Product Development of Flakes Cereal Based on Brown Seaweed Flour (*Sargassum* sp.): Prospects of Food Materials from Papua with Low Glycemic Index

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ABSTRACT

Brown seaweed (*Sargassum* sp.) as an antidiabetic agent contains iodine, protein, vitamins, minerals (K, Mg, Na, Fe), tannins, phenols, and alginates which during the digestion process form a gel that functions to absorb carbohydrates and slow down the absorption of glucose so that it can be digested and lowers blood sugar levels. The purpose of this study was to determine how to manufacture, evaluate the quality and value of the glycemic index of flakes cereal food products based on brown seaweed flour. Evaluation of cereal quality is by chemical testing on F1, F2, F3 based on the parameters of % carbohydrate, % protein, % fat, % water content, % ash content. The glycemic index test was prepared using a Completely Randomized Design (CRD) with 5 repetitions using 25 male mice (*Mus musculus*) as test animals. The results of this study obtained the formula for cereal flakes with the best composition in formula three (F3), namely brown seaweed flour 14.05 %w/w, wheat flour 9.36 %w/w, cornstarch 7.02%w/w, crunchy 0.23 %w/w, developer 0.11% w/w, essence 0.23 %w/w, sorbitol 7.02 %w/w, and skim milk 30.45 %w/w. From the evaluation results of chemical testing of flakes cereal based on brown seaweed flour has a carbohydrate content of 63.475%, water content 7.21%, ash content 11.07%, total fat 8.835%, protein 9.41%, total energy 371.055 kcal, and energy from fat 79.515 kcal and GI value 54.39. The conclusion of this study was that the formulation and quality testing of cereals met SNI standards, namely the parameters of carbohydrates, proteins, and fats and had a low GI value.
Keywords: glycemic index; Brown seaweed; *Sargassum* sp.; Cereal Flakes

ABSTRAK

Rumput laut cokelat (Sargassum sp.) sebagai agen antidiabetes mengandung iodine, protein, vitamin, mineral (K, Mg, Na, Fe), tanin, fenol, dan alginat yang selama proses pencernaan membentuk gel berfungsi mengabsorpsi karbohidrat dan memperlambat penyerapan glukosa sehingga dapat menurunkan kadar gula dalam darah. Tujuan penelitian ini untuk mengetahui cara pembuatan, evaluasi mutu dan nilai indeks glikemik dari produk pangan sereal flakes berbasis tepung rumput laut cokelat. Evaluasi mutu sereal yaitu dengan pengujian kimia pada F1,F2,F3 berdasarkan parameter % karbohidrat, % protein, % lemak, % kadar air, % kadar abu. Pengujian indeks glikemik disusun dengan Rancangan Acak Lengkap (RAL) sebanyak 5 kali pengulangan menggunakan hewan uji 25 ekor mencit jantan (Mus musculus). Hasil penelitian ini didapatkan formula sereal flakes dengan komposisi terbaik pada formula tiga (F3) yaitu tepung rumput laut cokelat 14,05 %b/b, tepung gandum 9,36 %b/b, tepung maizena 7,02 %b/b, perenyah 0,23 %b/b, pengembang 0,11% b/b, essen 0,23 %b/b, sorbitol 7,02 %b/b, dan susu skim 30,45 %b/b. Dari hasil evaluasi pengujian kimia sereal flakes berbasis tepung rumput laut cokelat memiliki kadar karbohidrat 63,475% , kadar air 7,21%, kadar abu 11,07%, lemak total 8,835%, protein 9,41%, energi total 371,055 kcal, dan energi dari lemak 79,515 kcal serta nilai IG 54,39. Kesimpulan penelitian ini didapatkan formulasi dan pengujian mutu sereal yang memenuhi SNI yaitu pada parameter karbohidrat, protein,dan lemak serta memiliki nilai IG rendah.
Kata kunci*: Indeks glikemik; Rumput laut cokelat; Sargassum sp.; Sereal Flakes*

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INTRODUCTION

Indonesia is the largest archipelagic country in the world that has abundant marine natural resources, including various types of seaweed (algae) and sponges. The general condition of coral reef exposure in eastern Indonesia is different from the western and central parts. The reef shelf area is part of the *Sargassum* seaweed habitat. Differences in the substrate and environmental conditions of the *Sargassum* seaweed species are influenced by the waters of the Pacific Ocean (Kadi, 2005).

