Haan®), and sucrose (Gulaku®), were obtained from local market of Solo (Indonesia).

2.2. Starter preparation
The starter culture preparation was described with simple modifications [10]. A loopful of *L. acidophilus* FNCC 0051 and *L. plantarum* FNCC 0027 were inoculated into 9 ml of sterilized MRS broth, and incubated at 37°C for 24 hours. The biomass was collected by centrifuging at 3000 rpm for 15 mins at 4°C, accompanied by washing through sterilization in 0.85% NaCl. Also, the biomass was inoculated into 100 ml of pasteurized skimmed milk (5% w/v), and incubated at 37°C for 18 hours. Therefore, 5% (v/v) culture of MRS broth was inoculated into 5% (w/v) 100ml pasteurized skimmed milk, and incubated at 37°C for 18 hours.

2.3. Cheese whey frozen yogurt preparation
Based on [11] with simple modifications, the cheese whey frozen yogurt was prepared. Cheese Whey of 77% ml (v/v) was added with 5% skimmed milk (w/v), 10% sucrose (w/v), 8% whipped cream (w/v), and arrowroot starch concentrations of 0%, 2%, 4%, and 6% (w/v). The formula was mixed for 3 mins, and pasteurized at 85°C for 15 mins, with the mixture being cooled at 42°C. After the 42°C temperature was attained, *L. acidophilus* and *L. plantarum* were inoculated at 3% (v/v) to the pasteurized mixture, and incubated at 37°C for 24 hours. The process was further continued with aging at 4°C for 24 hours, while stirring with an ice cream maker, DeLonghi ICK6000, for 30 mins. After the conclusion of the process, the cheese whey yogurt was frozen at 18°C for 24 hours.

2.4. Physical characteristic analysis
The sample viscosity was determined using the Brookfield Viscometer [12], the melting rate was also determined, by using the Mesh Screen method [13], total dissolved solids by using a Hand Refractometer (ATAGO) [14]. Moreover, the overrun also being determined [15].

2.5. Sensory characteristics
The sample sensory characteristics were evaluated by using the hedonic test with a total of 50 panelists, for the determination of colour, odour, acidity, texture, and overall [16]. Panelists provided an assessment on the level of preference, without comparing other samples, with a scale of:

1 = disliked extremely    4 = neutral    7 = like extremely
2 = disliked very much    5 = liked
3 = disliked              6 = liked very much
3. Result and discussion
The cheese whey frozen yogurt was analyzed for physical properties, such as the total dissolved solids, viscosity, overrun, and melting rate. The results is shown in Table 1.

Table 1. Effect of arrowroot starch (Marantha arundinacea L.) as stabilizer on physical characteristic cheese whey frozen yogurt*

| Arrowroot Starch | Total dissolved solids (°Brix) | Viscosity (cP) | Overrun (%) | Melting rate (g/minute) |
|------------------|-------------------------------|---------------|-------------|------------------------|
| 0%               | 23.110±0.190                 | 350.366±10.707| 11.178±0.690| 25.109±2.134           |
| 2%               | 23.000±1.000                 | 452.500±15.565| 20.013±0.262| 19.480±0.183           |
| 4%               | 24.557±0.509                 | 417.466±10.865| 39.988±0.168| 22.071±0.326           |
| 6%               | 26.667±1.155                 | 567.400±10.897| 51.385±0.203| 23.053±0.570           |

*The value followed by different letters in the same column shows a significant difference at the significance level α = 0.05.

3.1. Physical characteristic of cheese whey frozen yogurt

3.1.1. Total dissolved solids
The results showed that the concentration of arrowroot starch affected the total value of dissolved solids in the cheese whey frozen yogurt. Table 1 showed that the total value of dissolved solids in the cheese whey frozen yogurt had an average between 23.000 to 26.667 °Brix. However, the sample with the addition of 6% arrowroot starch as stabilizer, had the highest total dissolved solid value. With the increment of arrowroot starch addition, the value of total dissolved solids increased, due to bulk water being bound by the stabilizer [13]. Furthermore, increasing the solute reduced the formation of ice crystals, which in turn results in soft and sticky texture. The maximum total dissolved solids of yogurt ice cream were discovered to be 38.41 °Brix [17], as the frozen product with the addition of inulin also possessed a value of 34.77 °Brix [15]. Therefore, according to the stated standards, the results in this study showed that the maximum total dissolved solids were 26.667 °Brix.

