

**Abstract.** *Sargassum polycystum* is one type of brown algae that contains many bioactive compounds, including polyphenols. This compound is known to be anti-hyperglycemic that beneficial for the control of blood glucose and diabetic symptoms in diabetics. Symptoms caused by hyperglycemia are weight loss, polyphagia, polyuria, and polydipsia. Polyphenols are compounds that dissolve quickly and are easily obtained by decoction. The purpose of this study was to examine *S. polycystum* decoct for improvement in diabetes symptom in type 2 diabetes mellitus rats. This study was carried out at the Laboratory for Physiology and Biomedicine on the Medical Faculty of the Universitas Brawijaya. This study consisted of 7 treatments: negative control, negative control + metformin, diabetes control, diabetic rats + metformin, diabetic rats + 0.5 mL of decoct, diabetic rats + 1 mL of decoct, and diabetic rats + 1.5 mL of decoct, respectively. Blood glucose and diabetes symptom were observed at the end of the study. The results showed that the diabetic rat group suffered from hyperglycemia and diabetes symptoms. Treatment of *S. polycystum* decocts on type 2 diabetes mellitus rats decreased blood sugar levels and improved diabetes symptom. However, the results were not as optimal as in diabetic animals treated with metformin. The conclusion is that *S. polycystum* decoct can reduce hyperglycemia and diabetes symptoms in rats with type 2 diabetes mellitus.

1. Introduction
Diabetes mellitus is a metabolic disorder characterized by high blood glucose (hyperglycemia). Hyperglycemia in people with type 2 diabetes mellitus occurs as a result of insulin resistance. Insulin levels in people with DM 2 are enough, but the number of receptors on the cells has decreased. It makes it difficult for glucose to enter the cell until the cells lack glucose deficiency and, ultimately, hyperglycemia. It followed by several diabetes symptoms, such as polyphagia, polydipsia, polyuria, and decreasing body weight [1].

*Sargassum* sp is a species of brown algae from the Phaeophyceae class. This biota is known to contain several bioactive compounds, including polyphenols. This compound is known to have an anti-hyperglycemia effect [2; 3; 4]. The anti-hyperglycemia activity of it based on carbohydrate metabolism and glucose homeostasis [5].

Polyphenols can be extracted by decoction. Decoct is a liquid obtained by extracting ingredients in the water at 90 °C around 30 minutes. Detached material can be in the form of substances that have not been processed or are still in a new state [6]. The purpose of this study was to evaluate the *S. polycystum* decoct in improving diabetes symptoms in type 2 diabetic rats.

2. Methodology
The equipment used in this study was the Glucometer (GlucoDr. AGM-2100), gloves, and mouse cages. Brown algae (*S. polycystum*) obtained from Talango island, Sumenep district, Madura. Male Wistar rats (*Rattus norvegicus*) aged 2-3 months were used as animal models diabetes. Thirty-five rats weighing 200 ± 10 g were acclimatized for seven days and
received food and drinks *ad libitum*. The mice were divided into 7 groups, including: (1) negative control, (2) negative control + 1 mL decoct, (3) DM, (4) DM + metformin, (5) DM + 0.5 mL decoct, (6) DM + 1 mL decoct and (7) DM + 1.5 mL decoct. A type 2 DM group of rats obtained by the administration of high-cholesterol pellets on normal rats for two weeks and then they injected with streptozotocin at a dose of 20 mg/kg body weight. Blood sugar levels measured on the 7th day after streptozotocin injection. Rats with a blood sugar level of more than 200 mg/dL were classified as diabetic and used in research. For negative control rats, the group injected with only a citrate buffer solution. During the experimental period, the rats were fed with pellets and distilled water *ad libitum*. From day 0, body weight, drinking volume, feed consumption weight, and urine volume measured every five days, while blood sugar levels measured at the end of the study [7]. The data obtained between the groups analyzed for a variance with a confidence interval of 5%.