Diabetes Mellitus (DM) is a disease characterized by hyperglycemia that occurs due to abnormalities in insulin secretion, abnormal insulin action mechanisms, or both (Perkeni, 2011). Type 2 diabetes is progressive, so it is necessary to control blood glucose as an effort to prevent the risk of complications. The glycemic index number is an indicator in assessing how quickly the effect of blood sugar levels after eating food. One strategy in dietary regulation to help control blood glucose is through choosing foods with a low glycemic index (Franz, 2012).

The International Diabetic Federation predicts an increase in DM sufferers in Indonesia from 7.3 million in 2011 to 11.8 million in 2030, of which 90% - 95% are type 2 DM. Report on the results of Basic Health Research (Riskesdas) conducted in 2013 by The Ministry of Health shows that the highest prevalence of DM is in the province of West Kalimantan, which is 11.1%. Meanwhile, Papua occupies the lowest position in the prevalence of DM in Indonesia, which is 1.7% (Indrasari, 2009).

Brown seaweed has antidiabetic activity (Oh et al., 2016). Other research conducted showed that the extraction of polysaccharides was able to reduce 54.20% blood sugar levels in mice and the glycemic index value of type 2 diabetes patients could be controlled (Samudra & Chintama, 2018). With consuming beverages enriched with alginate content from seaweed (Harden et al., 2012). The use of brown seaweed as an antidiabetic agent comes from the families Lessoniaceae, Ishigeaceae, Sargassaceae, Fucaceae, Laminariaceae, Alariaceae, and Dictyotaceae which have been identified as having phlorotannin compounds (Gunathilaka et al., 2020).

Seaweed has the potential to be developed as a functional food product because it contains nutrients and bioactive components such as phenolic compounds, natural pigments, sulfated polysaccharides, and fiber that function to improve health (Erniati et al., 2016). Currently, the consumption of dietary fiber in Indonesia is still dominated by materials from land plants, while the use of materials derived from aquatic plants is still limited. Efforts to explore the potential of the sea are very interesting, starting from cultivation and also regarding its use in various fields of human life.

The development of seaweed diversification products also plays a role in providing selected products according to consumer tastes, including the development of functional food products. Seaweed (Sargassum sp.) can be found on the coast of Base G Jayapura but has not been used optimally by the local community so that this study aims to make flakes cereal products based on brown seaweed flour which has a low glycemic index.

RESEARCH METHODS

Equipments

Glucometer (*glucodr super sensor*™ from Allmedicus co., ltd.), strip reagen, scissors, oral probe, HK-860 flouring machine, spoon, stirrer, cake brush, scale, oven, mesh 80, mixer, basin, container, beaker, mortar, and stamper.

Ingredients

Brown seaweed (*Sargassum* sp.) obtained from Jayapura Base-G Beach, wheat flour, wheat flour, cornstarch, crunch,

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developer, essence, skim milk, sorbitol, low fat margarine, Na-CMC, glucose monohydrate, conventional cereal FF®, water, handscoon, and alcohol swab.

Experimental Animals

The experimental animals used were 25 male mice (*Mus musculus*) with a body weight of 15-30 grams obtained from mouse breeders in Jayapura. This research has obtained ethical approval with No.: LB.02.01/2/KE.450/2021

Making Chocolate Seaweed Flour

First, a sample of brown seaweed (*Sargassum* sp.) was taken on the coast of Base G Jayapura. Sampling was done by combing the beach with a sampling method by hand. The collected samples were then washed with seawater first to remove sand and dirt. Then put in the container during transportation. Then it is processed following the stages of processing seaweed into flour (Ristanti, 2003). The manufacture of seaweed flour consists of size reduction, cleaning, washing, soaking, drying and milling.

The sorted seaweed was broken into small pieces with a size of 3-5 cm with the aim of facilitating the cleaning process then washed using fresh running water for 3 days to clean the dirt and salt that was still attached after that it was soaked in rice washing water for 12 hours to reduce the fishy smell of seaweed. The samples were then drained and dried using an oven at 60°C to dry for a week. The dried seaweed samples were then ground using the HK-860 Flour Machine and then sieved with a mesh size of 80 (180 µm).

