Food Research 5 (3) : 152 - 162 (June 2021)
Journal homepage: http://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Consumption of jelly dessert containing porang (*Amorphophallus oncophyllus*) glucomannan and inulin along with low-calorie diet contributes to glycemic control of obese adults: a randomized clinical trial

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Article history:
Received: 21 September 2020
Received in revised form: 31 October 2020
Accepted: 1 January 2021
Available Online: 23 May 2021

Keywords:
Fasting blood glucose,
Insulin resistance,
Inulin,
Obesity,
Porang glucomannan

DOI:
https://doi.org/10.26656/fr.2017.5(3).461

Abstract

Obesity is often correlated with insulin resistance and diabetes. Obese people need to consume high fiber, high protein, low fat, and/or low calories food. In this report, the effect of the consumption of jelly containing porang glucomannan and inulin along with a low-calorie diet on the development of insulin resistance and fasting blood glucose (FBG) in obese adults were studied. A total of fifty-five volunteers of both sexes, aged 21 to 35 years, and body mass index (BMI) ≥23 kg/m^2, were randomized to 3 groups: treatment group, placebo group, and control group (not given any jelly). All participants should consume 1500 kcal daily for the first 4 weeks and 1200 kcal/day for the next 4 weeks, including 2 cups of jelly (120 g per cup) per day. Jelly with porang glucomannan and inulin maintain a normal level of insulin resistance index of individuals with normal FBG and significantly suppress insulin resistance development in individuals with FBG above normal baseline. These results significantly correlate with the intake of fiber. The FBG was maintained under normal conditions in individuals with normal baseline and improved from diabetes to prediabetes category in individuals with above normal baseline.

1. Introduction

Obesity is a long-term effect of energy consumption that is greater than the energy released by the body. World Health Organization (WHO) made it one of their priority to fix (WHO, 2003). In Indonesia, the prevalence of obesity in the adult population increased significantly from 14.8% in 2013 to 21.8% in 2018. The prevalence of overweight also increased from 11.5% to 13.6% in those 5 years. Also, central obesity increased from 2013 to 2018 (Indonesian Ministry of Health, 2018). Obesity often associated with other non-communicable diseases such as cardiovascular disease (Fujii and Sakakibara, 2012; Li *et al.,* 2019), cancer (Andersson *et al*., 2017), and diabetes (Kahn *et al*., 2006; Atasoy *et al.,* 2018). Overweight sufferers are also associated with the ease of experiencing insulin resistance (Fujii and Sakakibara, 2012) so that blood sugar homeostasis is disrupted. Therefore, obesity prevention and treatment are needed.

Treatment of obesity can be done by controlling energy intake from food, increasing physical activity, and changing lifestyles. Although, there are factors that can't be changed namely genetic factors (WHO, 2000a). A low-calorie diet is commonly practiced by people, it recommends a carbohydrate intake of 55-60% of total daily energy intake, low-fat, which is less than 30% of energy intake, and restriction of energy intake, which is around 800-1,200 kcal/day for women and 1,200- 1,500 kcal/day for men (Strychar, 2006). So that this diet asks people to reduce the amount and type of certain foods for relatively a long time (Grundy *et al.*, 2004) resulting in low compliance. Therefore, the existence of dietary support products that have the capacity to promote satiety will greatly support the low-calorie diet. One of the foods that have this capacity is soluble fiber. Foods with high soluble fiber content can manage obesity (Kovacs and Mela, 2006) by increasing gastric emptying time because of its viscosity. This can also lower glucose

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eISSN: 2550-2166 / © 2021 The Authors. Published by Rynnye Lyan Resources

absorption (McIntosch and Miller, 2001; Zheng *et al*., 2019).

