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Original Research Article

Enhancing Metabolic Parameters: The Impact of Porang Glucomannan on Body Weight, Intraperitoneal Fat, Fasting Blood Glucose, and GLUT-4 Levels in Rats Fed a High-Fat and High-Carbohydrate Diet

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ABSTRACT

Porang glucomannan (GMP) can be fermented to produce various short-chain fatty acids, which are expected to enhance insulin sensitivity and improve GLUT-4 expression. This research aims to validate the effect of porang glucomannan supplementation on body weight, intraperitoneal fat, fasting blood glucose and GLUT-4 levels in rats fed with high-fat and high-carbohydrate (HFHC) diet. The research was carried out using a posttest-only control group design, with data collected from a sample size of 30 Sprague-Dawley rats divided into five groups, each consisting of five rats, namely normal, HFHC, GMP25, GMP50, and GMP100. Except for the normal group, the other four groups were fed HFHC diet for 21 days, followed by specific treatments for each group for 28 days. The parameters measured included body weight, intraperitoneal fat weight, fasting blood glucose and GLUT-4 levels. GMP100 group demonstrated the most favourable results in fasting blood glucose levels, GLUT-4 levels, and intraperitoneal fat weight. In contrast, GMP25 group exhibited the best outcome in terms of body weight. Porang glucomannan supplementation improved body weight, blood glucose levels, GLUT-4 levels, and intraperitoneal fat in rats on HFHC diet, with the most effective dose observed at 100 mg/200 gBW.

Keywords: Glucomannan, Porang, GLUT-4, Fasting Blood Glucose, Intraperitoneal Fat

Introduction

The composition of high-fat and high-carbohydrate (HFHC) diet is closely associated with metabolic syndrome,[1] a condition characterized by a cluster of symptoms affecting the cardiometabolic system. These symptoms include central obesity, hyperglycemia, hypertension, and dyslipidemia.[1] The primary causes of metabolic syndrome are the consumption of high-calorie diet and insufficient physical activity.[2] Metabolic syndrome has become a global concern due to its increasing prevalence and numerous complications. According to data from the American Heart Association Journal (AHA), the prevalence of metabolic syndrome in Asia has risen to 25.8% of the total population and continues to grow. In Indonesia, the occurrence of metabolic syndrome is also on the rise, along with an increased risk of obesity and weight gain. The prevalence of metabolic syndrome in Indonesia is reported to be 39.0% in 2020.[3] Among the Indonesian population, metabolic syndrome affects 14.3% of the elderly, with higher prevalence in women than men.[4] The escalating occurrence of metabolic syndrome in society necessitates effective treatment approaches. Besides lifestyle modification and drug consumption, metabolic syndrome can be solved with natural ingredient consumption as therapy or functional food, such as porang glucomannan.

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The higher the consumption rate of carbohydrate and fat, the greater its uptake by the liver, resulting in elevated blood glucose levels in the portal vein. This rise in blood glucose concentration stimulates the release of insulin hormone. However, prolonged high-carbohydrate and high-fat diet consumption can lead to insulin resistance, causing hyperglycemia, weight gain, and increased intraperitoneal fat. Fat accumulation in high-fat diet promotes the production of reactive oxygen species (ROS) and triggers endothelial apoptosis. This contributes to the development of the metabolic syndrome and exacerbates vascular dysfunction and inflammatory response.[5] Management of metabolic syndrome typically involves lifestyle modifications and pharmacotherapeutic drugs to address hyperglycemia, hypertension, and dyslipidemia.[6] Another approach to reducing the risk of metabolic syndrome is using porang glucomannan. However, research on the effects of porang glucomannan on metabolic syndrome is still limited, necessitating further research to validate its potential impact on body weight, intraperitoneal fat, fasting blood glucose, and GLUT-4 levels.

Porang glucomannan has become increasingly popular as a functional food due to its high soluble fibre content and its gel-like thick structure. These soluble and thick characteristics challenge digestive enzymes, resulting in a slower gastric emptying rate and inhibiting fat absorption in the small intestine.[6] This makes porang glucomannan an effective component for weight management. Porang glucomannan, also known as *Amorphophallus muelleri Blume*, is an indigenous tuber commonly found in Indonesia. It shares a similar soluble fibre structure[7] to konjac glucomannan, which is prevalent in Japan, Korea, and China.[8] Previous research have demonstrated that supplementation with konjac glucomannan at a dosage of 3 g/day has a positive impact on reducing body weight in adults who are overweight or obese.[7,9,10]