Cereal Formulation

The formulation process is carried out by mixing the ingredients that have been prepared and then weighed and mixed with certain ratios obtained based on literature studies. The manufacture of cereal flakes dough is printed in a round shape and placed on a gutter that has been smeared with margarine first. Roasting cereal flakes is carried out for 25 minutes at a temperature of 120ºC (Malinda et al., 2012)

Table 1. Modification of Cereal Flakes Formula

	Ingredients	F1 (%w/w)	F2 (%w/w)	F3 (%w/w)
1	Chocolate Sea Grass Fluor	0	6,72	14,05
2	Fluor	26,63	6,72	0
3	Wheat Fluor	17,75	4,4	9,36
4	Maizena	13,31	3,36	7,02
5	Essence Vanila	0,44	0,11	0,23
6	Crispy	0,44	0,11	0,23
7	Developer	0,22	0.05	0,11
8	Sorbitol	13,31	3,36	7,02
9	Skim milk	22,19	22,43	30,45
Total		100	100	100

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Cereal Flakes Evaluation

In this study, evaluations were carried out on the preparation of cereal flakes, namely hedonic testing and chemical testing. Hedonic testing is carried out to determine the level of preference or feasibility of a product so that it can be accepted by the panelists. Parameters observed included color, aroma, taste and texture of flakes cereal products using 25 untrained panelists. The score used has the following rating categories: 1 dislike very much (DVM), 2 don't like it (D), 3 quite like it (QL), 4 like it (L), 5 really like it (RL). Chemical tests based on parameters of water, ash, protein, fat, and carbohydrate content were carried out at the Saraswanti Indo Genetech (GIS) Laboratory, Bogor. The selected formula is considered in terms of panelist acceptance, its significance value and the parameters in chemical testing that affect the glycemic index value.

Pre Clinical Evaluation for Determination of Glicemic Index

The glycemic index value of a carbohydrate food source shows how much blood sugar levels increase after consuming the carbohydrate expressed as a percentage response to a carbohydrate portion which is equivalent to a standard reference of 50 g glucose (Schwingshackl & Hoffmann, 2013). But in this study it will be equivalent to 10 g/kg glucose for humans and converted to a dose of mice.

This test used a standard control in the form of glucose monohydrate with a dose of 26mg/20gBW, a positive control, using conventional cereal FF® at a dose of 28mg/20gBW, a negative control of 1% Na-CMC suspension and the control treatment used was brown seaweed flour at a dose of 43mg/20gBW and selected flakes cereal treatment with a dose of 40mg/20gBW.

On the day of measurement, the mice were first measured for fasting blood glucose levels (0 minute) then each mice were given a test food, the mice received measurements of blood glucose levels after 30 minutes, 60 minutes, 90 minutes, and 120 minutes. Determination of the glycemic index in this study using the AUC (Area Under Curve) method. The AUC calculation follows the trapezoidal formula formed in the lower area of the curve between time (hours) and glucose levels (mg/dL). The trapezoid method is done by calculating all the area of the trapezoidal building in the blood glucose rise curve which is then added up.
Trapezoidal building area was calculated by formula:

$$\text{Trapezoidal area} = \frac{\text{Number of parallel sides}}{2} \text{ X height}$$

The glycemic index is calculated by comparing the area under the curve of the test food (seaweed flour and seaweed flour-based cereal flakes) with the standard food (glucose). Blood glucose levels (each time sampling) are plotted on two axes, namely the time axis (X) and the blood glucose level axis (Y). GI is determined by comparing the area of the curve between the food whose GI is measured and the reference food multiplied by 100.

$$\text{GI} = \frac{\text{Area Under Curve sample}}{\text{Area Under Curve standard glucose}} \text{ X 100}$$

Data analysis

The hedonic test data was processed using SPSS for Windows version 24 with Kruskal Wallis analysis, chemical test data were presented in tables and narratives, while the glycemic index test for mice (*Mus musculus*) used Microsoft Excel and SPSS for Windows version 24 with Paired Sample Test analysis.

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RESULTS AND ANALYSIS

Making Chocolate Seaweed Flour

The stages of the flour processing process generally consist of material selection, cleaning, size reduction, drying, milling / flouring, and screening (Suyanti & Murtiningsih, 2011). The stages of processing seaweed flour follow the method (Ristanti, 2003) with modifications. Samples of Brown Seaweed (Sargassum sp.) taken on the coast of Base-G Jayapura Municipality were collected as much as 5 kg and sorted until the remaining 4 kg 350 g. Drying in the processing of brown seaweed uses a temperature of 60°C with the oven method because it has a stable and centralized temperature so that the heating can be evenly and thoroughly. The results of milling using a flour machine obtained as much as 443 g of brown seaweed flour with a fine level of passing an 80 mesh sieve (180μm).