3. Result and discussion

3.1. Blood glucose

The blood sugar level is a term that indicates the level of glucose in the blood. The blood sugar concentrations or serum glucose levels strictly regulated in the body. Glucose that flows through blood is an energy source for body cells. Blood glucose measurement is done to determine whether or not there is a significant increase in blood glucose levels that is later related to the diagnosis of DM. Table 1 shows the blood glucose level among treatment groups.

| Groups                        | Blood glucose (mg dL⁻²) | Body weight (g) | Polyuria (mL)  | Polyphagia (g) | Polydipsia (mL) |
|-------------------------------|-------------------------|-----------------|----------------|----------------|-----------------|
| (-) control                   | 123.6±6.66             | 229.8±3.71      | 7.3±0.45       | 16.4±0.42      | 13.3±0.45       |
| (-) control + 1.0 mL decoct   | 120.8±9.18             | 223.0±8.18      | 8.7±0.45       | 16.7±0.45      | 12.3±0.45       |
| DM                            | 342.2±15.27            | 152.7±5.93      | 22.2±1.15      | 24.6±0.42      | 47.8±0.84       |
| DM + metformin                | 172.2±9.86             | 208.7±5.63      | 11.3±0.45      | 18.4±0.42      | 18.3±1.20       |
| DM + 0.5 mL decoct            | 337.6±14.88            | 164.7±3.03      | 20.6±0.89      | 24.1±0.74      | 44.0±0.79       |
| DM + 1.0 mL decoct            | 236.6±10.60            | 176.8±3.27      | 17.0±0.79      | 21.3±0.45      | 36.8±1.15       |
| DM + 1.5 mL decoct            | 198.2±10.85            | 192.9±5.34      | 13.4±0.42      | 19.7±0.45      | 26.4±0.89       |

* Superscript shows the difference between the treatments.

Table 1 shows the blood glucose levels of normal mice (A), and normal mice + *S. polycystum* decoct (B) is no different. *S. polycystum* decoct, and the active ingredients contained therein are not anti-hypoglycemic in healthy people. Blood sugar levels in normal mice treated with polyphenol also showed the same results [8]. It is possible that the active ingredients, which are hypoglycemic in healthy people, have been hydrolyzed by the digestive microflora until they lose their activity. The gastrointestinal microflora hydrolyzes polyphenols that consumed in healthy people to monomers. In contrast, when monomers consumed, it is still contained and detected in the urine of healthy people [7].

Figure 1 shows blood glucose levels in DM (C) mice higher than DM + metformin (D) mice. Reduced blood sugar levels in diabetic rats with metformin, as this compound can suppress the production of liver glucose and increase cell glucose uptake. Metformin is an oral biguanide class anti-diabetic. The mechanism of action of the biguanide group is to suppress glucose production produced by the liver, to stimulate glucose uptake, to suppress the production of excess glucose and to reduce the absorption of glucose in the intestine by the increased use of glucose by peripheral tissues [9].
Table 1 shows the blood glucose level of DM (C) mice higher than DM + S. polycystum decoct 1 mL (F), and DM + S. polycystum 1.5 mL decoct (G), whereas for DM + S. polycystum 0.5 mL decoct (E) is no different. It shows that polyphenols can reduce blood glucose levels. Polyphenols can inhibit the absorption of blood sugar from the intestine and accelerate the digestive process that occurs in the digestive system so that carbohydrates present in ingested food will not be absorbed much by the intestine [7]. Polyphenols can significantly reduce blood glucose levels by inhibiting liver glucose-6-phosphatase activity so that the gluconeogenesis process will be inhibited [5]. Other mechanisms that may be responsible for the hypoglycemic effect are increased glucose uptake, inhibition of the intestinal GLUT system, and decreased gene expression that regulates the process of gluconeogenesis [10].

3.2. Body weight
Weight loss is one of the properties that result from diabetes mellitus. The incidence of weight loss in people with diabetes due to high glycolysis in body cells while taking glucose is very low. Table 1 shows the body weight performance among treatment groups.

Table 1 shows that the bodyweight of A and B is not different. Normal rats weighed between 200 and 250 g [3]. This study shows that the administration of S. polycystum decocts able to suppress weight gain. The presence of secondary metabolites in the Sargassum sp. thought to affect the rat's weight gain [7]. The presence of phlorotannin in the methanol extract from Sargassum sp. no effect on weight loss in mice in which the metabolic process and protein intake in the digestive tract is not interrupted. The administration of S. echinocarpum-methanol extract in a dose of 625 mg/kg body weight did not lead to metabolic disorders in test animals [11]. The content of polyphenols in Sargassum sp. decoct able to inhibit the activity of the pancreas lipase enzyme in the hydrolysis of fat to reduce the risk of obesity [7].