3.1.2. Viscosity
Viscosity is the measure of a liquid's thickness [12]. The thickness of the ice cream affects the absorption of water into the cells of the dough [18]. Furthermore, the results showed that the mean viscosity value was 350.366-567.400 cP. The cheese whey frozen yogurt with the addition of 6% starch, had the highest viscosity than the other three samples. The higher the addition of the starch concentration, the greater the viscosity produced, as the arrowroot had processed a maximum of 32.92% [9]. However, heat clicking a result activation of molecular thermodynamics starch resulted in the termination of hydrogen bonds, which improves the mobility of the granular cells, therefore enabling the thickness of the texture. Also, the arrowroot starch consists of two fractions, namely the amylose (water binding capacity and the gelatinization process of starch) and amylopectin (starch swelling and solubility) components [19]. Therefore, increasing the viscosity value was influenced by the overrun and total dissolved solids [20].

3.1.3. Overrun
Overrun is an important factor to determine the texture quality and melting power of ice cream. It is related to the amount of air passing through, during the stirring process. Furthermore, Table 1 showed that the average value of overrun in this study was significantly different, ranging between 11.178-51.385%. The cheese whey frozen yogurt with the addition of 6% starch, had the highest overrun than the other three samples. The higher the addition of the arrowroot starch concentration, the greater the volume of the cheese whey frozen yogurt. However, the increase in volume during the mixing process enables the formation of bubbles. The results of overrun value in the range of 50%, corresponds with a previous study [15]. Also, the addition of arrowroot starch increases the incorporation of air, distributes it in the ice cream cell, minimizes the development of large crystals, and maintains the stability of the bubbles, during agitation in the bubbling process [21].
3.1.4. Melting rate. Melting rate is the product's ability to completely melt with a specified mass, at a certain time. The melting rate was determined by measuring the rate of fluid passing through the filter in units of time [22]. Furthermore, the analysis showed that the concentration of arrowroot starch affected the melting rate of the cheese whey frozen yogurt. Also, Table 1 showed the results of the yogurt melting rate, which was between 19.480 g/min to 25.109 g/min. The cheese whey frozen yogurt without the addition of starch had a melting rate of 25.109 g/min, which was the highest among the samples. Moreover, the addition of starch increased the solids, causing the freezing point to drop, with the water binding capacity getting stronger, while reducing free fluid movement. The higher the amount of bulk water trapped in the cell, the lower the melting rate of the ice cream. This result confirms that the melting rate was related to the viscosity value. Therefore, high viscosity produces symbiotic yogurt ice cream, with a lower melting rate [3].

Furthermore, the increase in the melting rate of ice cream was directly proportional to the increment in the concentration of arrowroot starch. Glycerol (1-4%) supplementation affected the melting rate in probiotic frozen yogurt with 2% inulin, at 0.37, 0.40, 0.44 and 0.49 g/min, respectively, compared to the control of 0.39 g/min [23]. This result was discussed because of glycerol and inulin function as cryoprotectants, which affected glass transition temperature. During freezing, the viscosity of the product increases, causing the bonds of water molecules to become stronger, with drop in temperature affecting the hardness rate and melting speed. Therefore, frozen yogurt with glycerol supplementation prevents the development of ice crystals, causing a decrease and increase in hardness and melting rates, respectively.

3.2. Sensory characteristic
Cheese whey frozen yogurt was analyzed for sensory characteristics, using acceptance test. The results of the test is shown in Table 2.

| Arrowroot Starch | Color   | Flavor  | Texture | Acidity  | Overall  |
|------------------|---------|---------|---------|----------|----------|
| 0%               | 5.22±0.790a | 5.02±0.795a | 5.44±0.837b | 4.74±0.986a | 5.18±0.896a |
| 2%               | 5.46±0.952a | 5.22±0.932a | 5.16±0.997b | 5.32±0.999b | 5.58±0.950b |
| 4%               | 5.44±0.733a | 5.16±0.681a | 4.56±0.993a | 4.94±0.998b | 5.18±0.748a |
| 6%               | 5.54±0.788a | 4.88±0.872a | 5.06±0.998b | 4.68±0.999a | 5.20±0.990a |

*The values followed by different letters in the same column show a significant difference at the significance level α = 0.05
**Like level = 1: disliked extremely, 2: disliked very much, 3: disliked, 4: neutral, 5: liked, 6: liked very much like, 7: like extremely

3.2.1 Colour.
Colour is an important parameter in determining consumer acceptance of a product. The colours of cheese whey frozen yogurt is shown in Figure 1.

