Nutritional composition, glycemic index, glycemic load, and organoleptical quality of glucomannan-enriched soy milk ice cream

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Abstract. Over the past decades, the number of childhood obesity cases has increased significantly, which led to an increase in the number of adults suffering from degenerative diseases such as diabetes mellitus (DM). Glucomannan-Enriched Soy Milk Ice Cream (GSMIC) may prevent obesity in children. The aim of the study was to test the level of carbohydrates, protein, fat, dietary fiber, glycemic index, glycemic load, and organoleptic quality of GSMIC. This experiment used a completely randomized design to test three formulations of glucomannan flour and soy milk (0.5%, 1.5%, and 2.5%). The products were tested for nutritional composition, and evaluated on glycemic index, glycemic load, and organoleptic quality. GSMIC 2.5% had higher levels of dietary fiber and high carbohydrate, protein, and fat content compared to ice cream (3.99%, 30.7%, 1.50%, 1.33%, respectively). The glycemic index of ice cream and 2.5% GSMIC were 75.83 (75%) and 51.48 (51%), respectively, while the glycemic load of ice cream and 2.5% GSMIC were 9.04 and 11.61, respectively. Based on the organoleptic analysis, formulation preferred by the panellists was 2.5% glucomannan flour. Glucomannan flour affected the level of carbohydrates, protein, fat, dietary fiber, glycemic index, glycemic load, and organoleptic quality in soy milk ice cream.

Keywords: glucomannan flour, soy milk, glycemic index, glycemic load, organoleptic quality

1. Introduction

Obesity is a nutritional problem caused by positive energy balance [1]. The prevalence of overweight and obese cases in children has increased gradually from 4.2% in 1990 to 6.7% in 2010. This trend is expected to reach up to 9.1% or 60 million in 2020. In Indonesia, according to the Basic Health Research, 10.8% of children aged 5 to 12 years old will be overweight and 8.8% will be obese in 2020 [2]. Childhood obesity increases the risk of other various diseases such as cardiovascular disease and diabetes mellitus (DM) in adulthood.

DM is a metabolic disease characterized by elevated blood sugar levels caused by impaired insulin secretion and/or insulin function [3]. According to the Basic Health Research, the percentage of cases of DM has increased from 1% in 2007 to 2.1% in 2013 [4]. Obesity is a major risk factor of DM [5]. One solution to overcome this problem is by consuming foods containing high fiber with a low glycemic index.

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Ice cream is a food product favored by all people in Indonesia especially children and adolescents. The consumption of ice cream in Indonesian increased from 0.3 liters per capita in 1999 to 0.5 liters per capita in 2004. In Indonesia, ice cream is generally made from cow's milk and is high in fat. However, we propose an alternative formulation of ice cream by replacing the cow's milk with soy milk. Soy milk has protein content and amino acid composition similar to cow's milk. In addition, soy milk contains minerals and vitamins in sufficient quantities, contains no lactose, and is low-fat, cholesterol-free, and high in nutrition [6].

Ice cream is usually made using Carboxyl Methyl Cellulose (CMC) as a thickening agent. CMC is one of the most widely used additives in the food industry as a thickening agent. In this study, CMC was replaced with glucomannan flour, obtained from konjac (*Amorphophallus konjac*) and used as a thickener or stabilizer to improve the nutritional value of the soymilk ice cream. Glucomannan flour derived from konjac contains 5% crude fiber is a soluble fiber that is high in hydrocolloid, low in calories, and has a low glycemic index. It is widely used in the food industry both as a functional food or food additive. Glucomannan flour can be used as an alternative stabilizer or thickening agent and reduces blood glucose and lipids in pre-clinical studies of DM [7]-[9]. The use of food products such as ice cream enriched by glucomannan flour is a new innovative method to produce healthier ice cream for patients with obesity and DM. The aim of the study was to test the levels of carbohydrates, protein, fat, dietary fiber, glycemic index, glycemic load, and the organoleptic quality of Glucomannan-Enriched Soy Milk Ice Cream (GSMIC).

2. Materials and Methods

This study was an experimental study with a complete randomized design. The independent variable of this research was glucomannan flour and soy milk ice cream, while the dependent variable was the level of fiber, carbohydrates, protein, fat, glycemic index, glycemic load, and organoleptic quality.