Some sources of soluble fiber are hydrocolloid. Hydrocolloids are a heterogeneous group of long-chain polymers characterized by their property of forming viscous dispersions and/or gels when dispersed in water (Saha and Bhattacharya, 2010). Jelly dessert is made from hydrocolloid (mostly k-carrageenan), sugar, and water. Adding glucomannan in the manufacture of jelly would form a gel that is both strong and elastic, and can reduce syneresis (Akesowan, 2002; Dai *et al*., 2016; Dai *et al*., 2018). Besides, glucomannan can physiologically affect the lipid profile and blood sugar of the host in several studies (Vuksan *et al*., 2000; Chearskul *et al*., 2007; Kuan-Un Cheang *et al*., 2017). Hence, it can be used in body weight management and can improve glycemic control. Glucomannan reduces the production of ghrelin, a hormone that induces hunger (Chearskul *et al*., 2009) as well as can cause satiety because it can delay gastric emptying but accelerates the transit time of food in the digestive tract. Glucomannan can be extracted from the tubers and roots of the *Amorphophallus* plant. In Japan and China, konjac glucomannan is extracted from the tuber of *Amorphophallus konjac* and widely used to make various food products. In Indonesia, there are also tubers of the same genus, local people called it "porang" (*Amorphophallus oncophyllus*) which can also be extracted to porang glucomannan (Harmayani *et al*., 2014).

Another potential and popular soluble fiber widely used in food manufacturing is inulin, which can be extracted from chicory, dahlia bulbs, onions, Jerusalem artichoke, bananas, *etc.* Physiologically, according to the study of Zhu *et al*. (2019), consumption of both short and long-chain inulin can influence the lipid profile of experimental animals. Inulin can also reduce plasma triglyceride (TG) levels in obese people (Tovar *et al*., 2012). According to Russo *et al.* (2010), pasta containing inulin was able to influence TG and high-density lipoprotein (HDL) levels in humans than before treatment. The addition of inulin also can reduce fasting blood sugar, fructosamine, glycated haemoglobin (HbA1c), and homeostasis model assessment of insulin resistance (HOMA-IR) index but weren't significantly different from control.

Some researches using glucomannan and inulin in obese subjects have been conducted on experimental animals (Han *et al*., 2013; Nurliyani *et al*., 2018; Zhu *et al*., 2019) as well as human subjects (Birketvedt *et al*., 2005; Keithly and Swanson, 2005). However, there was no research that has combined glucomannan and inulin to treat obese people before. The addition of inulin into jelly dessert is aimed to increase the dietary fiber content to more than 6%, hence it complies with the Indonesian regulation for high fiber food according to National Agency for Food and Drug Control, Republic of Indonesia. Inulin was used since it had better physicochemical properties compared to other hydrocolloids (Mensink *et al*., 2015). The purpose of this study was to determine the effect of consumption of jelly dessert containing porang glucomannan and inulin along with low-calorie diet on the development of insulin resistant (TG/HDL ratio) and fasting blood glucose (FBG) in obese adults.

2. Materials and methods

2.1 Participants

Overweight and obese participants around Yogyakarta, Indonesia were recruited into the study by poster posted on social media. Individuals who responded to the advertisements were online interviewed to ensure they met the initial criteria for inclusion into the study: 18-40 years old, body mass index (BMI) over 23 kg/m^2, not an athlete, no presence or known history of major diseases, not using prescription medication and/or natural health products at least 2 weeks before the study period, neither pregnant nor lactating, not smoking, not consuming alcohols, and not having the binge eating disorders.

Potential participants meeting the initial criteria were invited to the anthropometrics (height, weight, waist circumference) measurement and diet education class. All participants gave informed written consent before participating in the research. This study was approved by the Medical and Health Research Ethics Committee (MHREC) Faculty of Medicine, Public Health, and Nursing Universitas Gadjah Mada, Indonesia (Reference number of the ethical approval letter: KE/FK/0096/EC).

2.2 Experimental designs

This study used a randomized, single-blind design. Participants were randomized into 3 groups: treatment, placebo, and control group. The treatment group was given jelly desserts containing porang glucomannan (purity of 97.28±1.02%) and inulin as much as 7.37%, while the placebo group was given jelly dessert with carrageenan at the same level as in treatment jelly, and the control group was not given any jelly for the intervention. Water, ash, total protein, lipid, carbohydrate (by difference), soluble fiber, non-soluble fiber, total dietary fiber, inulin content and calories of jelly in sequence were 81.63±0.29; 0.27±0.01; 0.16±0.01; 0.16±0.03; 17.79±0.27; 0.71±0.07;