Table 1 shows that body weight was lower in DM (C) rats than in normal rats (A). DM rats are unable to use blood glucose as energy due to insulin resistance. For the energy needs of the tissue, the body draws energy from other energy sources such as fat and protein. Insulin deficiency means that glucose cannot get into the cells so that the body's energy requirements covered by lipolysis [9]. Fat in various tissues is mobilized and broken down by beta-oxidation to generate energy. Fat loss causes weight loss. Another study showed that diabetic rats lost weight due to reduced insulin production or increased insulin resistance so that using glucose as the primary source of energy is wasted in the body and does not get into the cell and ultimately decreases [10].

Table 1 shows that DM rats gained weight after the administration of metformin. Metformin can increase body weight along with decreased blood sugar. The use of metformin can be said to be effective in treating DM because the weight gain is almost normal. Metformin is often used to treat type 2 DM due to its properties that can lower blood sugar and lose weight [9].

Table 1 shows that the bodyweight of DM (C) rats is lower than that of DM + S. polycystum decoct (E), (F), and (G), respectively. The increase in body weight along with the increase in the dose of Sargassum sp. The content of polyphenols in Sargassum sp. decoct thought to increase body weight in DM rats. Several studies have shown that the administration of polyphenols can increase body weight in DM rats since these compounds can increase the ability of cells to glucose uptake [7; 8; 11].

3.3 Polyuria
Diabetic have an increased frequency and increased urine volume. The body cells experience an increase in glycolysis, and excess water then excreted in the form of urine. Table 1 shows a profile of polyuria in normal, diabetic, and diabetic rats treated with S. polycystum decoct.
Table 1 shows that urine volume in normal rats (A) and normal rats + *S. polycystum* (B) decoct was not different. It indicates that the administration of *S. polycystum* decoct under normal conditions it has no diuretic effect. An active ingredient is said to have a diuretic effect if it can increase the urine volume [12]. The diuretic condition is increasing the solution absorption rate and inhibiting the reabsorption of Na\(^+\) and Cl\(^-\). It induces increasing the volume of the Na\(^+\) solution, and the water in the distal and proximal tubules has increased [11].

Table 1 shows that the urine volume of DM (C) rats is higher than that of normal rats (A). It shows that hyperglycemia and glucosuria occur in DM (C) rats, which increases the osmotic pressure in the kidney tubules and inhibits water reabsorption, causing polyuria. If the blood sugar level in a diabetic is very high, the glomerular filtrate contains glucose above the reabsorption threshold. As a result, excess glucose is excreted in the urine, which leads to an enormous loss of calories. A very high urine volume in patients with DM caused the loss of various electrolytes, water, and glucose [11].

Table 1 shows that urine volume decreased in DM rats treated with metformin. It shows that metformin can increase muscle glucose uptake and prevent new liver glucose production. It causes the cell respiration to decrease. By-products of cellular respiration are H\(_2\)O. The decrease in cell respiration means that the H\(_2\)O produced is also low. As a result, water in the form of urine is released from the body with a smaller volume [9].

Table 1 shows the urine volume of DM (C) rats that are higher than DM + *S. polycystum* (E), (F), and (G) decoct groups, respectively. It shows that polyphenols can reduce urine volume—the decreasing urine volume, along with a decrease in blood sugar levels in the body. Polyphenols can increase insulin sensitivity so that blood sugar can get into the cells and be converted into energy so that the intensity of cell respiration also decreases. The by-products of cellular respiration here are H\(_2\)O and CO\(_2\). The decrease in the breathing process means that the H\(_2\)O produced is also low. As a result, water in the form of urine is released from the body with a smaller volume [10; 12].

### 3.4. Polyphagia

Frequent and excessive consumption of food is called polyphagia. Diabetic suffer from this symptom due to the disturbance in carbohydrate metabolism, so body cells are ravenous because the body cells lose many calories. Table 1 shows an image of polyphagia in normal, diabetic, and diabetic mice treated with *S. polycystum* decoct.