2.1. Food Production

There were 3 treatments and 1 control (t = 4) noted by symbols P0 (0% glucomannan flour, 0.3% CMC; 83.7% soy milk), P1 (0.5% glucomannan flour; 83.5% soy milk), P2 (1.5% glucomannan flour; 82.5% soy milk), P3 (2.5% glucomannan flour; 81.5% soy milk). Soy milk and glucomannan flour with 3 different concentrations were obtained from a preliminary study based on the composition of a stabilizer in ice cream making, whereas the control of the standard stabilizer formula was CMC. Each treatment group was analyzed in repeated testing including analysis of levels of dietary fiber, carbohydrate, protein, and fat, while the glycemic index test on ice cream and 2.5% GSMIC were conducted without repetition.

Soy milk was made using ratio of soybean and water of 1:4. Soy milk was made by sorting soy beans and soaking, washing, grinding, filtering, and cooking by heating at a temperature of 80ºC for 10-15 minutes. Ice cream was made from raw materials including soy milk, 10% stevia sugar Tropicana Slim® Alergon, 5% whipped cream, vanilla essence, water, and 1% salt. The ice cream was made by mixing all the ingredients, stiring, and heating at 80ºC for 10 minutes. Then the mixture was put into the ice cream maker (Donper, USA) for 30-60 minutes and frozen for 24 hours at a temperature of -45º to (-23)ºC.

2.2. Product Analysis

The protein concentration test was carried out with the Kjeldahl method, the fat concentration test was carried out with the Soxhlet method, the carbohydrates was carried out by different method, dietary fiber was carried out with the enzymatic method, and the glycemic index was carried out with the Incremental Area Under the Blood Glucose Response Curve (IAUC) method [10]-[12].

For the glycemic index test, a minimum of 8 panelists were used [12]. To avoid drop out, this study used 9 subjects. One day prior to the experiment, the panelists fasted for 10 hours (drinking water allowed) starting from 10.00 pm to 8:00 am the next day. The criteria for subjects were Body Mass

Index (BMI) between 18.5-22.9kg/m2, fasting blood glucose <110mg/dl, and age 20-24 years. The capillary blood of the subjects was taken to measure fasting glucose levels. Furthermore, panelists were asked to consume pure glucose, ice cream, and GSMIC. Blood samples were taken every 30 minutes (minutes 30, 60, 90, and 120) after testing the food for 2 hours. Each treatment was given within three days to avoid bias. The glycemic index test was carried out using a glucometer (Autocheck GCU 3 in 1, Taiwan). Secondary data was collected using the Indonesian National Standard (SNI) for ice cream quality requirements.

2.3. Statistical Analysis

The results of the analysis of the nutritional composition were analyzed statistically using One Way ANOVA (95%) and tested further by the Tukey test to determine significant difference between treatment and control groups. Organoleptic tests using 5 scale (hedonic scale), i.e. 1 = Dislike very much, 2 = Dislike, 3 = Neutral, 4 = Like, and 5 = Like Very Much. The 25 semi-trained panelists used were students of Nutrition Science Faculty of Medicine, Diponegoro University. The results of organoleptic tests were analyzed using Friedman test and continued using Wilcoxon to determine significant difference between treatment and control groups. Mean value was obtained then categorized into ≤1.4 "Dislike very much", from 1.5 to 2.4 "dislike", from 2.5 to 3.4 "neutral", 3.5 to 4.4, "like" and ≥4.5 "Like Very Much." The glycemic index data collected from the measurement were analyzed using univariate statistical method by calculating the average value of measurement data. The result used to describe the levels of glycemic index and glycemic load of GSMIC.

3. Results and Discussion

3.1. Nutritional Composition

The results of the analysis of nutrient content of Glucomannan-enriched Soy Milk Ice Cream (GSMIC) shows that there were significant differences between carbohydrate, protein, and fat between four products ($p<0.05$). Ice cream with 2.5% glucomannan flour contained the highest carbohydrate and protein, and the lowest fat composition (Table 1).

Table 1. Nutrition composition of ice cream and GSMIC.

Formulation	Carbohydrate (g)	Protein (g)	Fat (g)
P0	24.26 ± 0.78^{d}	7.71 ± 1.04^{a}	3.06 ± 0.12^{a}
P1	27.06 ± 0.54^{c}	4.91 ± 0.48^{b}	2.36 ± 0.16^{b}
P2	28.34 ± 0.22^{b}	3.20 ± 0.40^{c}	1.95 ± 0.16^{b}
P3	30.17 ± 023^{a}	1.50 ± 0.04^{d}	1.33 ± 0.06^{c}
	p=0.000	p=0.000	p=0.000

P0=ice cream; P1=0.5% glucomannan flour; P2=1.5% glucomannan flour; P3=2.5% glucomannan flour. Figures followed by different superscript letters (a, b, c, d) in the same column indicate significant differences.

