The effect of Taro (Colocasia esculenta L.) and Lesser Yam flour (Dioscorea esculenta L.) as thickener agent on physical characteristics of frozen wheygurt

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Abstract. The results showed that the addition ratio of taro and lesser yam flour affected to the physical characteristics of frozen wheygurt. The addition of lesser yam flour increased total soluble solids until the addition ratio of 2:2 due to the higher ash content of lesser yam (2.87%) than taro (0.44%). Sample with addition ratio of 1:3 and 0:4 significantly different compared to other samples, due to the starch content difference between taro (70-80%) and lesser yam (51.34%). Addition ratio of taro and lesser yam flour do not have a significant effect on the viscosity of the frozen wheygurt, due to both starch have similar setback viscosity. Lesser yam setback viscosity was 684.8 cP, while taro was 838.3 cP. Setback viscosity showed a high tendency of retrogradation. The addition ratio of taro and lesser yam flour have a significant effect to the overrun of frozen wheygurt. Addition ratio of taro and lesser yam flour have a significant effect to melting rate of frozen wheygurt. This result was caused by higher peak viscosity of taro starch compared to lesser yam, thus produced thicker gel than lesser yam. This lead increased water contents in the mixtures entrapped and slows down water mobility, hence melting rate would decrease.

1. Introduction

Cheese whey is a by-product of the cheese-making process in the form of green-yellowish liquid. The cheese-making industry generated 9 kilos of cheese whey to make a kilogram of cheese1. Cheese whey contains 0.006-0.0070% fat, 0.3% -0.9% protein, 3.04-5.00% lactose, 0.5-0.62% ash2. Cheese whey can be utilized as various fermented products because of its compounds can be used by bacteria as growth medium source3.

Frozen yogurt is now a rising trend among other fermented drink products. Frozen yogurt is a dessert which combines ice cream texture with nutritive and health properties of yogurt4. The textural quality of frozen yogurt determined by dairy fat and total solids of the used milk. However, cheese whey contains low total solids which make its derived product has low viscosity compared to commercially fermented products3.

The viscosity of whey based product can be improved by thickener addition. Hydrocolloid often used as thickener. One of the most common hydrocolloid types used is starch. Arrowroots starches are suitable for acidic and frozen product like frozen yoghurt5. Taro (Colocasia esculenta L.) and lesser yam (Dioscorea esculenta L) have potential to be used as thickener because of their high starch content (approximately 51.34-70.92%), and the same amylpectin and amylose fraction ratio (taro
21.44:78.56 and lesser yam 24.30:75.7). However, these two materials have different gelatinization profile. Taro starch has high peak gelatinization viscosity\(^6\) thus makes ice cream made from taro starch melts slowly\(^7\). Lesser yam starch has low peak gelatinization viscosity\(^8\) thus makes ice cream can melt in an ideal time range\(^9\). In this study, taro and lesser yam flour are combined to find the best physical characteristics of frozen wheygurt. Furthermore, these two tubers have prebiotic contents which can be utilized as lactic acid bacteria (LAB) growth medium in human digestion system and metabolites formation, such as oligosaccharides in taro\(^10\) and inulin in lesser yam\(^11\).

The aim of this study was to determine the effect of taro and lesser yam flour on frozen wheygurt physical characteristics which includes viscosity, overrun, melting rate and total solids.

2. Materials and Methods

2.1. Materials
Mozzarella cheese whey obtained from cheese industry in Boyolali (Indonesia). Lactic acid bacteria used in this study were *Lactobacillus acidophilus* FNCC 0051 and *Lactobacillus plantarum* FNCC 0027 from Food and Nutrition Culture Collection Yogyakarta (Indonesia). Taro flour bought from Naya Tepung Bogor (Indonesia) and lesser yam flour bought from Kusuka Ubiku Bantul (Indonesia). Other materials used in frozen wheygurt preparations were egg yolk, sucrose (Gulaku®), whipping cream (Anchor®, 33.33% fat).

2.2. Starter Preparation
Both *L. acidophilus* FNCC 0051 and *L. plantarum* FNCC 0027 were inoculated in separate sterile deMan Rogosa Sharpe (MRS) broth medium and incubated at 37°C for 24 hours. 2% (v/v) of each culture of MRS broth were inoculated to 100 ml pasteurized skim milk and incubated at 37°C for 24 hours. The cultured skim milk contains \(10^8\) cells/ml of bacterial cells.