Table 1 shows that the consumption of normal mice (A) and normal rats + *S. polycystum* decoct (B) is no different. The adequacy of the energy requirement usually influences consumption. Individuals stop eating when their energy needs are met. The active substance in the decoct shows that it does not affect normal people. The polyphenols consumed in normal individual bodies are usually not absorbed by the intestinal tract and hydrolyzed by the microflora of the digestive tract. The metabolites produced do not directly influence the increase in hunger feelings [11].

Table 1 shows that the consumption of DM (C) rats is higher than that of normal rats (A). The body needs an entry of glucose at the time of hyperglycemic cells. The lack of glucose causes cells to lack energy and increases hunger. In the event of hyperglycemia, the body cannot accurately convert glucose into energy. This condition leads to excessive hunger, so this correlates with an increase in food intake. When the blood glucose level is high, the gluconeogenesis of cells increases so much that the cell urgently needs an energy source [12].

Table 1 shows that DM rats treated with metformin decreased their feed consumption. It shows that metformin can increase glucose uptake so that the lack of cell energy substrate can be met. The ability of metformin to restore the ability of cells to absorb glucose means that body cells in diabetics do not experience a lack of energy reserves [9].

Table 1 shows that the feed consumption of DM (C) rats is higher than that of DM + *S. polycystum* decoct (E), (F) and (G) groups, respectively. It shows that the active
ingredient in the decoct can reduce the frequency of consumption. Active ingredients such as polyphenols have an antihyperglycaemic effect and can increase insulin sensitivity in order to convert blood sugar into energy and glycogen [5]. If the glucose that enters the body can be converted into energy, the energy requirement in the cells for carrying out activities is covered, so that the stimulation of hunger decreases under DM conditions [5].

3.5. Polydipsia
Diabetic also has a lot of frequency and volume of drinking. This situation is a reaction of the body when it lacks fluids. Therefore, the body needs many fluids to replace lost fluids in the body. Table 1 shows an image of polydipsia in normal, diabetic, and diabetic rats treated with *S. polycystum* decoct.

Table 1 shows that the drinking volume of normal rats (A) and normal rats + *S. polycystum* decoct (B) is not different. The content of polyphenols in *S. polycystum* decoct shows no hypoglycemic effects in the normal group. This phenomenon is due to the hydrolysis of the bioactive substances so that their ability to stimulate blood sugar intake decreases or is lost [11].

Table 1 shows that the drinking volume of DM (C) mice was higher than that of normal mice (A). This condition indicates that DM rats have hyperglycemia. High blood sugar levels cause the body's osmotic pressure to change, which ultimately leads to osmosis to balance the osmotic pressure. The kidneys receive much water, which causes DM patients to urinate frequently. As a result, the body lacks water; the person concerned becomes dehydrated and ultimately increases the symptoms of thirst and drinking (polydipsia)—the increase in drinking water consumption in the DM group caused by compensation for physiological factors. Then the body feels thirsty and often wants to drink in large quantities [5; 11].

Table 1 shows that metformin can reduce the drinking volume of DM rats. It shows that metformin can improve insulin sensitivity in cells, increasing the amount of glucose entering the body's cells. Metformin is an oral biguanide class anti-diabetic. The mechanism of action of the biguanide group is to suppress the glucose production produced by the liver, to reduce insulin resistance, and to reduce the speed of gluconeogenesis by activating AMPK (adenosine monophosphate kinase) [9].

Table 1 shows the drinking volume of DM (C) mice that are higher than DM + Sargassum decoct (E), (F), and (G) groups, respectively. Polyphenols content in Sargassum decoct can increase insulin sensitivity, which leads to improved glucose metabolism in the body cells. A reduced blood sugar level means that the body does not need much water to dilute the urine, so the body does not become dehydrated, which correlates with a low drinking volume. A little drinking volume also leads to a reduction in the amount of urine released by the body [11].

4. Conclusion
*S. polycystum* decoct can reduce hyperglycemia and diabetes symptoms in rats with type 2 diabetes mellitus.

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