Obesity in children and adolescents can be overcome with the proper diet. Provision of a balanced diet in accordance with Requirement Daily Allowances (RDA) is recommended for obese children. Since children are still growing and developing, they need a diet with 3 main meals and 2 snacks [13]. The nutrient content per serving of a snack is generally up to 10% of daily caloric needs.

GSMIC was formulated to meet nutritional needs without causing weight gain if consumed properly – generally, one serving of ice cream that is equal to 90 grams. Recommended carbohydrate intake for obese children is approximately to 55% of daily recommended calories or 27.5 g per single snack [13]. The composition of carbohydrate in one serving of GSMIC in its highest concentration meet the recommendation at approximately 98.5%, as the higher the concentration of glucomannan

flour, the higher the carbohydrate content. Glucomannan is a complex carbohydrate and the soluble fiber that is included in polysaccharides increases carbohydrates [14].

The recommended fat intake is maximum 30% of calories which is equal to 6.6 g per serving. The composition of fat in one serving of the highest concentration GSMIC was 1.1 g and 18%, which meets the recommendation. The recommended protein intake is approximately 15% of caloric needs, equivalent to 7.5g per serving of a snack. The protein content in one serving of ice cream with the highest glucomannan flour substitution is 1.35 g, which meets 18% of recommended protein intake. In GSMIC, the protein composition was lower (2.6-2.8 g) than ice cream.

3.2. Dietary Fiber

The analysis of dietary fiber content of GSMIC showed that 2.5% GSMIC had the highest fiber content across other treatment groups (Table 2). Compared to ice cream with CMC stabilizer (ice cream), dietary fiber was increased by 1.69%. The results showed that there was a significant difference ($p<0.05$) of GSMIC on levels of dietary fiber.

Table 2. Dietary fiber composition of ice cream and GSMIC.

Formulation	Water-Soluble Fiber (%)	Water-Insoluble Fiber (%)
P0	1.06 ± 0.08^{c}	0.56 ± 0.09^{b}
P1	1.69 ± 0.16^{b}	0.82 ± 0.55^{a}
P2	2.07 ± 0.14^{b}	0.98 ± 0.55^{a}
P3	2.75 ± 0.09^{a}	1.24 ± 0.04^{a}
	p=0.000*	p=0.000*

P0=ice cream; P1=0.5% glucomannan flour; P2=1.5% glucomannan flour; P3=2.5% glucomannan flour. Figures followed by different superscript letters (a, b, c, d) in the same column indicate significant differences.

The results showed increased levels in each treatment group, such that the higher percentage of glucomannan flour, the higher composition of the dietary fiber in the ice cream. There were significant differences in dietary fiber in the GSMICs compared to ice cream ($p<0.05$). The glucomannan flour increased dietary fiber because glucomannan is a water-soluble fiber [7]-[8]. Glucomannan has been shown prolong gastric-emptying, thus increasing satiety and reducing body weight [15]-[16]. The dietary fiber in the ice cream was lower because the stabilizer used was CMC, a polymeric chain that consists of insoluble cellulose molecule which contains less soluble fiber [17].

Adequate consumption of dietary fiber could lower the risk of obesity. High fiber foods need longer time to chew and digest. Foods that contain insoluble fiber are not digested and increase the volume of food, thus reducing the risk of excessive consumption. Soluble fiber turns into a gel-like substance during digestion, prolonging the food in the intestines, and making the body feel satisfied for longer [18]. According to a research, glucomannan is more effective when administered at a smaller dose because it has high viscosity. Consuming glucomannan 3 g per day for 8 weeks reduces weight by 1.4-2.49 kg [19]. Regulation from the Head of National Agency of Drug and Food of the Republic of Indonesia number HK.00.05.52.6291, recommends 25 g/2.000 calories or 30 g/2500 calories for children and adolescents aged 2 to 20 years old [20]. One serving of 2.5% GSMIC (90 g) contains 3.59 g of fiber. Thus, eating one serving of GSMIC meets the 14% requirement of dietary fiber.

3.3. Blood Glucose Response

Variations in the concentration of GSMIC resulted in differences in glucose response in healthy subjects. The blood sugar tests showed that there was an increase 30 minutes the test foods and continue to decreased gradually (Figure 1). An increment in blood glucose lowering corresponded with the addition of glucomannan flour. The highest blood glucose increment occurred after

consuming pure glucose intake and the lowest occurred after consuming 2.5% GSMIC. The blood glucose response after ice cream consumption was higher after 30 and 60 minutes compared to 2.5% GSMIC and lower after 90 and 120 minutes. This condition could be due to the dietary fiber composition, the higher fiber consumed the lower blood glucose response [21].

