Effect of Sweet Fermented Black Glutinous Rice on the Sensory Evaluation, Physical, Chemical and Microbiological Qualities of Goat Milk Ice Cream

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Abstract In order to develop the goat milk ice cream for having an admired taste and health benefits, the objective of this research was to supplement the sweet fermented black glutinous rice (SFBGR) into goat milk ice cream with three different levels (10%, 20%, and 30%). The ice cream samples were analyzed for sensory, physical, chemical and microbiological properties. The results showed that the ice cream with 30% SFBGR was the most acceptance sample by panelists. The addition of 30% SFBGR resulted in an increasing of total soluble solid, viscosity, overrun and purple color, whereas the melting rate was decreased, compared to the controlled goat-milk ice cream. Moreover, the addition of 30% SFBGR into goat milk ice cream decreased energy, fat and cholesterol which were harmful for human health. In contrast, total dietary fiber, vitamins, minerals, flavonoid and anthocyanin contents were increased. The analysis of food hygiene showed that total bacteria found in ice cream samples were passed the standard from the Ministry of public health, Thailand. Moreover, there was no E. coli, S. aureus and Salmonella spp. found in ice cream samples. Therefore, it concluded that the goat milk ice cream supplemented with 30% SFBGR could be developed further on an industrial scale to add value of agricultural products, especially pigmented rice and goat milk.

Keywords: goat milk, ice cream, sweet fermented black glutinous rice


1. Introduction

Ice cream has been widely consumed as a dairy dessert due to its providing cooling and refreshing sensation [1]. Normally, ice cream is made from fat, milk solids non-fat, sweetener, stabilizer, emulsifier, water, and flavor [2]. In the ice cream processing, those ingredients are mixed, which is then pasteurized and homogenized to form a smooth texture and air dispersion. After that, ice cream is aged and then frozen [3]. The ice cream can be stood out by appealing and creating the flavors and tastes [4]. In addition, the adding of fruit into an ice cream provides nutrients for health benefits such as vitamins, minerals, and other functional compounds [5]. Therefore, the use of antioxidant compounds such as anthocyanins or flavonoids can improve an ice cream to have a function for health benefits [6].

The ice cream is not only made using cow milk but also goat milk [7]. In general, goat milk has less lactose content [8] smaller fat globules, higher β-casein and κ-casein content, compared with cow milk [9]. This is useful for human digestion due to their easy metabolized in human digestive system. Moreover, goat milk contains lower α-S1 casein which resulting in less casein allergic in some consumers. Goat milk also has anti-inflammatory compounds which provide heart benefits and health immunity [9]. In addition, López-Aliaga et al. (2003) and Barrionuevo et al. (2002) [10,11] showed that goat milk has better nutrient metabolism efficiency (protein, manganese, iron, and copper) than those in cow milk.

There are many ingredients for ice cream processing, however, this research interested in a characteristic one which was a sweet fermented glutinous rice (Khao-mak). It is a traditional Thai dessert which has more sweet, less sour and low alcohol content [12]. The Khoa-mak fermentation was briefly shown. Firstly, glutinous rice was washed to remove dusts, and then soaked until soft. Secondly, soaked glutinous rice was steamed until cooked, and then cooled down prior to the fermentation. Finally, cooked glutinous rice was inoculated with traditional culture (Loog-pang) to ferment at ambient temperature under an anaerobic system for 1-3 days. In Loog-pang,
many fungi which were *amylomyces* and *rhizopus* were found. They produced an amylolytic enzyme which converts rice flour to fermented sugars and unique flavor [13]. Moreover, yeast that found in that starter culture can convert fermented sugars to alcohol and lactic acid [12]. Normally, Khoa-mak can be made from both white and black glutinous rice. However, black rice had higher anthocyanins - a pigment responsible for red and blue color, compared with those in white rice [14,15,16]. The consuming of foods contained anthocyanins, resulted in health benefits, for example, anti-microbial activity, visual improving, neurological supporting and non-communicable diseases preventing [17].

Therefore, this research aimed (i) to develop a goat milk ice cream supplement with sweet fermented black glutinous rice, (ii) to evaluate the sensory characteristics for consumer acceptance and (iii) to investigate the physical, chemical and microbiological qualities. This research also expected that ice cream can be an alternative dessert which promotes consumer’s health and can be produced as a commercial production for adding the value to local agricultural products.