![Figure 1. Colors of cheese whey frozen yogurt](image-url)
no significance for colour score. Table 2 further showed the average score of a panelist on the colour parameter, which was between 5.22 to 5.54, i.e., all the formulas tend to be preferred by the assessment personnel. Moreover, the frozen yogurt had a white and clean colour [19], with the resulting data observed to be influenced by the materials used. Therefore, whey is a clear greenish liquid from the manufacture of cheese [1], which when added to skimmed milk improves its colour, to become whiter.

3.2.2 Odour
Odour is an important parameter in determining the level of consumer preference. Generally, consumers do smell products, in order to determine whether they are fit for consumption or not. Furthermore, the analysis showed that the concentration of arrowroot starch had no significance for odour score. Table 2 also showed that the average score of panelists on the parameters of the assessment results in terms of scent, was between 4.88 to 5.22. The odour was produced from the lactose fermentation process by lactic acid bacteria, which produced acetaldehyde, diacetyl, acetic acid, and other compounds. However, acetaldehyde, acetyl, and acetic acid are compounds causing the appearance of a distinctive flavour in yogurt and its derivatives [24].

3.2.3 Texture
Texture is the condition of particles making up the arranged structure (body), which is influenced by the composition of the cheese whey frozen yogurt mixture. Table 2 showed that the texture score was between 4.56-5.44, with the addition of 4% starch concentration achieving the lowest score. This result was analyzed by following the viscosity obtained in this study, which stated that cheese whey frozen yogurt with the addition of 4% starch, has a significantly lower viscosity, compared to that of 2% arrowroot concentration, namely 417.466 cP. Furthermore, the texture formed was related to the viscosity of cheese whey frozen yogurt. The higher the viscosity, the thicker the texture becomes. However, rheological bonds, such as viscosity, affects the hardness of the product [22]. The texture affected by temperature fluctuations, meant that the product seems to easily undergo recrystallization [9]. Also, the addition of arrowroot starch as a stabilizer, serves to maintain product stability and bind water, in order to slow down recrystallization process [15]. Moreover, frozen yogurt as a product, possesses a soft uniform texture like pudding, which is not runny [19]. Also, the texture was influenced by the composition of the materials used, which was assumed to be due to the protein content in skimmed milk. Therefore, the protein contained in skimmed milk functions to form a compact soft texture, while also preventing the formation of a coarseness [25].

3.2.4 Acidity
Acidity as a sour taste, results from the fermentation process of bacteria in lactose metabolism, with the hydrolysis of starch to lactic acid and other compounds [3]. The results of the analysis stated that the values were significantly different. Also, Table 2 showed that the average preference score on the acidity was between 4.68-5.32, with high LAB activity increasing lactic acid production and decreasing pH. In this study, lactic acid levels of cheese whey frozen yogurt and pH values were also produced at 0.776% and 3.971% (data not shown), respectively. Furthermore, the acidity of frozen yogurt was produced, due to the increased activity of LAB in the fermentation of lactose into simple components, while increasing the production of organic acids [26]. Also the taste was influenced by the additional ingredients used, such as sweeteners, whipped cream, skimmed milk, and stabilizers. However, the sweetness of cheese whey frozen yogurt resulted from the addition of sugar. Also, frozen yogurt has a sweet taste, due to the addition of 10% glucose [27].

3.2.5 Overall
Overall is an assessment of the total quality parameters of the product, considering colour, odour, acidity, and texture. The analysis showed that the arrowroot starch concentrations of 0%, 4%, and 6%, affected the overall preference level of cheese whey frozen yogurt. Based on the result of Table 2, the mean score on the parameters of overall was 5.18 to 5.58. Furthermore, the treatment with starch concentration of 2% showed a significantly higher assessment, compared the other three samples. The cheese whey frozen yogurt that panelists prefer was white in colour, sour-flavoured, with a non-coarse texture. Therefore, it was observed that the overall cheese whey frozen yogurt with the addition of 2%
starch concentration, produced the highest score.

4. Conclusion
The results in this study showed that the addition of arrowroot starch as stabilizer, affected the physical characteristics of cheese whey frozen yogurt. The addition of 6% arrowroot starch, had a significantly higher effect on total dissolved solids, viscosity, and overrun. Also, it was observed to affect the melting rate of cheese whey frozen yogurt as well. Moreover, the addition of 2% arrowroot starch was the best formula accepted by consumers. Also, the addition of arrowroot starch as stabilizer, does not affect the panelists' preference for colour and odour.

5. References

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