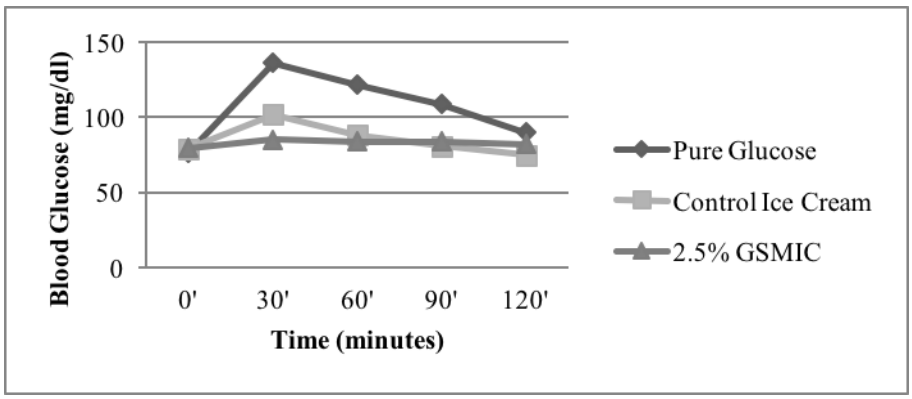

Figure 1. Blood glucose response graph

3.4. Glycemic Index and Glycemic Load

The glycemic index (GI) of GSMIC obtained from the average value of the nine subjects glycemic index is shown in Table 3. The 2.5% GSMIC had lower GI (51.48) compared to the control ice cream (75.83). The results of Glycemic Load (GL) for GSMIC was categorized as low glycemic load for ice cream (9.04) and medium glycemic load for the 2.5% GSMIC (11.61) (Table 4).

The glycemic Index (GI) test is conducted using pure glucose, ice cream, and 2.5% GSMIC. All tested foods were equivalent to 50 g carbohydrates determined by available carbohydrates. Available carbohydrates measures the total available carbohydrates that are easily digest, absorb, and metabolize [22].

Table 3. Glycemic index of Glucomannan-enriched Soy Milk Ice Cream.

Food tested	Glycemic Index	Category*
Control Ice Cream (P0)	75.83	High GI
2.5%glucomannan flour(P3)	51.48	Low GI

*Category: low glycemic index (<55); medium glycemic index (55-70); high glycemic index (>70)[30]

The GI value of foods were divided into three categories as follows: (1) low GI (<55), (2) medium GI (55-70), and (3) high GI (>70) [30]. Based on these categories, 2.5% GSMIC was categorized as a low GI food (51%) and ice cream was categorized as a high GI food, which decreased after addition of 2.5% glucomannan flour. Dietary fiber and production methods can affect GI changes [21].

Table 4. Glycemic load of Glucomannan-enriched Soy Milk Ice Cream.

Formulation	Serving portion (g)	Available Carbohydrate (%)	Available Carbohydrate per serving[a]	Glycemic Load[b]	Category[c]
P0	30	40.18	12.06	9.04	Low GL
P3	30	75.97	22.8	11.61	Medium GL

P0=ice cream; P3=2.5% glucomannan flour

[a] Available carbohydrate/serving =(serving portion/100g)*available carbohydrate

[b] Glycemic load=(glycemic index*available carbohydrate per serving)/100

[c] Categories: low glycemic load (<10), medium glycemic load (11-19), high glycemic load (> 20) [23]

The low GI value of GSMIC might be caused by glucomannan flour added into production. High fiber glucomannan flour (5.9 g/100g) could affect the GI value due to its role as physical obstacle in the digestion process [24]. Dietary fiber increases viscosity, provides longer satiety, decreases the absorption of macronutrients, influences the change of GI value, and lowers post-prandial blood glucose. Adequate fiber intake could be advantageous in controlling blood glucose and plasma lipid concentration [25]. Fiber addition has anhypoglycemic effect because it can slows down gastric-emptying and diffusion of glucose and glucose absorption so it reduces the increment of blood glucose [26]. The fiber addition process in the GSMIC can affect the GI value. The use of high temperature processing could result in the formation of starch gelatinization that is difficult to digest, therefore reducing the value of the glycemic index [27].

GI provides information on the speed of carbohydrate transformation into glucose but does not provide information about the amount of carbohydrates and the impact of certain food on blood glucose levels. Glycemic Load (GL) may provide more complete information on the effect of actual food consumption on increasing blood glucose levels. Consumption of low GI foods aims to reduce GL. GL is used to assess the impact of carbohydrate consumption considering the GI value of the food. GL is proportional to the carbohydrate composition of food such that the lower the carbohydrate content, the lower GL of the food. A smaller serving of food would trigger an increment raise in blood glucose level [33]. GL was categorized into three categories as follows: low GL (<10), medium GL (11-19), and high GL (> 20) [28].