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0.56±0.07; 1.27±0.14; 6.10±0.11%; and 70.12 kcal/100 g. While for placebo jelly in sequence were 87.80±0.08; 0.47±0.04; 0.09±0; 0; 11.63±0.04; 0.21±0.01; 0.42±0.08; 0.62±0.07; 0%; and 45.18 kcal/100 g. Jelly was distributed every week to participants to be consumed 2 cups (@ 120 g) per day at the snacking time (around 9 a.m. and 3 p.m.). All participants were educated to consume 1500 kcal daily for the first 4 weeks and 1200 kcal/day for the next 4 weeks. The blood measurements including FBG, TG, and HDL, were taken before and after treatment. To determine the food intake, food record was carried out before the study (2 working days, 1 weekend) and during the study: once every 2 weeks, with data 1 (weekdays at week 2) and data 2 (weekends at week 4) averaged to become mid data, also data 3 (weekdays at week 6) and data 4 (weekend week 8) averaged to become post data. Physical activity was recorded every 4 weeks using a short – International Physical Activity Questionnaire (short-IPAQ).

2.3 Blood glucose and lipid profile analysis

Participants were requested to fast overnight before 3 mL of blood samples were collected from the median cubital vein. Serum blood glucose and lipid profile analysis were done using Roche/Hitachi Cobas C Analyzer (Roche Diagnostics GmbH, D-68298 Mannheim) with the protocol of GLUC3 for glucose, TRIGL for triglycerides, and HDLC3 for HDL analysis.

2.4 Statistics and data analysis

The results are shown as means ± standard deviation. Comparison of pre- and post-treatments were performed with Student's *t*-test for paired values or Wilcoxon signed-rank test if the data were not normally distributed. A comparison among 3 groups was performed with ANOVA by using SPSS or Kruskal-Wallis test if the data were not normally distributed. A comparison of food intake was performed with ANOVA or Friedman test if the data were not normally distributed. Correlation tests were performed using Pearson or Spearman correlation (if data were not normally distributed). All differences were considered significant at the 5% level.

3. Results and discussion

Figure 1 shows the number of participants who joined in this research. As many as 87 people from registered applicants were qualified for this research inclusion criteria. All of them were randomized into 3 groups namely treatment, placebo, and control group.