Glucomannan possesses a structure that resists breakdown by salivary amylase and pancreatic amylase enzymes, making it susceptible to fermentation by bacteria in the colon.[7,11] This fermentation process converts glucomannan into a prebiotic substance that benefits pancreatic beta cells and insulin activity.[12] Long-term supplementation with konjac glucomannan has been shown to lower blood glucose

levels, maintain electrolyte balance, and enhance overall quality of life.[11] Furthermore, research have demonstrated that porang glucomannan supplementation increases the expression of GLUT-4, glucose transporter, through the activation of the phosphoinositide 3 kinase/PI3K enzyme pathway in diabetic rats induced with streptozotocin/STZ.[13] Another research showed that porang glucomannan supplementation increases HDL levels and reduces total cholesterol, triglyceride, and LDL levels in rats with metabolic syndrome.[8] Given the structural similarity between porang glucomannan and konjac glucomannan, it is reasonable to expect that porang glucomannan holds various potential advantages for managing metabolic syndrome. However, research on the specific benefits of porang glucomannan is still limited. This research aims to investigate the effects of porang glucomannan supplementation on body weight, blood glucose levels, GLUT-4 transporter expression, and intraperitoneal fat weight in rats fed HFHC diet.

Materials and Methods

Animals

The experimental research used a posttest-only control group design on 30 male Sprague-Dawley rats (±8 weeks old at ±150-200 g). The research was conducted at the Food and Nutrition Study Center of Universitas Gajah Mada, Yogyakarta, Indonesia.

Porang glucomannan preparation

Glucomannan used in this research was in powder form from CV. Nura Jaya Surabaya, Indonesia. Glucomannan powder was derived from porang tuber, scientifically known as *Amorphophallus muelleri Blume*, which is indigenous to Indonesia.

Ethics statement

The ethical approval for the research was obtained from the Research Bioethics Commission, Faculty of Medicine, Universitas Islam Sultan Agung, Semarang, Central Java, Indonesia (No.290/IX/2017/Komisi Bioetik).

Experimental design

Rats were divided into 5 groups, each consisting of 5 rats, including the normal group (normal), high-fat, high carbohydrate diet group (HFHC), HFHC+25 mg/200 g BW porang glucomannan group (GMP25), HFHC+50 mg/200 g BW porang glucomannan group (GMP50), and HFHC+100 mg/200 g BW porang glucomannan group (GMP100). All rats were acclimatized to their respective diet during the adaptation phase, which lasted for 7 days. After the adaptation period, rats in HFHC groups were fed HFHC diet for 21 days, while those in the normal group were fed the standard AIN-93M feed. After completing high fat high carbohydrate diet for 21 days, the groups were treated from day 22 as follows. GMP25 group received supplementation of 25 mg/200 g BW of porang glucomannan, GMP50 group were given 50 mg/200 g BW, and GMP100 group was administered 100 mg/200 g BW of porang glucomannan. The treatment was administered for a duration of 28 days, from day 22 to day 49

Parameters measurement

On day 50, several parameters were measured, including body weight, intraperitoneal fat weight, fasting blood glucose levels, and GLUT-4 levels. Body weight and intraperitoneal fat weight were measured using a scale, accurately recording weight of rats in each group. For the assessment of blood glucose levels and GLUT-4 levels, blood serum samples were collected from the ophthalmic vein on day 50. Blood glucose levels were determined using Glucose Oxidase - Peroxidase Aminoantypirin (GOD-PAP) enzymatic photometric test. GLUT-4 levels was measured using the ELISA method, while the optical density was determined spectrophotometrically at a wavelength of 450 nm ±2 nm.

Statistical analysis

The data analysis for this research involved conducting a One-way ANOVA test followed by a Post Hoc test. The data were analyzed at a confidence levels of 95%, and a p-value less than 0.05 was considered statistically significant. The data were processed using SPSS 26 and Graph pad Prism 8 programs.