Cereal Formulation

The stages of optimizing the cereal formula have been carried out 5 times. The selection of additional ingredients and the weights used in the formula are adjusted to the shape and taste of the cereal. The consideration of additional ingredients used in cereal flakes has a mutually supportive function to produce cereal flakes which are expected to be liked. The experiment was not only carried out on the consideration of additional ingredients but also on manufacturing techniques with the aim of knowing how to make cereal flakes that were practical so that through the optimization stage, the modified cereal formula was obtained with the composition and weight of the ingredients listed in **Table 1**.

Wheat flour in cereals provides easy mixing and high water absorption. Wheat flour as an additive to form cereals and cornstarch as a binder in the manufacture of cereal flakes. Some of the functions of margarine are to prevent the cereal dough from sticking to the gutters, and to add flavor to the cereal. Skim milk as an additive in cereals aims to improve color, aroma, retain water absorption and increase the nutritional value of cereals. The vanilla essence in the cereal gives it aroma, while the cake developer can soften and expand the dough and crunchy ingredients that play a role in the texture of the cereal. Sorbitol was chosen as an artificial sweetener because it is a sugar alcohol that is metabolized slowly in the body so it does not cause an increase in blood sugar. In the cereal formula the amount of sorbitol used meets the standards range of the Codex Alimentarius Commission and the United States Food and Drugs Administration.

Flakes Cereal Evaluation

In **Figure 1**, the color in the third formulation (F3) gave the highest rating response with an average of 4.24 followed by the first formulation (F1) which had an average rating response of 4.08 in the like category while in the second formulation (F2) 3.92 in the moderate-like category. The aroma of cereals in the first formulation (F1) is preferred with an average rating of 4.16 and the second formulation (F2) an average numerical scale of 4.08 which is categorized as liking while the third formulation (F3) has an average of 3.92 which is quite -like. The texture of the cereals showed the response of the panelists to the assessment scale with a moderate-like scale in the first formulation (F1) of 3.76, the second formulation (F2) 3.88 and the third formulation (F3) 3.88. In terms of taste, the first formulation (F1) gave an assessment response on a numerical scale of 3.92, the second formulation (F2) had an average numerical scale of 3.56 and the third formulation (F3) had a rating response of 3.48 which was categorized as quite like. The hedonic test showed that 25 panelists preferred the appearance of the first formulation (F1) in terms of taste and aroma but in terms of color and texture 25 panelists preferred the third formulation (F3). The results of the significance test on the color, aroma, taste and texture of cereals F1, F2, and F3 showed that sig (≥0.05) so it could be concluded that the three cereal formulations were identical or had the same rating.

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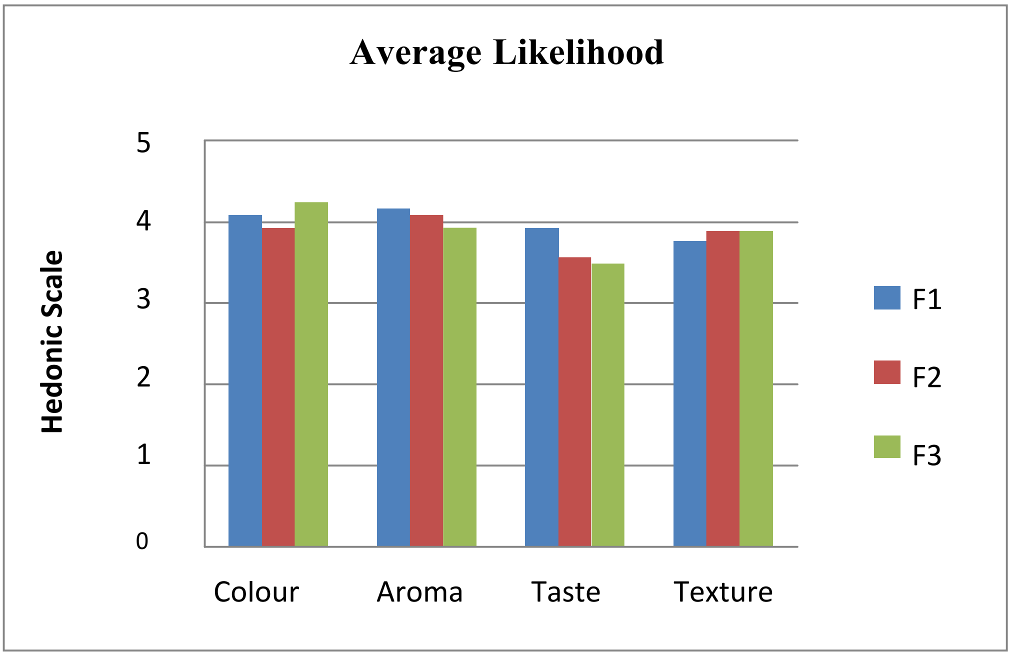