### 2. Materials and Methods

#### 2.1. Materials

The goat milk was collected from local farms in Sichon, Nakhon Si Thammarat, Thailand. This was pasteurized at 85°C for 5 sec using a water bath [18]. The sweet fermented black glutinous rice (SFBGR) was purchased from Sud-Sri brand, Sichon, Nakhon Si Thammarat, Thailand. Other ingredients, including whipping cream from Magnolia gourmet; sugar from Mitr-phol; skimmed milk, stabilizer, dextrose, emulsifier from Miss ice cream; drinking water from Nestlé, and liquid vanilla flavor from Winner were purchased from local markets.

#### 2.2. Chemical Composition of Goat Milk and SFBGR

##### 2.2.1. Proximate Analysis of Goat Milk and SFBGR

The analysis of pH, total soluble solids, crude protein, carbohydrate, crude fat, crude fiber and ash were done using modified methods from AOAC (2016) [19]. For the calculation of energy from goat milk and SFBGR was done using equation 1.

\[
\text{Energy (Kcal)} = (4 \times \text{Carbohydrate (g)}) + (4 \times \text{Protein (g)}) + (9 \times \text{Fat (g)}) \tag{1}
\]

##### 2.2.2. Total Flavonoids, Phenolic and Anthocyanins Content of SFBGR

Total flavonoids in SFBGR were determined using aluminum chloride colorimetric assay. Quercetin was used as a standard (R2= 0.999). This was adapted from Chang et al. (2002) [20]. For total phenolic compounds, their analyses were done using Folin-Ciocalteau colorimetric method. To quantified these compounds, gallic acid was used as a standard (R2= 0.995).

#### 2.3. Goat Milk Ice Cream with SFBGR

##### Preparation

In order to study the effect of SFBGR on the qualities of goat milk ice cream, the standard ice cream recipe [22] was modified by mixing with SFBGR at 0, 10, 20 and 30% (Table 1). Briefly, goat milk was added with all ingredients, and then pasteurized at 85°C for 5 sec. After that, the mixture was mixed with SFBGR, and then pasteurized at the same condition prior flavor adding. The ice cream mixture was cooled down to 37±2°C prior to the homogenization for 3 min. After that, the homogenized ice cream mixture was aged at 4±1°C for 12 h. A portion of ice cream mixture was measured for viscosity. Finally, the ice cream mixture was frozen using an ice cream maker (Cuisinart, ICE-100BC, United States) for 40 min, kept ice cream in plastic container prior stored in at -24°C for 24 hours, then analyzed for % overrun and melting rate of ice cream.

| Table 1. The recipe of goat milk ice cream with SFBGR |
|-----------------|-----------------|-----------------|-----------------|
| Ingredients     | 0% SFBGR (%)    | 10% SFBGR (%)   | 20% SFBGR (%)   |
| Goat milk       | 350 (35)        | 250 (25)        | 200 (20)        |
| Whipping cream  | 200 (20)        | 200 (20)        | 200 (20)        |
| Skimmed milk    | 60 (6)          | 60 (6)          | 60 (6)          |
| Sugar           | 40 (4)          | 40 (4)          | 40 (4)          |
| Dextrose        | 30 (3)          | 30 (3)          | 30 (3)          |
| Stabilizer      | 12 (1.2)        | 12 (1.2)        | 12 (1.2)        |
| Emulsifier      | 5 (0.5)         | 5 (0.5)         | 5 (0.5)         |
| Water           | 300 (30)        | 250 (25)        | 200 (20)        |
| Vanilla flavor  | 3 (0.3)         | 3 (0.3)         | 3 (0.3)         |
| SFBGR           | 0 (0)           | 100 (10)        | 200 (20)        |

2.4. Sensory Evaluation of Goat Milk Ice Cream with SFBGR

The quantitative sensory assessment was done using 9-point hedonic scales. This took place in separate sensory booths in daylight, and a room temperature set at 25°C. The 3 g of ice cream with various SFBGR contents (0, 10, 20 and 30%) were labelled with a random number prior presented to the 60 untrained assessors. In this study, ice cream samples were stored at -24°C immediately after manufacturing. After that, the temperature of ice cream samples was controlled to -10°C before presenting to assessors. Ice cream samples were shown to assessors in balanced and randomized succession and assessors were requested to consume the samples and evaluate them on appearance, color, flavor, taste, texture and overall. The intensity of each attribute was recorded on 1-extremely dislike to 9-extremely like scores [23]. This research was...
investigated and approved by the institutional ethics board, Walailak University (WUEC-21-003-01).

2.5. Physical Properties of Goat Milk Ice Cream with SFBGR

According to the sensory evaluation of ice cream samples, the ice cream which was the most acceptances from assessors was analyzed for physical properties as following.