Results and Discussion

The composition of macronutrients in one's diet significantly determines their overall quality of life. Therefore, it is essential to establish an accurate formula for macronutrient composition to enhance well-being. Improper composition, such as excessive consumption of carbohydrate or fat coupled with a sedentary lifestyle, can have detrimental effects and contribute to developing metabolic syndrome symptoms.[2,12] The excessive intake of fat and carbohydrate leads to their conversion into lipids and glucose, which are stored in adipocytes and contribute to adipocyte enlargement.[12] This results in an increase not only in overall body and intraperitoneal fat weight but also in fasting blood glucose levels. Consuming high carbohydrate diet with low fibre content leads to elevated levels of postprandial blood glucose, insulin, and triglycerides while reducing HDL levels.[12] Furthermore, high carbohydrate diet has been linked to the onset of hypertension.[13] High-fat diet promotes the production of free fatty acids that hinder glucose uptake by muscles, leading to hyperglycemia. It stimulates processes such as gluconeogenesis and lipogenesis, thereby contributing to the accumulation of visceral fat.[4] Fat accumulation in visceral organs also triggers the generation of ROS, causing adipocyte peroxidation and ultimately resulting in insulin resistance.[12] Given these implications, it is important to monitor levels of GLUT-4, a protein transporter, as well as intraperitoneal fat weight following porang glucomannan supplementation.

The consumption of HFHC diet for 21 days in this research disrupts the metabolic pathways of carbohydrate and fatty acids, as shown in Figure 1. The average body weight after treatment exhibited significant differences between HFHC group and GMP25, GMP50, and GMP100 groups ($p<0.05$). These results also showed no significant difference in body weight between the normal group and GMP100 group, as well as between GMP25 and GMP50 groups ($p>0.05$). HFHC group displayed highest body weight, while GMP25 and normal groups had the lightest and lower body weight, respectively. Additionally, the supplementation of porang glucomannan at a dose of 100 mg/200 g BW did not result in a significantly different body weight compared to the normal group. Porang glucomannan at 25 mg/200 g BW and 50 mg/200 g BW groups also decreased body weight, even lighter than the normal group. The presence of insoluble fibre and the formation of a thick gel by glucomannan contributed to the delay in gastric emptying, prolonged satiety, and subsequent reduction in body weight among adults with overweight or obese.[7,8] According to the European Food Safety Authority (EFSA), consuming 3 g of glucomannan in divided doses can effectively reduce body weight in overweight adults.[14]

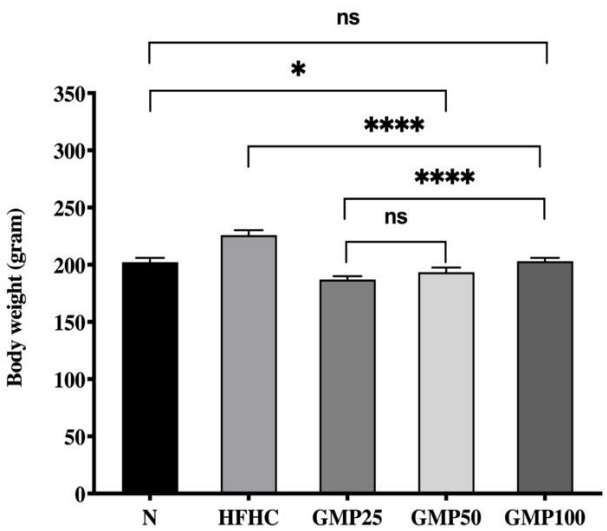

Figure 1: Body weight after treatment

Fasting blood glucose (FBG) levels in rats supplemented with porang glucomannan at a dose of 100 mg/200 g BW exhibited a similar trend to the average body weight and was significantly different compared to the normal group. As shown in Figure 2, the average fasting blood glucose levels after treatment significantly differed between HFHC group and GMP25, GMP50, and GMP100 groups ($p<0.05$). Fasting blood glucose levels in GMP25, GMP50, and GMP100 groups were lower than those in HFHC group, supporting the hypothesis that porang glucomannan can reduce fasting blood glucose levels in metabolic syndrome. High intake of carbohydrate in HFHC group leads to increased glucose uptake by the liver, resulting in elevated glucose levels in the portal vein and circulating blood.[1] However, glucomannan, composed of beta-D-glucose and beta-D-mannose polysaccharide chains linked by acetyl groups in a 1:1.6 ratio with 1,4 linkages, cannot be broken down by salivary amylase and pancreatic amylase enzymes. This condition makes glucomannan's molecular structure remain unchanged until it reaches the colon. Intact glucomannan is then fermented by colon bacteria into a prebiotic substance that improve the function of pancreatic beta cells and insulin activity,[15] ultimately reducing blood glucose levels.[12] Glucomannan also enhances viscosity by forming an impermeable gel layer in the digestive tract, preventing the interaction between complex carbohydrate and enzymes such as alpha-glucosidase and alpha-amylase. As a result, glucomannan is not hydrolyzed into glucose, leading to lower glucose levels in the intestinal mucosa. The reduced glucose levels contributes to a decrease in the expression of intestinal glucose transporters, such as SGLT-1, which reduces glucose uptake across the membrane and consequently lowers blood glucose levels in circulation.[16] These findings align with previous research conducted by Fang, who stated that glucomannan reduces blood glucose levels and lowers the risk of diabetes mellitus type 2.[8] Porang glucomannan also has a prebiotic effect.[17] Another research revealed that supplementation with inulin, another prebiotic substance, improved glucose levels, serum insulin, and HOMA-IR (Homeostatic Model Assessment of Insulin Resistance) in rats model of metabolic syndrome.[18]