The GL of the ice cream and 2.5% GSMIC were 9.04 and 11.61, respectively. Due to the carbohydrate composition in the flour, the higher the level of added glucomannan flour, the higher the GL level. 2.5% GSMIC was classified as medium GL food. GSMIC could be used as an alternative snack for diabetics but should be limited to 1-2 servings/day. In addition, the GL diet has been shown to improve glycemic control, serum lipid reduction, and cardiovascular and diabetes risk reduction [29]. A Japanese study concluded that there is a relationship between a diet high in GL and risk of type 2 diabetes in women [30].

3.5. Organoleptic Quality

The results of the organoleptic test for GSMIC is shown in four parameters in Table 5. There were no significant differences in the color, flavor, and taste parameters of the three concentrations of GSMIC (0.5%, 1.5%, 2.5%). However, there were significant differences in color, flavor, and taste of GSMIC (0.5%, 1.5%, 2.5%) compared to the ice cream. There were no significant differences between ice cream and 2.5% GSMIC in texture ($p<0.05$). Ice cream and 2.5% GSMIC shared similar color and texture scores. 2.5% GSMIC had the most preferred flavor and taste (hedonic scale 3.13).

Table 5. Organoleptic quality of Glucomannan-enriched Soy Milk Ice Cream.

Formulation	Categories			
	Color	Flavor	Taste	Texture
P0	4.00 ± 0.86^{a} (like)	4.52 ± 0.71^{a} (very like)	2.12 ± 0.78^{b} (dislike)	$3.36 \pm 1{,}18^{a}$ (neutral)
P1	3.08 ± 0.90^{b} (neutral)	2.84 ± 0.89^{b} (neutral)	2.92 ± 0.75^{a} (neutral)	2.68 ± 0.80^{b} (neutral)
P2	3.00 ± 0.86^{b} (neutral)	3.12 ± 0.83^{b} (neutral)	2.84 ± 1.02^{a} (neutral)	2.72 ± 0.79^{b} (neutral)
P3	3.44 ± 0.65^{b} (neutral)	3.20 ± 0.95^{b} (neutral)	2.96 ± 1.02^{a} (neutral)	2.92 ± 1.07^{a} (neutral)
	p=0.001	p=0.000	p=0.005	p=0.041

P0=ice cream; P1=0.5% glucomannan flour; P2=1.5% glucomannan flour; P3=2.5% glucomannan flour. Figures followed by different superscript letters (a, b) in the same column indicate significant differences.

There was no significant difference between GSMIC products (0.5%, 1.5%, 2.5%) in color. The hedonic scale in ice cream texture parameter was high for 2.5% GSMIC and low for 1.5% GSMIC. GSMIC flavor had a neutral hedonic scale and, according to the results of statistical test, the rating showed a significant difference across each GSMIC group. The 2.5% was preferred by the panelists because ice cream production reduced the percentage of soy milk and increased the glucomannan flour added.

The hedonic rating on the texture of ice cream products were neutral across each GSMIC products. However, according to the statistical tests, there was a significant effect of the amount of glucomannan flour added. The panelists preferred the 2.5% GSMIC due to the texture because glucomannan is a water-soluble fiber and contains strong hydrocolloids that are soluble in cold water by a thick gel mass [14]; the more glucomannan flour added, the more viscous ice cream products produced.

Using glucomannan flour in soy milk ice cream as a CMC replacement and as a stabilizer for this product could be accepted by consumers. However, the mean of panelists hedonic scale was higher in the control product which used CMC as the stabilizer.

4. Conclusion

Glucomannan flour addition to soy milk ice cream production affected carbohydrates, protein, fat, dietary fiber, glycemic index, glycemic load, and organoleptic quality, and higher flour glucomannan concentration increased fiber and carbohydrates and lowered fat and protein. GSMIC has a low glycemic index at 2.5% glucomannan concentration (51.48) and a low glycemic load at 0% glucomannan flour concentration (9.04). The addition of glucomannan flour to soy milk ice cream production reduced GI but increased GL. Panelists preferred 2.5% GSMIC due to its organoleptic quality on the parameters of color, flavor, taste, and texture. The 2.5% GSMIC preferred by the panelists contains higher dietary fiber and lower fat.

5. Sugesstion

The concentration of soybean milk protein content in ice cream should be reanalyzed to obtain the best formulations in order to lower the value of glycemic index and glycemic load. In addition, it is important to test the physical properties of ice cream as well as possible metal and microbial contamination.

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