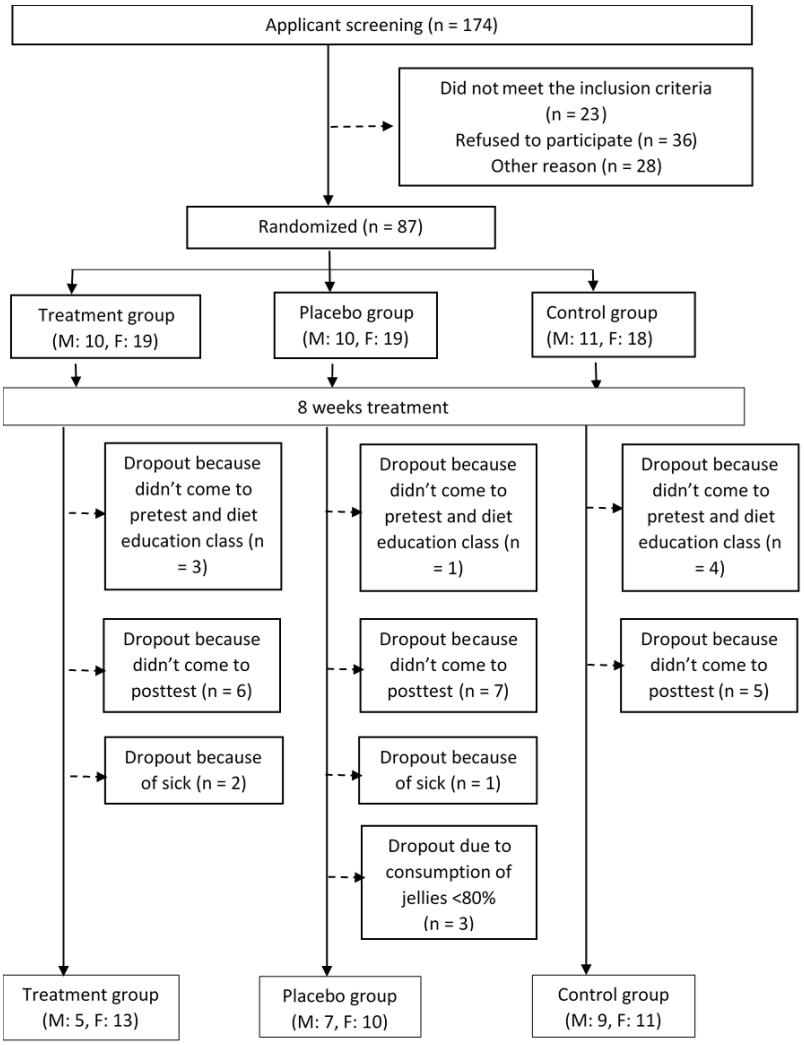

Figure 1. Flowchart of participants during the research. Remarks: M: male, F: female,

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Some participants were dropped out of this research because they didn't join the diet education class and first blood measurement, didn't attend the post blood measurement, sick, or didn't meet the jelly consumption criteria. During the research, we found an adverse event from 1 participant who suffered from diarrhea since she was very sensitive to inulin. According to Roberfroid (2005), there were 3 categories in terms of the amount of non-digestible carbohydrate people can tolerate non-sensitive persons (can consume 30 g/day or more almost without undesirable reactions), sensitive persons (can consume 10 g/day without undesirable reactions but can experience undesirable reactions at 20 g/day or higher), or very sensitive persons (already experience undesirable reactions at 10 g/day or even lower). The undesirable reactions could be flatulence, intestinal pressure, noise, and cramps, and/or diarrhea. In the end, the data were analyzed from 55 participants remaining. In the treatment group, there were 5 males and 13 female participants. The placebo group consists of 7 males and 10 female participants. The control group consists of 9 males and 11 females. The dropout rate of this study reached 36.78% because the post-test was held during the Covid-19 pandemic, so many respondents chose not to come to the hospital for blood sample collection.

The characteristic of these participants can be seen in Table 1. Body mass index (BMI) was calculated as weight divided by height (in meters) squared. From Table 1, all groups showed a BMI of more than 25 kg/m^2 and a waist circumference of more than 80 cm. It showed that all the participants included in this research were categorized as obese (for adult Asian) according to WHO (2000b). There were no statistical differences ($p>0.05$) observed in the 3 groups for initial age and anthropometric parameters.

After 8 weeks of treatments, the insulin resistance index (TG/HDL ratio) and fasting blood glucose can be seen in Table 2 and Table 3. The TG/HDL ratio can be used as an indicator of insulin resistance (Iwani *et al*., 2017; Borrayo *et al*., 2018; Yeh *et al*., 2019). Actually, direct insulin sensitivity or resistance testing is performed using the hyperinsulinemic-euglycemic clamp (HEC) method, but this method must be done in a special laboratory, time and money-consuming. HEC method is less effective for studies with many subjects and routine testing. HOMA-IR, the simpler method usually used to investigate insulin resistance, requires laboratory experts because blood samples must be immediately tested or saved at cold temperatures and plasma must be immediately frozen due to unstable insulin (Iwani *et al*., 2017). Moreover, insulin measurement is not a routine test for obese people.

Table 2 shows that in the normal baseline FBG category, the TG/HDL ratio for all groups was increased, although not significant. Clinically at the end of the study, the TG/HDL ratio exceeded the TG/HDL cut-off ratio which could potentially indicate insulin resistance. Cut-off ratio for TG/HDL to indicate an insulin resistance according to Giannini *et al.* (2011) were 2.27 in obese white adolescents; 2.26 in overweight and type-2 diabetes mellitus adults in India (Jayanthi *et al*., 2017); and 2,197 in adults and elderly Taiwanese (Yeh *et al*., 2019). In the treatment group, the increase of the TG/HDL ratio was the lowest while the highest increase was in the control group.

In the above normal baseline FBG category, the TG/HDL ratio in the treatment group significantly decreased. There was only 1 participant in the placebo group so that the TG/HDL ratio statistics before and after treatment could not be analyzed. From that one participant, there was an increase in the TG/HDL ratio. Whereas in the control group there were relatively no changes occurred. Clinically, in the placebo and control groups, after 8 weeks of treatment, the TG/HDL ratio showed a risk of insulin resistance whereas in the treatment group was not.

