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Research Article

The Effect of Healthy Boba Pearl Drink on Post-Prandial Glucose

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ABSTRACT

This study was a randomized controlled trial using a repeated experimental design with a pre-test and a post-test control group. The study subjects were women of childbearing age, aged 20–30 years, with no diagnosed chronic diseases and with baseline fasting blood glucose levels less than 125 mg/dL. Participants were randomly assigned to treatment and control groups. The treatment group received 350 mL of healthy boba drink, while the control group received 350 mL of commercial boba drink. The healthy boba drink was made by mixing 67 mL of fresh milk, 133 mL of soy milk, 1 g of stevia sweetener, 100 g of red dragon fruit, and 40 g of healthy boba pearls. It contained 215 kcal of energy, 8.82 g of protein, 8.90 g of fat, 30.78 g of carbohydrate, and 1,808 g of fiber. Each group had an initial fasting blood glucose levels measurement before the intervention, and postprandial glucose levels were measured at the end of the intervention (one time of intervention). The collected data were analyzed univariately to analyze the effect of treatment on postprandial glucose using the independent t-test. The result indicated that the subjects in the treatment group and 96.2% of the subjects in the control group had fasting glucose levels less than 126 mg/dL. Both participants in the control and treatment groups had postprandial glucose levels less than 200 mg/dL. The mean glucose level was 89.49 mg/dL in the treatment group and 92.57 mg/dL in the control group. The study results showed that the treatment group that consumed the healthy boba drink had a lower average postprandial glucose level than the control group. The statistical test results showed that there was a significant effect of healthy boba drink consumption on postprandial glucose levels in the treatment group ($p<0.000$). It is concluded that the healthy boba drink intervention had a significant effect ($p<0.000$) on lowering blood glucose by 5.82 mg/dL after the initial treatment. The results of this study are a major first step for future work to develop a healthier boba drink.

INTRODUCTION

The prevalence of prediabetes, especially the prevalence of IGT, in the young age group (15–24 years) in Indonesia has increased drastically every year (Paramita & Lestari 2019). The term of prediabetes is significant because of its widespread occurrence and the heightened likelihood of development to overt Type 2 Diabetes Mellitus (T2DM) in individuals with prediabetes (Schlesinger *et al.* 2022). There has been a significant increase in the number of diabetes cases in Indonesia, with the reported cases increasing from 10.7 million in 2019 to 19.47 million in 2021 (International Diabetes Federation 2021). According to the 2018 Basic Health Survey (Riskesdas) in Indonesia, the rate of diabetes cases among women was 1.8% higher than among men, indicating a slight increase from 2013, when the difference was only 1.7% (MoH

RI 2013 & 2018). Inadequate management of T2DM can lead to the onset of non-communicable conditions such as cardiovascular disease, stroke and renal failure. The Indonesian government has pledged to prioritize the prevention and treatment of non-communicable diseases.

Boba, or bubble tea, is particularly popular in large urban centers with significant populations of Asian American Pacific Islander (AAPI) youth and young adults (Min *et al.* 2017). It has emerged as a significant player in the global beverage industry and has garnered considerable attention in mainstream culture. The global market value of boba tea was recorded at USD2.15 billion in 2019, increasing to USD2.3 billion in 2020. It is projected to reach USD4.3 billion by the year 2027 (Chia *et al.* 2023). Boba tea consists of whole milk, sweetened condensed milk, tea, sugar, and chewy tapioca pearls, which are usually mixed with sweet chocolate or soaked in liquid palm sugar. It has a distinctive taste and chewy sensation that can be addictive (Fajrin *et al.* 2022).

Due to its extremely high sugar content, boba tea, despite its popularity, poses a potential health risk that can cause many negative side effects. Therefore, boba milk tea should be consumed with caution as it is not the healthiest drink available (Zubairi *et al.* 2023). Several attempts have been made by researchers to find alternative solutions to the problem of T2DM, including by the development of innovative boba drink products, which are originally high in energy and fat and low in fiber. Our previous study resulted in a healthier boba drink that was low in energy and fat and high in fiber. The healthy drink with healthy boba pearls used in this study was the modification of the commercial boba tea with a ratio of tapioca flour, porang glucomannan flour and kappa carrageenan of 7:2:1 and passed an acceptability test with a relatively high acceptability level (≥75%) (Fajrin *et al.* 2022). Porang (*Amorphophallus muelleri* Blume) is an ideal dietary choice due to its high fiber content and low cholesterol levels, making it suitable for those following a diet and those with hypertension and diabetes mellitus. Moreover, porang tubers contain glucomannan, which is known for its ability to reduce blood glucose and cholesterol levels (Suryana *et al.* 2022). Therefore, a study is needed to determine whether a drink containing healthy boba pearls has an effect on increasing postprandial glucose or not.