2.5.1. Viscosity of Ice Cream Soluble

The ice cream mix samples which aged at 4°C for 12 hours were evaluated for viscosity using viscometer (Brookfield Engineering Laboratories Inc., United States). The samples were analyzed at 5±1°C with UL/Y adapter. The speed test was controlled at 250 rpm. The results were reported in Pa.s unit.

2.5.2. Overrun

The overrun of ice cream samples was calculated using the method from Akin et al. (2007) [24]. Briefly, the ice cream soluble was transferred into the exacted volume container, and then weighted. The ice cream was frozen using ice cream maker. After that, it was transferred into the same container with exacted volume, and then weighted. The record data was calculated for the overrun (%) using equation 2.

\[
\text{Overrun} = \frac{\text{Ice cream soluble} - \text{Frozen ice cream} \times 100}{\text{Frozen ice cream}}
\]

2.5.3. Melting Rate

The melting rate of ice cream sample was determined using the modified method from Atalar et al. (2021) [25]. Briefly, 50 g of ice cream was scooped and frozen at -18°C. After that, it was weighted prior placed on the wire grid (no. 8). The ice cream was left for the melting at 25±2°C. The melted ice cream was weighted every 10 min for 1 h. The recorded data was calculated for melting rate using equation 3.

\[
\text{Meltdown rate} = \frac{\text{Melted ice cream weight} \times 100}{\text{Initial ice cream weight}}
\]

2.5.4. Color Parameter

The ice cream samples were measured for color parameter under CIE system using colorimeter (Konica Minolta CR400, Germany). The calibration with a white plate was done prior analysis. For measurement, the ice cream samples were placed on an opaque plate, and then D65 light was originated from measuring port to samples for color analysis. The colour result was expressed as L* (lightness), a* (greenness-redness), and b* (Blueness-yellowness).

2.6. Chemical Composition of goat Milk Ice Cream with SFBGR

According to the sensory evaluation of ice cream samples, the ice cream which was the most acceptances from assessors was analyzed for chemical composition as following. The analysis of pH, moisture, crude protein, carbohydrate, crude fat, saturated fat, cholesterol, dietary fiber, insoluble fiber, soluble fiber, ash, vitamin A, vitamin B1 and anthocyanin content were done using modified methods from AOAC (2016) [19]. For vitamin B2, this was analyzed using modified method from Wehling and Wetzel (1984) [26]. The analysis of vitamin B9 was done using method from Chen et al. (2006) [27]. Calcium, magnesium, phosphorus, iron, total sugar, fructose, glucose, sucrose, maltose, and lactose content in ice cream sample were analyzed using modified method from AOAC (2019) [28]. Furthermore, total flavonoids were determined using aluminum chloride colorimetry [29], whereas quercetin was used as a standard (R2= 0.999). For phenolic compounds analysis, Folin-Ciocalteu colorimetric method was used Singleton et al. (1999) [30]. This quantification was done using gallic acid as a standard (R2= 0.950).

2.7. Microbiological Analysis of Goat Milk Ice Cream with SFBGR

To monitor the hygiene of ice cream samples, the ice cream which was the most acceptances from assessors was analyzed for microbiological quality.

2.7.1. Total Plate Count

1 ml of an ice cream dilution (10^-1 - 10^-4) in phosphate buffer (PBS) solution was transferred to petri dish prior pouring 12-25 ml of melted plate count agar for pour plate technique. The solution was gently mixed, and then incubated at 35°C for 48 hours. After that, the colony of microorganism was found if the sample was contaminated [31].

2.7.2. *Escherichia coli*

The dilution of ice cream was prepared in the range of 10^-1 - 10^-3 using phosphate buffer (PBS) solution. After that, 1 ml of each dilution was transferred into Lauryl tryptose (LST) broth with gas detected tube, and then incubated at 35°C for 24 hours. If *E. coli* grown, gas was observed. After that, 1 loop of broth from observed LST tube was streaked on Eosin methylene blue (EMB) agar, and then incubated at 37°C for 24 hours. If *E. coli* was grown, a metallic sheen colony was found [32].

2.7.3. *Staphylococcus aureus*

The ice cream samples were diluted using phosphate buffer (PBS) solution in the range of 10^-1 - 10^-7. There were inoculated on trypticase soy agar (TSA) using spread plate technique, and then incubated at 35°C for 45-48 hours. After that, the clear gold colony was found if *S. aureus* grown [33].