From Table 3, in the normal baseline FBG category, there was a decrease of FBG in treatment and control groups while in the placebo group the FBG rose even though it was not statistically significant. Clinically, FBG can be maintained under normal conditions with the help of porang glucomannan and inulin. For participants with FBG above the normal category, after 8 weeks of treatment, the FBG was decreased significantly in control groups, while in the treatment groups also

Table 1. Characteristic of participants involved in this research

	Treatment Group (n = 18)	Placebo Group (n = 17)	Control Group (n = 20)	*p*-value
Age (years)	27.89±4.89	25.88±4.36	27.50±4.30	0.386
Bodyweight (kg)	80.64±10.93	74.51±14.54	76.79±13.74	0.383
Height (cm)	159.92±8.32	159.80±7.86	160.64±8.58	0.944
BMI (kg/m^2)	31.54±3.67	29.07±4.61	29.65±4.18	0.191
Waist circumference (cm)	92.88±7.66	88.09±8.55	88.55±16.33	0.166

Values are expressed as means ± standard deviations. p-values of > 0.05 indicated that there were no significant differences for values within each line. BMI: body mass index

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Table 2. TG/HDL ratio in the beginning and end of treatments in each group

	Treatment Group	Placebo Group	Control Group	*p-value*
Normal FBG (<100 mg/dL)				
Participants (n)	15	16	15	
Beginning	2.13±0.83	2.63±1.61	2.73±1.49	0.4471
End	2.43±0.92	2.99±1.61	3.63±2.92	0.6932
Change	0.29±0.59	0.36±1.04	0.91±2.39	0.8852
p-value	0.0743	0.1823	0.1734	
Above normal FBG (≥100 mg/dL)				
Participants (n)	3	1[5]	5	
Beginning	2.09±0.03	3.95	2.60±1.59	0.5031
End	1.66±0.14	4.09	2.60±1.25	0.1891
Change	-0.43±0.16	0.14	0.00±0.79	0.6241
p-value	0.046*[3]		0.9913	

Values are expressed as means ± standard deviations. p-values of > 0.05 indicated that there were no significant differences for values within each group. [1] ANOVA, [2] Kruskal-Wallis, [3] t-test, [4]Wilcoxon signed-ranks; [5]statistical analysis to compare at the beginning and the end could not be performed; *there were significant differences (*p-values* < 0.05) within the beginning and end of treatment. TG: triglyceride, HDL: high-density lipoprotein, FBG: fasting blood glucose.

Table 3. Fasting blood glucose (FBG) in the beginning and end of treatments in each group

	Treatment Group	Placebo Group	Control Group	*p-value*
Normal FBG (<100 mg/dL)				
Participants (n)	15	16	15	
Beginning	92.40±4.78	91.50±5.99	92.67±4.25	0.799[1]
End	92.13±6.43	93.75±8.18	91.53±7.42	0.690[1]
Change	-0.27±4.10	2.25±6.72	-1.13±7.18	0.291[1]
p-value	0.805[2]	0.200[2]	0.551[2]	
Above normal FBG (≥100 mg/dL)				
Participants (n)	3	1[3]	5	
Beginning	132.33±28.11	101.00	107.2±2.77	0.153[1]
End	120.67±21.22	94.00	101.40±5.08	0.150[1]
Change	-11.67±10.97	-7.00	-5.80±4.15	0.563[1]
p-value	0.207[2]		0.035*[2]	

Values are expressed as means ± standard deviations. p-values of > 0.05 indicated that there were no significant differences for values within each group. [1]ANOVA, [2]t-test, [3]statistical analysis to compare at the beginning and the end could not be performed, *there were significant differences (*p-values* < 0.05) within the beginning and end of the treatment.

decreased but was not significant. In the placebo group, the significance could not be analyzed because it only consisted of 1 participant. However, clinically, in the negative control group FBG after treatment remained in the category of prediabetes. Whereas in the treatment group, FBG can be improved from diabetes to prediabetes. These results support previous research by Russo *et al.* (2010), soluble fiber (inulin) could decrease FBG at the end of the research, compared to baseline. Likewise, the effect of konjac-mannan on FBG in the study of Vuksan *et al.* (1999) and Vuksan *et al.* (2000).