GLUT-4, an insulin transporter found in adipose tissue and muscle, predicts metabolic syndrome. The enlargement of adipose cell size can trigger insulin resistance and affect GLUT-4 activity in people with metabolic syndrome.[19] As shown in Figure 3, there was no significant difference in GLUT-4 levels between the normal and GMP100 groups ($p>0.05$). However, the average GLUT-4 levels significantly differed between HFHC group and GMP25, GMP50, and GMP100 groups ($p<0.05$). Highest GLUT-4 levels was in the normal group, followed by GMP100, while the lowest was in HFHC group. The short-chain fatty acids produced from the fermentation of fibre in porang glucomannan have the potential to improve insulin sensitivity and increase GLUT-4 expression. This indicates that glucomannan supplementation may have a beneficial effect in reducing the risk of diabetes mellitus.[20] Insulin plays a role in glucose metabolism by activating the phosphatidylinositol-3 kinase (PI3K) enzyme. The activated PI3K enzyme promotes the translocation of GLUT-4 transporter proteins from cytoplasmic vesicles to the cell membrane surface, increasing glucose uptake by skeletal muscle cells and adipose tissue.[21] In a research conducted by Fatchiyah *et al*. in 2019, glucomannan supplementation in diabetic rats induced with streptozotocin (STZ) resulted in increased expression of the PI3K enzyme, which is expected to increase GLUT-4 transporter protein expression as well.[11]

GLUT-4 levels in blood were assessed using flow cytometry or ELISA techniques. In this research, the measurement of GLUT-4 levels was performed on serum samples rather than on muscle or adipose tissue. This approach was chosen because GLUT-4 transporter protein is also present on the membrane of mononuclear cells, such as monocytes and lymphocytes.[22] Unlike its activity on muscle and adipose tissue, the activity of GLUT-4 on mononuclear cell membranes is not influenced by insulin or insulin-independent mechanisms. However, levels of GLUT-4 on these membranes is sensitive to insulin stimulation, leading to an increase in GLUT-4 levels when insulin is present. Other research has suggested that alterations in GLUT-4 levels on mononuclear cell membranes may indicate the presence of insulin resistance. Additionally, it has been observed that physical activity can increase GLUT-4 levels on the surface of lymphocyte cell membranes.[20] Other research shows an increase in GLUT-4 levels on mononuclear cell membrane surface in individuals with type 2 diabetes since GLUT-4 protein stored in intracellular vesicles will be transmitted to the cell surface to be bound with insulin.[22]

In this research, the measurement of GLUT-4 levels was performed solely after the treatment period, limiting the ability to compare them with the previous outcome. Therefore, it is important to conduct further research to investigate the effects of porang glucomannan on other parameters associated with a metabolic syndrome like blood pressure, and lipid profile.

The effect of porang glucomannan supplementation on intraperitoneal fat weight significantly differed among the groups. According to the Post Hoc test results trend, the average intraperitoneal fat weight in this research is different from other parameters. Highest intraperitoneal fat weight was observed in HFHC group, while the group with fat weight closer to the normal group was GMP100. Figure 4 shows the significant differences in intraperitoneal fat weight across all groups, including the normal and GMP100 groups, normal and GMP50 groups, HFHC and GMP100 groups, GMP25 and GMP100 groups, GMP25 and GMP50 groups, and GMP50 and GMP100 groups ($p<0.05$).