2.3. Frozen wheygurt preparation
Frozen wheygurt was prepared by mixing the materials (cheese whey, 12% (w/v) sucrose, 13% (w/v) whipping cream, 2% (w/v) egg yolk and 2.5% (w/v) thickener) for 10 minutes. The mixtures were pasteurized at 75°C for 30 min and cooled until 45°C. 2% (v/v) of each *L. acidophilus* and *L. plantarum* culture starters were inoculated into pasteurized mixtures and incubated at 37°C for 18 hours. Frozen wheygurt then refrigerated for 5 hours, frozen for 30 minutes at -18°C for 30 minutes, mixed using mixer for 20 minutes and frozen for 24 hours.

2.4. Physical characteristics analysis
The samples total soluble solid was determined using gravimetric method (AOAC 941.08). The viscosity was determined using Brookfield Viscometer\(^12\). Overrun was evaluated using following equation:

\[
\text{Overrun} (\%) = \frac{A - E}{B} \times 100 \quad (\text{Rezaei et al., 2012}).
\]

Note: A: Weight of unit mix, B: weight of equal volume (ml) of frozen yogurt

To evaluate melting rate, 2 grams of frozen yogurt was placed in a sealed cup and frozen for two days. Samples then were taken out from the freezer and put in room temperature. The time required for the frozen wheygurt to melt was measured using a stopwatch\(^14\).

3. Results and Discussion

3.1. Total soluble solid
The adequacy of total soluble solids in ice cream dough serves to increase the thickness of ice cream dough and to maintain the air bubbles stability\(^15\). The increasing amount of dissolved solids shows that the amount of water in the dough decreases and reduces the amount of ice crystallization\(^15\). Moreover,
total soluble solids also affect the ice cream texture. If total soluble solids contents were high, the ice cream texture will be flaccid, otherwise if total soluble solids contents were low resulted in ice crystal formation and coarse texture.\(^7\)

The result (Table 1) showed that the addition ratio of taro and lesser yam flours have a significant effect on the total soluble solids of wheygurt. The addition of lesser yam flour increased the total soluble solids until addition ratio of 2:2. This is caused by the higher ash content of lesser yam (2.87%) than taro (0.44%)\(^8\). Sample with addition ratio 1:3 and 0:4 significantly different compared to other samples, due to the starch content difference between taro (70-80%) and lesser yam (51.34%). Total soluble solid is influenced by the composition of the mixtures. Total soluble solid in ice cream is composition materials in solid form\(^16\). This study used taro and lesser yam flour which have starch contents. Starch composes mix solid content, furthermore, the amylopectin molecule on the starch is very tight causing produced frozen yogurt has high total soluble solid\(^19\). Total soluble solid of all samples was under required standard (34%)\(^19\) due to water and solid content ratio which is not balanced and syneresis occurred by the gel matrix of taro and lesser yam flour. The produced frozen wheygurt has higher water content and lower solid content.

### Table 1. Effect of taro and lesser yam flour as thickener agent on physical characteristics of frozen wheygurt*

| Formulation | Total Soluble Solids (%) | Viscosity (cP) | Overrun (%) | Melting Rate (min) |
|-------------|--------------------------|----------------|-------------|-------------------|
| Taro: Lesser Yam |                           |                |             |                   |
| 4:0         | 18.618\(^ab\) ± 1,061    | 9,22\(^a\) ± 2,220 | 2,770\(^a\) ± 0,0270 | 7,715\(^c\) ± 0,370 |
| 3:1         | 18.986\(^bc\) ± 0,737    | 10,07\(^b\) ± 1,746 | 2,477\(^b\) ± 0,215 | 7,946\(^c\) ± 0,135 |
| 2:2         | 19,378\(^c\) ± 0,532     | 9,51\(^c\) ± 1,114 | 2,562\(^c\) ± 0,103 | 7,656\(^c\) ± 0,382 |
| 1:3         | 17,920\(^d\) ± 0,839     | 9,06\(^d\) ± 0,540 | 1,951\(^d\) ± 0,190 | 6,388\(^d\) ± 0,118 |
| 0:4         | 17,709\(^d\) + 1,421     | 9,76\(^d\) ± 0,890 | 1,899\(^d\) ± 0,187 | 6,645\(^d\) ± 0,299 |

*Results in the same column with the same superscript were not significantly different (\(\alpha=5\%\))

#### 3.2. Viscosity

Frozen yogurt is an oil-in-water emulsion food system. Emulsions formed in frozen yogurt are unstable thermodynamically. Hydrocolloids usually act as emulsion stabilizers. As a material that can serve to maintain longer emulsion stability through adsorption mechanism. The way it works traditionally as a stabilizer by improving the structure, compacting, gelation of the aqueous continuous phase\(^20\).