In this study, a low-calorie diet is set at 1500 calories in the first 4 weeks and 1200 calories for the next 4 weeks. Table 4 showed participants' food intake at the beginning, middle, and end of the study for each treatment group. There were changes in energy intake from the middle to the end of the study compared to energy intake before treatment in all groups. Diet education class for a low-calorie diet were successfully carried out. There was no significant difference in energy intake for these three groups. Protein, fat, and carbohydrate intake gradually decreased until the end of the study for the three groups. There were no significant differences in protein, fat, and carbohydrate intake in the mid to end of the study when compared between groups. For fiber intake, there were significant differences in the three treatment groups until the end of the study. The highest dietary fiber intake was detected in the treatment group. This was due to the jelly dessert contain 7.37% total dietary fiber, hence consuming 2 cup of jelly dessert provide approximately 17.69 g of dietary fiber. Both placebo jelly and treatment jelly contain carrageenan, however, only treatment jelly contains glucomannan and inulin. Glucomannan and inulin, a soluble dietary fiber, could lower FBG better (Vuksan *et al.,* 1999; Vuksan *et al.,* 2000; Russo *et al.,* 2010) compare to other dietary fiber. Our study revealed that the amount of dietary fiber, as well as the type of dietary fiber, could give a different effect on the FBG.

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Table 2. TG/HDL ratio in the beginning and end of treatments in each group

	Treatment Group (n=18)	Placebo Group (n=17)	Control Group (n=20)	*p-value*
Energy (kcal)				
Beginning	1428.86±221.80^{aA}	1710.46±239.53^{bA}	1513.11±380.12^{a,bA}	0.020$^{\#1}$
Middle	1125.04±213.50^{B}	1201.23±203.36^{B}	1218.71±226.99^{B}	0.3801
End	1155.08±164.21^{B}	1142.60±295.47^{B}	1228.66±272.71^{B}	0.5251
p-value	<0.001*^{1}	<0.001*^{1}	0.022*^{3}	
Protein (g)				
Beginning	54.14±8.02^{aA}	63.91±9.94^{bA}	59.23±18.14^{a,b}	0.042$^{\#2}$
Middle	42.54±8.69^{B}	44.91±11.49^{B}	51.94±14.74	0.0561
End	47.43±11.10^{A,B}	43.35±13.97^{B}	50.84±15.28	0.2591
p-value	0.002*^{1}	<0.001*^{1}	0.2111	
Fat (g)				
Beginning	59.32±13.05^{A}	63.42±12.92^{A}	63.03±20.59^{A}	0.7051
Middle	38.84±9.68^{B}	40.96±12.59^{B}	47.95±14.99^{B}	0.0771
End	43.05±12.44^{B}	41.15±14.51^{B}	48.07±18.26^{B}	0.3691
p-value	<0.001*^{1}	<0.001*^{1}	0.014*^{1}	
Carbohydrate (g)				
Beginning	173.23±39.97^{a}	219.83±32.03^{bA}	180.16±45.80^{a}	0.002$^{\#1}$
Middle	156.82±35.48	166.58±40.66^{B}	153.85±33.87	0.5561
End	148.54±24.53	152.35±38.01^{B}	154.67±33.81	0.8441
p-value	0.0951	<0.001*^{1}	0.0551	
Fiber (g)				
Beginning	8.27±3.22^{A}	8.93±3.13	9.94±3.75^{A}	0.3191
Middle	23.04±5.78^{aB}	8.42±3.19^{b}	14.21±6.43^{cB}	<0.001$^{\#2}$
End	20.45±9.99^{aB}	8.34±3.38^{b}	11.13±5.20^{bA,B}	0.001$^{\#2}$
p-value	<0.001*^{3}	0.8491	0.019*^{3}	

Values are expressed as mean ± standard deviations.

$^{\#}$There was a significant difference (*p-values* < 0.05) within each group, values with different lowercase superscript within each line indicated that there were significant differences for values within each group (^{1}ANOVA; ^{2}Kruskal-Wallis).