2.7.4. *Salmonella*

The ice cream samples were pre-enrichment in buffered peptone water (BPW) broth with 10-fold dilution. This was incubated at 35°C for 24 hours. After that, 0.1 ml and 10 ml of the enrichment was added into Rappaport Vassiliadis soya (RVS) broth, and then incubated at 35°C for 24 hours. For selective plating, the inoculated was streaked on xylose lysine deoxycholate (XLD) agar and Hekonten enteric (HE) agar, and then incubated at 41.5 ℃.
for 24 hours. If Salmonella grown, the clear pink with black centered spot colony was found in XLD agar, whereas blue-green with black centered spot colony was found in HE agar [34].

2.8. Statistical Analysis

IBM SPSS Statistics for Windows, Version 21.0 software (IBM Corp., Armonk, NY, USA) was used for the statistical experimental analysis. The difference between the mean values was investigated at a 95% confidence (p < 0.05) confidence level, using the analysis of variance (ANOVA) with the post hoc Duncan test.

3. Results

3.1. Analysis of Chemical Composition in Goat Milk and SFBGR

3.1.1. Chemical Compositions of Pasteurized Goat Milk

The goat milk which used for ice cream preparation was analyzed for chemical compositions. The results showed that the pH of goat milk was close to neutral. Moreover, protein, fat, lactose, ash, total solid and solid not fat content were found as 3.32, 3.63, 4.24, 0.72, 11.86 and 7.75 g/100 g, respectively. The energy calculated from lactose, protein and lipid was 62.91 Kcal/100 g (Table 2).

<table>
<thead>
<tr>
<th>Composition</th>
<th>Pasteurized goat milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.52 ± 0.00</td>
</tr>
<tr>
<td>Protein (g/100 g)</td>
<td>3.32 ± 0.05</td>
</tr>
<tr>
<td>Fat (g/100 g)</td>
<td>3.63 ± 0.06</td>
</tr>
<tr>
<td>Lactose (g/100 g)</td>
<td>4.24 ± 0.02</td>
</tr>
<tr>
<td>Ash (g/100 g)</td>
<td>0.72 ± 0.03</td>
</tr>
<tr>
<td>Total solids (g/100 g)</td>
<td>11.86 ± 0.07</td>
</tr>
<tr>
<td>Solid nonfat (g/100 g)</td>
<td>7.75 ± 0.03</td>
</tr>
<tr>
<td>Energy (Kcal/100 g)</td>
<td>62.91</td>
</tr>
</tbody>
</table>

Data were expressed as mean ± standard deviation.

3.1.2. Chemical Compositions of SFBGR

The SFBGR which used for ice cream preparation was analyzed for chemical compositions. The results found that the pH in SFBGR was a mild acid. Moreover, moisture, protein, fat, carbohydrate, fiber and ash in SFBGR were showed as 57.10, 2.04, 1.12, 39.34, 0.30 and 11.86 g/100 g, respectively. Total soluble solid of that sample was found as 38 °Brix. The total flavonoid, total phenolic compound and anthocyanin content in SFBGR were found as 211 mg of GA/g, 106 mg of QE/g and 83.2 mg/g, respectively. Total soluble solid of that sample was found as 0.10 g/100 g, respectively. Total flavonoid (mg of GAE/g) 211 ± 0.20, Total phenolic (mg of QE/g) 106 ± 0.20, Anthocyanin (mg/g) 83.2 ± 0.20 and Energy (Kcal) 175.60 (Table 3). Low pH of SFBGR limited microbial growth of product made by fermented black glutinous rice from Nurerk and Junden (2022) [35].

![Figure 1](image_url)

3.2. Sensory Evaluation of Goat Milk Ice Cream with SFBGR

The sensory evaluation of goat milk ice cream samples which prepared with different levels of SFBGR was showed in Table 4. Their sensory score was done using 9-point hedonic scale. The results indicated that the goat milk ice cream with 30% SFBGR was the most accepted sample with the highest score in all attributes. This was also significantly different from others (p<0.05). Moreover, an increasing of SFBGR in goat milk ice cream recipe resulted in an increasing of appearance, color and texture score from sensory evaluation.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>0% SFBGR</th>
<th>10% SFBGR</th>
<th>20% SFBGR</th>
<th>30% SFBGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>7.05±1.43</td>
<td>7.13±0.79</td>
<td>7.75±0.97</td>
<td>8.23±0.87</td>
</tr>
<tr>
<td>Color</td>
<td>6.90±1.40</td>
<td>7.00±1.16</td>
<td>7.30±1.23</td>
<td>7.78±1.15</td>
</tr>
<tr>
<td>Flavor</td>
<td>7.07±1.40</td>
<td>7.45±1.03</td>
<td>7.23±1.20</td>
<td>7.57±1.45</td>
</tr>
<tr>
<td>Taste</td>
<td>7.30±1.43</td>
<td>7.72±0.90</td>
<td>7.43±1.17</td>
<td>8.08±1.14</td>
</tr>
<tr>
<td>Texture</td>
<td>7.45±1.32</td>
<td>7.67±0.88</td>
<td>7.75±1.08</td>
<td>7.82±0.89</td>
</tr>
<tr>
<td>Overall</td>
<td>7.32±1.67</td>
<td>7.72±0.83</td>
<td>7.42±1.25</td>
<td>8.25±0.88</td>
</tr>
</tbody>
</table>