Figure 1. Cereal Hedonic Test Results

Table 2. Results of Chemical Testing

Parameters	Results			
	F1	F2	F3	Tepung
Energy fromFat (kcal/100g)	64,035	68,265	79,515	15,525
Total Energy (kcal/100g)	400,895	386,165	371,055	289,445
Protein %	7,875	9,575	9,41	8,43
Total Fat %	7,115	7,585	8,835	1,725
Water Content %	3,61	5,04	11,07	14,67
Ash Content %	5,06	7,9	7,21	15,125
Carbohydrate %	76,34	69,9	63,475	60,05

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In chemical testing (**Table 2**), the formula that was chosen to be continued in the glycemic index test was the third formula (F3) because it met SNI 01-4270-1996 on carbohydrate, protein, and fat parameters. The third formula (F3) also has the highest amount of fat and protein. High protein levels are thought to stimulate insulin secretion and high fat levels can slow the rate of gastric emptying. This is a factor that can affect the glycemic index because the higher the protein and fat levels, the lower the glycemic index value. Foods that contain high available carbohydrates have a high glycemic index value. The formula that has the lowest carbohydrate value is the third formula (F3).

Glicemic Index

The effect of food consumption on blood glucose levels over a certain period is called the glycemic response. A good understanding of the glycemic response is needed, both for healthy people to avoid DM, and people with DM. In general, foods that raise blood glucose levels quickly have a high GI, while foods that raise blood sugar levels slowly have a low GI (Ragnhild, 2004); (Siagian, 2004); (Atkinson et al., 2008).

From **Figure 2**, it can be seen that after giving the cereal test food, the peak of the increase in blood glucose occurred at the 30th minute of 90.8 mg/dL and decreased successively at the 60th minute, which was 73.8 mg/dL, in the 15th minute. 90 which is 67 mg/dL until the 120th minute which is 60.4 mg/dL. While in the positive control, namely the comparison cereal, the increase in blood glucose in the 30th minute was 92.4 mg/dL while the peak of the increase in blood glucose occurred at the 60th minute, which was 109.8 mg/dL and decreased in the 90th minute by 103 mg. /dL until the 120th minute which is 91.8 mg/dL.

The difference in the peak of the increase in blood glucose in the test cereal and the comparison cereal was at 30 and 60 minutes where the test cereal had a peak at 30 minutes and the comparison cereal was longer at 60 minutes because the main ingredients in the cereal were different types. The test cereal was made from brown seaweed and the comparison cereal from corn. This is also in accordance with the statement (Frei et al., 2003) that carbohydrates from different plants have different glycemic responses.