*There was a significant difference (*p-values* < 0.05) within the beginning, middle, and end of treatments, values with different uppercase superscript within each column indicated that there was a significant difference for values within the beginning, middle, and/or end of treatments (^{1}ANOVA; ^{3}Friedman test).

Physical activity can also influence the results of this research. Table 5 shows the participants' physical activity during the research, reported as multiples of the resting metabolic rate (MET) in min/week and grouped into inactive (<700 MET min/week), minimally active (701-3000 MET min/week), and HEPA active or health-enhancing physical activity, a high active category (>3000 MET min/week). The majority of participants' physical activity was in category 2 (minimally active). In each category, there were no significant differences in physical activity between groups (p>0,05). This means that if there were changes in FBG and/or TG/HDL ratio were not associated with the difference in physical activity of participants among the groups.

Table 2 shows that there was a significant decrease in TG/HDL ratio in the treatment group. The correlation test is carried out, intake of energy, protein, fat, and carbohydrate in these groups and categories were not significantly correlated with a decrease of the TG/HDL ratio. The one that correlated significantly (p<0.01) with it was the intake of dietary fiber. Fiber intake in the treatment group was significantly different at the beginning and end of the study and significantly different from other groups (Table 4). Dietary fiber in jelly consumed 2 cups/day increased fiber intake in the treatment group so that it can significantly correlate with the TG/HDL ratio. The Spearman rho's correlation (r) was -1,000. This means that the higher fiber intake was perfectly correlated with a decrease in the TG/HDL ratio.

In this research, we used a combination of two soluble dietary fibers namely porang glucomannan and inulin, to make jelly. The treatment had a good effect on the TG/HDL ratio and FBG of the participants. According to Weickert and Pfeiffer (2018), soluble fiber and insoluble fiber have different effects on blood sugar and the development of insulin resistance, although both have a satiating effect and can reduce body weight. Soluble fiber has the majority effect on postprandial effects to maintain glycemic control and insulinemic responses (Russel *et al*., 2016). The result is that it can control blood sugar homeostasis and prevents insulin resistance (Chearskul *et al.*, 2007; Kuan-Un Cheang *et*

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Table 5. Physical activity of the participants during the research

Categories	Treatment Group	Placebo Group	Control Group	*p-value*
Inactive (<700 MET min/week)				
n	1	3	4	
Physical activity	574.25±0.00	239.83±168.10	395.46±147.46	0.239
Minimally active (701-3000 MET min/week)				
n	14	10	11	
Physical activity	1781.00±664.44	1936.62±640.94	1461.45±654.79	0.246
HEPA active (>3000 MET min/week)				
n	3	4	5	
Physical activity	5279.33±2875.09	4330.50±1370.46	4957.67±1764.31	0.807

The results of physical activity are represented as the mean in MET min/week ± standard deviations. *p-values* > 0.05 indicated that there were no significant differences for values within each group (significance analysis using ANOVA). MET min/week: multiples of the resting metabolic rate (minutes/week). HEPA: health-enhancing physical activity.

al., 2017; Weickert and Pfeiffer, 2018). The mechanism is through its ability to increase intraluminal viscosity. This has an impact on slowing gastric emptying. The rate of carbohydrates into the small intestine becomes evenly distributed and causes the blood glucose curve to become flat, with no surge in blood sugar, and a surge in insulin secretion can be prevented (McIntosh and Miller, 2001; Keithly and Swanson, 2005). As a result, there is an improvement in blood glucose homeostasis (Vuksan *et al.*, 2000; Chearskul *et al*., 2007; Weickert and Pfeiffer, 2008). Also, due to the intraluminal viscosity, the bioavailability of starch is low and reduces the accessibility of the α-amylase enzyme. As a result, the diffusion rate of starch results in lower digestion, blood sugar (postprandial) does not increase sharply (Leclere *et al*., 1994; Goff *et al.,* 2018). Consumption of soluble fiber can reduce hunger, increase fullness, and reduce the desire to eat compared to control (Kacinik *et al.,* 2011; Monsivais *et al*., 2011), through the regulation of GLP-1, PYY, and CCK hormones (Rivellese *et al.,* 2012; Goff *et al.,* 2018). In the previous studies of our team, it was found that porang glucomannan and inulin in our product could lower the energy and fat intake significantly (in the next test meal) compared to placebo jelly (without porang glucomannan and inulin) and konjac glucomannan jelly. Reduced food intake means there will be an improvement in blood sugar metabolism. According to Rivellese *et al*. (2012), there is also a mechanism in which undigested carbohydrate is able to be fermented in the colon, changing the profile of microbiota of the colon. These prebiotic properties are found in porang glucomannan (Harmayani *et al.,* 2014) and inulin (Roberfroid, 2005; Hiel *et al*., 2019). Changes in the microbiota of the colon can reduce subclinical inflammation and increase SCFA so that it can increase glycolysis and reduce glucose production by the liver. Both of these means will improve glycaemia control.