Data were expressed as mean ± standard deviation. Means with the same letter are not significantly different (p>0.05).

3.3. Analysis of Physical Properties in Goat Milk Ice Cream with SFBGR

According to the sensory evaluation of goat milk ice cream samples, the one with 30% SFBGR was the most acceptances from assessors was analyzed for physical properties. This was compared with the goat milk ice cream with 0% SFBGR, which was the control sample (Table 5). The results showed that an adding of SFBGR in goat milk ice cream resulted in an increasing of viscosity, overrun, total soluble solid and red color. However, melting down, lightness and yellow color were decreased (Figure 1).
Table 5. Physical properties of goat milk ice cream with 0% and 30% SFBGR

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Goat milk ice cream with SFBGR</th>
<th>0% SFBGR</th>
<th>30% SFBGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity (Pa.s)</td>
<td></td>
<td>120.00 ± 0.11 b</td>
<td>190.0 ± 0.09 b</td>
</tr>
<tr>
<td>% Overrun (g/100 g)</td>
<td></td>
<td>55.72 ± 1.38 b</td>
<td>70.12 ± 1.96 b</td>
</tr>
<tr>
<td>% Melting down (g/min)</td>
<td></td>
<td>0.93 ± 0.06 b</td>
<td>0.48 ± 0.22 b</td>
</tr>
<tr>
<td>Total soluble solid (°Brix)</td>
<td></td>
<td>14 ± 0.09 b</td>
<td>20 ± 0.12 b</td>
</tr>
<tr>
<td>Lightness (L*)</td>
<td></td>
<td>89.02 ± 0.50 a</td>
<td>75.30 ± 0.42 a</td>
</tr>
<tr>
<td>Green-red (a*)</td>
<td></td>
<td>3.25 ± 0.13 b</td>
<td>5.12 ± 0.13 b</td>
</tr>
<tr>
<td>Blue-yellow (b*)</td>
<td></td>
<td>45.12 ± 0.29 b</td>
<td>20.15 ± 0.10 b</td>
</tr>
</tbody>
</table>

Data were expressed as mean ± standard deviation. Means with the same letter are not significantly different (p>0.05).

Figure 1. The appearance of goat milk ice cream with 0% and 30% SFBGR

3.4. Analysis of Chemical Compositions in Goat Milk Ice Cream with SFBGR

According to the sensory evaluation of goat milk ice cream samples, the one with 30% SFBGR was the most acceptances from assessors was analyzed for chemical composition. This was importance for the quality of the ice cream. The results showed that an adding of SFBGR in goat milk ice cream resulted in an increasing of protein, total carbohydrate, sucrose, insoluble and soluble dietary fiber, ash, magnesium, phosphorous, iron, vitamin A, vitamin B1, vitamin B2, vitamin B9, total flavonoids, total phenolic acids and anthocyanins content. However, pH, moisture, saturated fat, cholesterol, lactose, sodium, calcium and energy were decreased (Table 6). Moreover, most chemical composition in goat mil ice cream with 0% SFBGR was significantly different from one with 30% SFBGR (p<0.05).

Table 6. Chemical composition of goat milk ice cream with 0% and 30% SFBGR

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Goat milk ice cream with SFBGR</th>
<th>0% SFBGR</th>
<th>30% SFBGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>6.31 ± 0.00 a</td>
<td>5.58 ± 0.06 b</td>
</tr>
<tr>
<td>Moisture content (g/100 g)</td>
<td></td>
<td>74.79 ± 0.20 a</td>
<td>72.16 ± 0.35 b</td>
</tr>
<tr>
<td>Protein (g/100 g)</td>
<td></td>
<td>2.23 ± 0.05 b</td>
<td>2.99 ± 0.09 a</td>
</tr>
<tr>
<td>Total fat (g/100 g)</td>
<td></td>
<td>17.45 ± 0.32 a</td>
<td>8.07 ± 0.35 b</td>
</tr>
<tr>
<td>Cholesterol (mg/100 g)</td>
<td></td>
<td>27.02 ± 0.12 a</td>
<td>22.39 ± 0.12 b</td>
</tr>
<tr>
<td>Total carbohydrate (g/100 g)</td>
<td></td>
<td>5.00 ± 0.11 b</td>
<td>16.31 ± 0.15 a</td>
</tr>
<tr>
<td>Total sugar (g/100 g)</td>
<td></td>
<td>10.48 ± 0.10 b</td>
<td>12.85 ± 0.10 a</td>
</tr>
</tbody>
</table>