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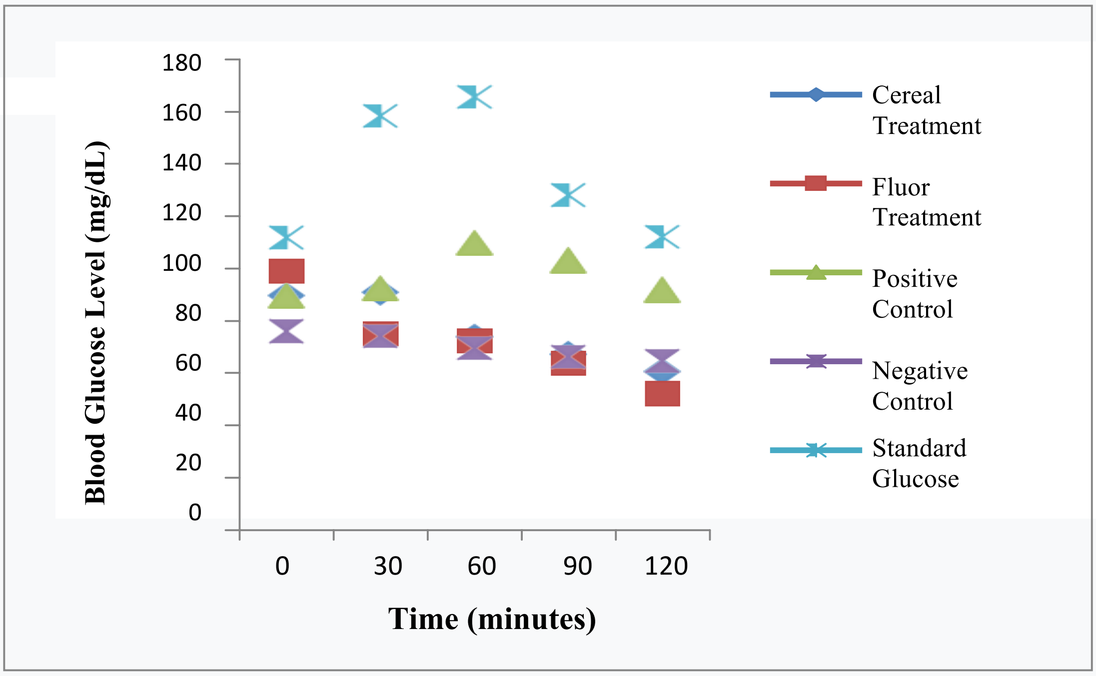

Figure 2. Blood Glucose Response of Mice

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In this study, the negative control used was Na-CMC which can be seen in the graph after feeding from 30 to 120 minutes there was a decrease. This is not much different from the glycemic response in seaweed flour treatment which also decreased at 30 to 120 minutes after feeding. The decrease in blood glucose levels in brown seaweed flour was better than the negative control which was only given Na-CMC suspension. This is because brown seaweed has the potential as an antidiabetic agent that can lower blood sugar levels.

The results of phytochemical screening using methanol, ethyl acetate, and n-hexane extracts of Sargassum sp. positive contains flavonoid, saponin, phenol and tannin compounds (Pangestuti et al., 2017). The phenolic content in brown seaweed is 20-30% (Gazali et al., 2018). Florotanin is the main phenolic compound detected in brown algae (Koivikko, 2008). Supported by the statement (Gunathilaka et al., 2020) that brown seaweed species from the family Sargassaceae have phlorotannins identified as antidiabetic agents and (Oh et al., 2016) that brown seaweed has antidiabetic and anti-inflammatory activity. There are other studies, namely brown seaweed polysaccharides which can reduce 54.20% blood sugar levels in mice and polyphenols with an effectiveness percentage of 58.12% (Samudra & Chintama, 2018) there is also sodium alginate from brown seaweed which can reduce diabetes blood glucose type 2 (Thamrin Wikanta, 2003).

Table 3. Glycemic Index Value of Test Food

Test Food	GI	GI Category
Chocolate Seaweed Fluor	50,87	Low
Cereal Flakes	54,39	Low
Convensional Cereal	70,21	High

Based on **Table 3**, the highest glycemic index is conventional cereals, namely 70.21 the glycemic index of the comparison food is classified as high GI because it is at >70 susceptible. While the glycemic index value of the cereal flakes test is 54.39, this value is categorized as low because the GI value is <55. The difference in the GI value of the two cereals is in the main ingredient, namely the formula 3 cereal flakes test food using brown seaweed and conventional cereal using sugar coated corn. The low GI value in this study of flakes cereal is because it uses seaweed flour which also has a low GI value of 50.87. The GI value of seaweed flour is lower than that of cereal flakes because cereal flakes have other additives.

Factors that affect GI in food include fiber content, amylose and amylopectin ratio (Rimbawan and A. Siagian, 2004), starch digestibility, fat and protein content, and processing methods (Ragnhild, 2004). Each food component contributes to each other to produce a certain glycemic response. The presence of dietary fiber can affect blood glucose levels (Fernandes et al., 2005). In general, high dietary fiber content contributes to a low GI value (Trinidad et al., 2010). Dietary fiber can form a matrix outside the starch granules so that it can inhibit carbohydrate digestion (Alsaffar, 2011).