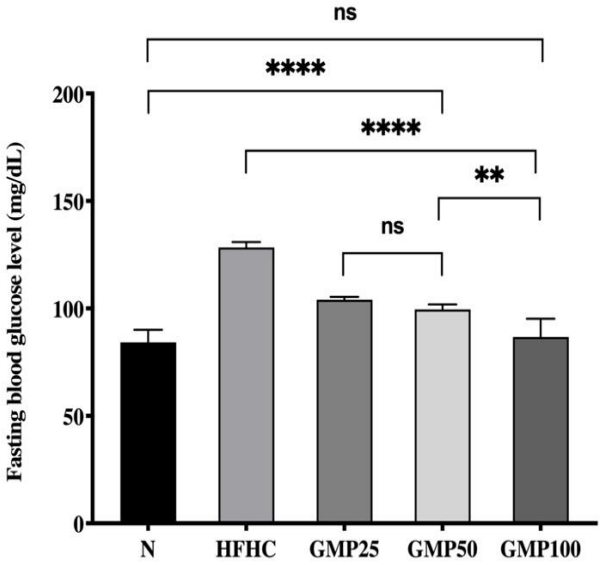

Figure 2: Fasting blood glucose levels after treatment

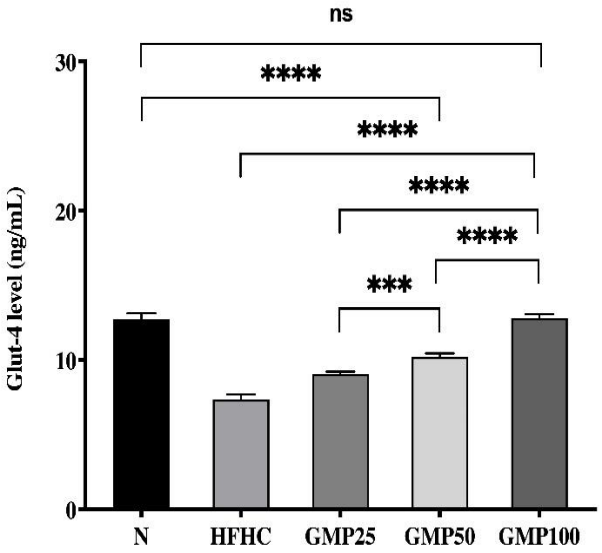

Figure 3: GLUT-4 levels after treatment

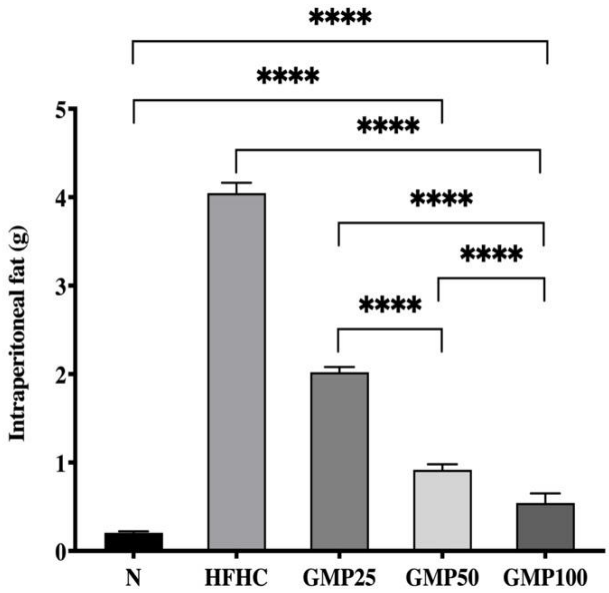

Figure 4: Intraperitoneal fat weight after treatment

According to the result, high fat and carbohydrate diet influences intraperitoneal fat weight, which serves as a parameter of metabolic syndrome. The supplementation of porang glucomannan, either after HFHC consumption or in combination with HFHC consumption, impacts intraperitoneal fat. Konjac glucomannan, a similar type of glucomannan, has been shown to reduce fat accumulation in internal organs, such as the liver, in rats fed high-fat diet and supplemented with konjac glucomannan. The thick consistency of glucomannan delays fat absorption.[21] Furthermore, glucomannan has the ability to promote the production of beneficial intestinal microflora, such as *bifidobacteria* and *lactobacillus*, which can lead to a reduction in plasma cholesterol levels in humans.[22] Other research has also demonstrated that konjac flour supplementation significantly reduces fat mass in high-fat diet and can reduce adipocyte size.[23]

Conclusion

In conclusion, the supplementation of porang glucomannan at a dosage of 100 mg/200 g BW showed the most favourable outcomes in terms of fasting blood glucose levels, GLUT-4 levels, and intraperitoneal fat weight in rats that were fed high fat and high carbohydrate diet. Additionally, body weight of the groups supplemented with 100 mg/200 g BW porang glucomannan did not significantly differ from that of the normal group.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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