Data were expressed as mean ± standard deviation. Means with the same letter are not significantly different (p>0.05).

3.5. Analysis of Microbiological Quality in Goat Milk Ice Cream with SFBGR

According to the sensory evaluation of goat milk ice cream samples, the one with 30% SFBGR was the most acceptances by assessors and was analyzed for microbiological quality. The results showed that E. coli, S. aureus and Salmonella spp. were not found in both goat milk ice cream samples were mixed with 0% and 30% SFBGR. Moreover, the total bacteria found in the ice cream samples were less than the requirement by the Ministry of public health, Thailand [36].

<table>
<thead>
<tr>
<th>Microbial strains</th>
<th>Goat milk ice cream with SFBGR</th>
<th>0% SFBGR</th>
<th>30% SFBGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total plate count (cfu/g)</td>
<td></td>
<td>4.9 x 10^7</td>
<td>1.1 x 10^7</td>
</tr>
<tr>
<td>Escherichia coli (/0.01 g)</td>
<td></td>
<td>not detected</td>
<td>not detected</td>
</tr>
<tr>
<td>Salmonella spp. (/25 g)</td>
<td></td>
<td>not detected</td>
<td>not detected</td>
</tr>
</tbody>
</table>

*S. aureus was not found in sample.

The quality requirement for total plate count is < 600,000 cfu/g; E. coli is not detected in 0.01 g of sample; S. aureus is < 100 cfu/g; Salmonella spp. is not detected in 25 g [36,37].
4. Discussion

4.1. Analysis of Chemical Composition in Goat Milk and SFBGR

4.1.1. Chemical Compositions of Pasteurized Goat Milk

The protein content of pasteurized goat milk was 3.32 g/100 g. This value was higher than the result reported by Ibrahim et al. (2020) [18] that found protein in goat milk was 2.89 g/100 g. Ibrahim et al. (2021) [38] also showed that protein in goat milk was found as 3.24 g/100 g. The solids not fat, fat and lactose in goat milk from this study was 7.7, 3.63, 4.24 g/100 g, respectively. These were less than those reported from Ibrahim et al. (2020) [18], who found that solids not fat, fat and lactose in goat milk were 7.84, 6.47, 4.31 g/100 g, respectively. According to the results, all chemical compositions were different. This was in agreement with Lad et al. (2017) [9], who showed that the chemical compositions of milk were different due to diet, season, breed, feeding management, environment conditions and lactation.

4.1.2. Chemical Compositions of SFBGR

According to the results, pH in SFBGR was mild acid. This was responded from organic acids contributed from the carbohydrate fermentation. This was in agreement with Yotmanee and Naksang (2021) [39], who showed that the fermentation of steamed rice using Aspergillus oryzae and Saccharomyces cerevisiae produced citric acid, malic acid, lactic acid, acetic acid and propionic acid. These organic acids resulted in the decreasing of pH in fermented solid media. The more fermentation times the more organic acids content. The protein, fat, fiber and ash in SFBGR were mostly increased from pigmented rice fermentation. This was in agreement with Wattanuruk (2021) [40], who showed that the fermentation of non-pigmented rice and pigmented rice increased protein, fat, fiber and ash content. In addition, the proteolysis of yeast during the fermentation derived more protein to fermented rice [41]. For the analysis of phytochemical compounds, flavonoids, phenolic acids and anthocyanins were found in the samples. This is in agreement with Yotmanee et al. (2011), Yotmanee (2018) and Shao et al. (2018) [16,41,42], who showed that the bran of pigmented rice contain a high content of phenolic acids (gallic acid, coumaric acid, ferulic acid and protocatechuic acid) and anthocyanins (cyaniding 3-glucoside and peonidin 3-glucoside). In addition, these phytochemical compounds were degraded from bran via the microbial metabolism during the fermentation. Therefore, the fermented rice and its liquid also contained a high content of flavonoids, phenolic acids and anthocyanins [41].