Dietary fiber, especially soluble dietary fiber, can reduce blood glucose response due to (i) an increase in viscosity in the stomach so that it slows the rate of emptying of the stomach and digestive tract causing a decrease in the amount of carbohydrates that can be digested (barriers to enzymes) and simple sugars that can be absorbed; (ii) dietary fiber causes changes in gastrointestinal hormone levels, nutrient absorption, and insulin secretion; and (iii) dietary fiber helps improve insulin sensitivity, stabilizes blood sugar levels thereby protecting against complications due to diabetes (Escudero lvarez & González Sánchez, 2006).

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Fiber from seaweed can help control body weight because it is a low-calorie diet (Rajapakse & Kim, 2011) and can inhibit the activity of -amylase and -glucosidase enzymes that play a role in the process of accumulating calories in the body (Nwosu et al., 2011) . Brown seaweed has been used as a commercial alginate producer and forms a gel during the digestive process to capture carbohydrates and slow down glucose absorption. The main ingredient of the test cereal, namely seaweed, had a fiber content of 39.67% (Matanjun et al., 2009) while in the comparison cereal it only had a fiber content of 2 g per 100 g package.

Starch and fiber are included in the polysaccharide group which is a complex carbohydrate. Complex carbohydrates are absorbed more slowly than simple carbohydrates, so they don't cause a rapid increase in blood glucose. Brown seaweed, which grows some species from the Pacific Ocean, contains a large number of polysaccharides, including alginate and polyphenolic bioactive compounds. (Vijay et al., 2017) reported that carbohydrates in brown seaweed consisted of fucoidan, laminaran, cellulose and alginate. The mechanism of polysaccharides in the human intestine functions as fiber and when it meets bacteria in the human intestine it is not easily digested by the digestive system (Suparmi & Sahri, 2009).

The content of protein and fat can form a food matrix with amylose, tends to slow the rate of gastric emptying so that it can reduce digestibility (Alsaffar, 2011). The higher the fat and protein content, the lower the GI. In the test cereal the protein and fat content was higher than the comparison cereal which could be seen from the nutritional value per 100 g. The fat content of the comparison cereal was 0.5% and the test cereal was 8.83% while the protein content of the comparison cereal was 4.5% and the test cereal was 9.41%.

One of the factors that affect the GI value of a food product is the processing method, such as heating (steaming, boiling, frying) and milling (flouring) to reduce particle size. Processing methods can change the physicochemical properties of foodstuffs such as fat and protein content, digestibility, and the size of starch and other nutrients (Arif & Budiyanto, 2014). Heating starch with excessive water causes starch to undergo gelatinization and structural changes. Reheating and cooling starch that has undergone gelatinization also changes the starch structure further which leads to the formation of new insoluble crystals, in the form of retrograded starch, thereby causing changes in the GI value (Haliza et al., 2006).

Normality analysis was carried out to determine whether the resulting data normally spread. The result of significant normality is more than 0.05 ($p>0.05$), it can be said that there is no difference in variance between data groups or in other words the data variance is the same and normally distributed. The results of the paired sample test analysis using a significant level ($p <0.05$) got a significant value of 0.000 where the value was lower than 0.05 so that H1 was accepted which indicated a significant difference between flakes cereal products based on brown seaweed flour and conventional cereal products.

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CONCLUSSION

Making selected formula cereals based on brown seaweed flour (Sargassum sp.) by mixing ingredients including brown seaweed flour 14.05 %w/w, wheat flour 9.36 %w/w, cornstarch 7.02%w /b, crunch 0.23 %b/b, developer 0.11% w/w, essence 0.23 %w/w, sorbitol 7.02 %w/w, and 30.45 %w/w skim milk. Roasting was carried out for 25 minutes at a temperature of 120ºC. Based on SNI 01-4270-1996 what has met the requirements is the content of protein, fat and carbohydrates. The selected formula (F3) cereal flakes based on seaweed flour in 100 g has a parameter value of 63.475% carbohydrates, 7.21% water content, 11.07% ash content, 8.835% total fat, 9.41% protein, 371.055 total energy. kcal, and energy from fat 79.515 kcal and has a GI value of 54.39 which is categorized as low.

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