Taro and lesser yam flours used in this study because of their starch contents, a hydrocolloid usually used as thickener. These flours can increase the viscosity because these flours contain high amylopectin fraction about 56-60%. Starch consists of two fractions which are amylose and amylopectin. Amylose is a water-soluble fraction, whereas amylopectin is a water-insoluble fraction. Starch can not dissolve in cold water and form an impenetrable suspension of light with a strong movement to settle. If the starch solution is further heated up to the point of gelling of the starch wherein the starch granules expand. The expanding starch granules will absorb water up to the maximum size of starch granules. Under these conditions the maximum viscosity increase has been achieved\(^21\). This resulted in the water content in the dough to be bound, thus increasing the viscosity of frozen wheygurt dough. Taro flour has a high peak viscosity, amounted to 2865.3 cP\(^6\). Viscosity peak indicates maximum viscosity that can be achieved by starch during gelatinization. The higher the viscosity peak, the more viscous and dense gel produced\(^6\).

The results showed that addition of taro and lesser yam flour do not have a significant effect on the viscosity of the frozen wheygurt (Table 1), due to both starch have similar setback viscosity. Lesser yam setback viscosity is 684.8 cP\(^22\), while taro is 838.3 cP. Setback viscosity showed a high tendency
of retrogradation. Starch retrogradation caused by the re-establishment of hydrogen bonds between the molecules of amylose and amyllopectin.

3.3. Overrun
Overrun shows the amount of air entrapped in the ice cream mixture. Overrun shows the ability of foaming and foam stability associated with a decrease in surface tension caused by protein molecules absorption.

The results showed that addition ratio of taro and lesser yam flour have a significant effect to the overrun of frozen wheygurt (Table 1). At the peak of gelatinization, taro has a viscosity of 2865.3 cP while lesser yam has a viscosity of 1030.4 cP thus the gel produced by taro was thicker and caused more air entrapped in frozen wheygurt dough and the overrun was higher. Overrun is influenced by mixtures viscosity, total soluble solids, thickeners as well as whipping process. High mixtures viscosity resulted in high overrun value. This is in accordance with Stokes’ Law where the higher the fluid viscosity, the slower particles velocity, consequently hinders air bubbles to coagulate. Hence, air bubbles remain dispersed and small-sized thereby increasing ice cream overrun.

In this study, whipping process was done using a hand-held mixer to replace ice cream maker, so there is a possibility of inconsistencies in the whipping process. Conventional method does not allow simultaneous stirring and cooling. The process is repeated and temperature change is occurred, so it is very influential to the overrun of ice cream.

3.4. Melting rate
Melting rate is the time required for ice cream to melt completely like the initial ice cream dough at room temperature. Good ice cream is ice cream that is resistant to melting at room temperature and within a certain time.

The results showed that addition of taro and lesser yam flour had a significant effect to melting rate of frozen wheygurt (Table 1). This result was caused by the higher peak viscosity of taro starch than lesser yam, thus makes taro produced thicker gel than lesser yam. This leads to more water contents in the mixtures being entrapped and slows down water mobility, therefore melting rate will decrease.

Melting rate depends on materials used in ice cream dough. Total soluble solids proportion in ice cream affected the ice cream melting rate. The increasing of total soluble solids can lower ice cream dough freezing point, hence more water contents being entrapped and decrease water mobility. The increasing of entrapped water in the mixtures will slow down ice cream melting rate. Dough viscosity and overrun also affected the ice cream melting rate. Ice cream with high viscosity has higher melting resistance. The high overrun rate will have slow melting rate due to lack of heat propagation rate caused by the large volume of air in ice cream. In general, ice cream with low overrun melts faster than ice cream with high overrun.

4. Conclusions
Addition ratio of taro and lesser yam flour affected the physical characteristics of frozen wheygurt. Sample with higher taro addition has better physical characteristic compared to sample with higher lesser yam addition. The addition of lesser yam flour increased total soluble solids until the addition ratio of 2:2. Sample with addition ratio of 1:3 and 0:4 significantly different compared to other samples, Addition ratio of taro and lesser yam flour do not have a significant effect to the viscosity of the frozen wheygurt, Addition ratio of taro and lesser yam flour have a significant effect on overrun and melting rate of frozen wheygurt.

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