In this study, the correlation between the TG/HDL ratio and FBG was not significantly related (P>0.05). However, the Spearman rho's correlation coefficient is positive (r = 0.010), if there were an increase in the insulin resistance index (TG/HDL ratio), then it was correlated with an increase in fasting blood sugar, even though the relationship is very weak. According to theory, in a state of insulin resistance, the target cells fail to respond to insulin so that more insulin concentration is required to respond to glucose than in normal condition. It causes impaired glucose uptake in muscles and increased gluconeogenesis by the liver. As a result, hyperglycemia occurs, both in the fasting and postprandial states (Ormazabal *et al*., 2018).

From the results of the study, the effect of glycemic control was more pronounced in the treatment group, whereas in the control group (diet was controlled but not given any jelly) there was relatively no change. Therefore, the combination of glucomannan porang and inulin in this jelly is recommended to support a low-calorie diet.

There was an interesting result from the correlation test of FBG changes in the control group (above normal baseline FBG). Protein intake was found to be a factor that correlates with changes in FBG ($p<0.05$). The relationship was very strong and negative in values (r = -0.899). This means that if there is a decrease in FBG then it is caused by the increase in protein intake. Proteins that have been broken down into amino acids can be used to synthesize various body proteins through anabolic reactions or can be converted to pyruvic acid which enters carbohydrate metabolism to produce energy. Several studies are still controversial about the contribution of protein in glucose metabolism. According to the research of Gannon et al. (2001), protein intake only produces a small amount in the body's blood sugar. However, some amino acids such as leucine and arginine can stimulate insulin secretion so that they can reduce plasma glucose concentrations (Yang *et al.*, 2010; Manders *et al.,* 2012).

The mechanism according to Manders *et al*. (2012) is leucine enters the TCA cycle (tricarboxylic acid cycle)

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of carbohydrate reserves as acetyl-CoA. Leucine previously converted by transaminases reaction to α-ketoisocaproic (KIC). In addition, leucine can also activate glutamate dehydrogenase (GDH) which converts glutamate (from the amino acid glutamine that enters the body) to α-ketoglutarate which enters the TCA cycle. Whereas the amino acid alanine enters and is converted to pyruvic acid and enters the TCA cycle. This metabolism produces ATP thereby increasing the intracellular ATP/ADP ratio. It causes the depolarization of the plasma membrane through the closure of ATP-sensitive K^+ channels. This depolarization makes Ca^{2+} able to enter intracellular and then increases insulin exocytosis (secretion). The amino acid arginine can also directly depolarize plasma membrane of β-cells. So that, the types of amino acids in proteins affect the glucose metabolism in the body.

4. Conclusion

After 8 weeks of treatment, jelly dessert containing porang glucomannan and inulin gave a good effect on the development of insulin resistance especially in obese people with FBG above the normal range. The combination of both is recommended to support a low-calorie diet.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

This study was supported by "Riset Inovatif Produktif (RISPRO)"-grant from the Ministry of Finance, Republic of Indonesia (Grant No: PRJ-40/ LPDP/2018). We wish to say thank you also to Rumah Sakit Akademik UGM where this research conducted and PT. Niramas Utama where jellies were made. We also thanked to Ayu Nindhitasani Bhakti Addini, Rissa Saputri, Rizka Qurrota'yun, and Puspita Mardika Sari as technical assistant of this project.

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