There are many benefits of flavonoids has been showed. Scarano et al. (2018) [43] reported that they had hypoglycemic effects and antioxidant activities, anti-bacterial activity, anti-inflammatory and immune-modulatory activity. In addition, the phenolic compounds showed that they decreased the oxidation of low-density lipoprotein, cholesterol and liposomes [42]. Moreover, anthocyanins also showed the benefits for human health such as anti-oxidation, glycemic regulation, neuroprotection, lipid profile regulation, retinal protection, relieving metabolic syndrome, enhancing immune response and anti-aging [44].

4.2. Sensory Evaluation of Goat Milk Ice Cream with SFBGR

The evaluation of the sensory property of goat milk ice cream with SFBGR showed that the increasing of SFBGR resulted in the increasing of appearance, color and texture of the ice cream sample, excepted flavor, taste and overall score. According to the results, the ice cream with 30% SFBGR was the most accepted sample from panelists. This can be explained that SFBGR contained anthocyanins, which contributed purple shad color and flour and fiber, which contributed more rough texture to the goat milk ice cream. Therefore, those scores had a relationship with liking score from the consumers in this research. This was in agreement with Yotmanee (2018) [41], who showed that the anthocyanins in pigmented rice bran derived the purple color during the fermentation. Therefore, that color imparted the pleasant color to the goat milk ice cream mixed with SFBGR. In addition, Yangılar (2015) [45], studied the effect of banana pulp flour to the texture properties of ice cream. Their results showed that the increasing of banana pulp flour resulted in the increasing of ice cream texture and gummying structure. However, the excess content of flour might be risked to the quality of ice cream due to its degradation and freeze thaw instability [16]. This effects on an unsmooth texture of ice cream and unacceptance liking score.

4.3. Analysis of Physical Properties in Goat Milk Ice Cream with SFBGR

According to the results, viscosity and % overrun of a goat milk ice cream with 30% SFBGR was higher than those in a goat milk ice cream with 0% SFBGR. This related with the total solid content, which was higher found in a goat milk ice cream with 30% SFBGR. This can be explained that the SFBGR contained carbohydrate in term of flour and fiber, which could absorb the water in an ice cream mixture. This increased a viscosity in ice cream [46]. Furthermore, the air cells can be more dispersed into an ice cream mixture during the hardening process that resulted in a higher % overrun. This in agreement with Goff and Hartel (2013) [1], they showed that the increasing of air while mixing promoted the viscosity of the ice cream, resulting in more homogeneity in the ice cream air-call and a higher rate of overrun. For the melting down analysis, % melting down of a goat milk ice cream with 30% SFBGR was less than those in a goat milk ice cream without SFBGR. This showed that the adding of SFBGR resulted in the decreasing of % melting down. It can be explained that the carbohydrate in SFBGR, which was starch absorbed the water for swelling. This promoted a consistency and stability of goat milk ice cream mixture. Therefore, this resulted in the delay of melting rate of goat milk ice cream with 30% SFBGR. This is in agreement with Peasura et al. (2020) [47], they showed that the supplementary pumpkin mash to ice cream resulted in a higher total solid, viscosity, and a delayed melting rate. Li et al. (1997) [48] also showed that
the increasing of free water content resulted in the increasing of melting rate, whereas the freezing point was decreased. In addition, Wu et al. (2019) [49] showed that the increasing of overrun rate resulted in the decreasing of melting down rate. For the analysis of ice cream color, goat milk ice cream without SFBGR showed a pale yellow, which was the original color from goat milk, whereas the adding of SFBGR derived a purple to the ice cream sample. This color derived from an anthocyanin which is found in pigmented rice [16,41]

4.4. Analysis of Chemical Compositions in Goat Milk Ice Cream with SFBGR

The addition of 30% SFBGR into goat milk ice cream showed a lower energy from fat, total fat, saturated fat and cholesterol, compared to goat milk ice cream without SFBGR. This can be explained that ice cream with 30% SFBGR contained less fat content from whipping cream and goat milk. This result was similar to the study from Boonterm et al. (2012) [50], they showed that the adding of 5% germinated brown rice into an ice cream resulted in the decreasing of the calories due to the reduction of fat by starch supplementary.

In addition, the goat milk ice cream with 30% SFBGR contained higher protein, carbohydrate and dietary fiber than goat milk ice cream without SFBGR. The higher amount of protein in goat milk ice cream with 30% SFBGR contributed from SFBGR, which had crude protein around 2.04%. This is in agreement with Pinciroli et al. (2009) [51], they showed that the main proteins in rice were glutelin, following by globulin, prolamin and albumin.

For dietary fiber, Ciudad-Mulero et al. (2019) [52] showed that the brown, black, and basmati rice had a higher insoluble dietary fiber, compared to soluble dietary fiber. This insoluble one was classified as cellulose, which was benefit for colon health. This can be explained that cellulose promotes a number of apoptotic epithelial cells in large intestine, which played as a protective role in the development of colon cancer. In addition, its water absorbance ability showed the stew bulky, improving the elimination of possible carcinogens and shortening bowel transit time.

For sugar analysis, the results showed that total sugar in goat milk ice cream without SFBGR was lower than that in a goat milk ice cream with 30% SFBGR. This caused from SFBGR contained more glucose and sucrose. This was related to the increasing of total soluble solid in SFBGR from 14 to 20 °Brix from our study. This was in agreement with the study by Halim et al. (2014) [53], they showed that the fermentation process increased the number of totals of soluble sugars. In contrast, lactose in goat milk ice cream with 30% SFBGR was decreased due to the reduction of goat milk and whipping cream.

The supplementary of 30% SFBGR into the goat milk ice cream showed a higher level of vitamin B1, vitamin B9, magnesium, phosphorus and iron compared to goat milk ice cream without SFBGR. This can be explained that rice contained vitamins and minerals such as vitamin B, potassium, magnesium, manganese and iron [42,54]. Moreover, that vitamins and minerals remained in the final product promoted a normal human physiology and prevents cardiovascular disease [55].

For phytochemical analysis, the content of flavonoids and anthocyanins in a goat milk ice cream with 30% SFBGR was higher than those in a goat milk ice cream without SFBGR. This was related to the flavonoids, anthocyanins and phenolic compounds found in SFBGR. In addition, the anthocyanins derived more blue color in the ice cream samples. This was in agreement with Maulani et al. (2019) [56], they showed that the anthocyanins were responsible for (-) b*, which means blue color. Khoo et al. (2017) [17] showed that anthocyanin provided health benefits that are anti-microbial activities, improve visual, support neurological health, and prevent non-communicable diseases. In addition, the content of phenolic compounds found in both ice cream samples was not significantly different. This can be explained that the phenolic compounds in SFBGR were decomposed by the pasteurization process. This study is consistent with Zhang et al. (2020) [57], they reported that a high heat resulted in a reduction of phenolic compounds due to their oxidation and decompose.

4.5. Analysis of Microbiological Quality in Goat Milk Ice Cream with SFBGR

Ice cream is a frozen dairy dessert, which produced by freezing an ice cream mix with continuous crystallization. This product seems to be safe for the consumers however it might be contaminated from pathogens due to ice cream ingredients (milk protein, fat, and lactose) can be a valuable source for microbial development owing to its nutritional content, neutral pH, and lengthy storage, even though it is stored in a frozen state. Actually, the pasteurization is a potential process to exterminate the microbial in an ice cream mixture, but they could be infected into the mixture after the pasteurization via the addition of contaminated ingredients and improper handling of the final products [58]. In order to prevent harmful from food pathogens, the hygiene quality of ice cream should be determined. According to results, both ice cream formulations had a total plate count less than 100,000 cfu/g. There was no detection of E. coli and Salmonella spp. in both ice cream samples, whereas S. aureus detected in those samples was less than 100 cfu/g. Therefore, the quality of ice cream samples passed the notification of the Ministry of public health No.354 and No.416 [36,37]. This result was similarly with Boonterm et al. (2012) [50], they analyzed for total bacteria in germinated brown rice ice, and their results showed that the total bacteria found in ice cream samples were close to 5,300 cfu/ml. However, Kim et al. (2005) [59] showed that total bacteria found in ice cream in Korea was 100 cfu/g, which less than those reported by our research and Boonterm et al. (2012) [50]. This can be explained that the different amount of bacteria in ice cream due to the different ingredients and processes.

5. Conclusion

The goat milk ice cream with 30% SFBGR was the most acceptable ice cream by the panelists. This was related to the adding of SFBGR, which improved the physical properties (viscosity, overrun, melting rate and
color) of the goat milk ice cream. The adding of SFBRG was not only improving the physical properties, but the chemical composition was also changed. According to this, energy, fat and cholesterol were reduced, whereas vitamins, minerals, flavonoid, and anthocyanin were increased. For the analysis of food hygiene, all microbes found in the ice cream samples were less than the standard from the Ministry of public health. Therefore, this was possible to develop a goat milk ice cream supplement with sweet fermented black glutinous rice on an industrial scale for promoting Thailand’s local agricultural products.

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