METHODS

Design, location, and time

A randomized controlled trial study using an experimental design with a pre-and post-test control group and was conducted in Pedurungan Tengah Urban Village, Pedurungaan District, Semarang City, Central Java Province from August to October 2023. This study has received ethical approval from the Health Research Committee (KEPK) of Semarang Health Polytechnic of the Ministry of Health with reference number 1134/EA/KEPK/2023.

Sampling

In this study, 54 subjects were randomly assigned in equal numbers to the treatment and control groups by lottery. Participants who got the odd number in the lottery entered the treatment group and those who got the even numbers in the lottery entered the control group. The target population for this research was women of childbearing age in Pedurungan District, Semarang City. Samples were collected using the consecutive sampling method. The inclusion criteria for this study were healthy women of childbearing age, aged 20–30 years, with no diagnosed chronic diseases and with baseline fasting blood glucose levels less than 125 mg/dL.

Healthy boba drink preparation

The formulation used to prepare the healthy boba drink for the treatment group in this study was based on modifications of Fajrin *et al.* (2022). Healthy boba pearls were prepared using tapioca flour, porang glucomannan flour and kappa carrageenan in a ratio of 10:2:1 (a mixture of 11.25 g of tapioca flour, 2,625 g of porang glucomannan flour and 1,125 g of kappa carrageenan). The boba pearls were boiled in boiling water for 25 minutes. The drink was made by mixing 67 mL of fresh milk, 133 mL of soy milk, 1 g of stevia sweetener, and 100 g of red dragon fruits until homogenized, adding 40 g of healthy boba pearls, and packaged in a 350 mL plastic cup. Referring to laboratory analysis of previous study by Fajrin *et al.* (2022), the drink with healthy boba pearls for the treatment group contained 215 kcal of energy, 8.82 g of protein, 8.90 g of fat, 30.78 of carbohydrate and 1,808 g of fiber.

The placebo beverage for the control group was prepared by mixing 25 g of instant milk tea, 200 mL of water, 20 mL of evaporated milk, and 10 g of palm sugar, and adding 40 g of boiled instant boba pearls, then packaged in a 350 mL plastic cup. According to the laboratory analysis of the previous study by Fajrin *et al.* (2022), the placebo beverage contained 215 kcal of energy, 0.66 g of protein, 2.34 g of fat, 68.69 g of carbohydrate and 0 g of fiber.

Data collection

The first step in data collection was to screen the population based on predetermined subject criteria. Participants who met the inclusion criteria were divided into treatment and control groups. All subjects had an initial fasting blood glucose levels measurement before the intervention and then then their post-prandial blood glucose levels were measured again two hours after the intervention. The treatment group received 350 mL of healthy boba drink, while the control group received 350 mL of commercial boba drink.

Fasting blood glucose and postprandial glucose were determined by blood tests performed at baseline and at the end of the intervention. Participants were instructed to visit an established and registered clinical laboratory to undergo these tests and have their blood glucose levels assessed. A trained technician at the laboratory collected blood samples by venipuncture. Biochemical analysis was performed using the Indiko™ Plus Clinical Chemistry Analyzer. The results of these clinical assessments were then e-mailed to the researchers. Data on subject characteristics (medical history, nutritional status, physical activity, and dietary intake) were obtained by completing a questionnaire, while macronutrient and fiber intake during the last 24 hours before treatment was obtained by direct interview using the 24-hour recall method. The nutritional status of the participants was determined by measuring body weight and height.

Data analysis

Categorical variables (medical history, nutritional status, physical activity, and medication use) obtained are presented in the form of proportions, while numerical variables (blood glucose in the treatment group and control group before and after given treatment) are presented in the form of mean, median, standard deviation, and minimum-maximum values. Data on nutritional status, macronutrient intake, and fiber intake of subjects in the treatment and control groups were tested using independent t-test. The confidence interval and significance level for the independent t-tests were set at 95% and 0.05, respectively.

RESULTS AND DISCUSSION

Fifty-four subjects were screened, but only 52 subjects met the inclusion criteria. Two subjects were excluded from the control group because they had fasting blood glucose greater than 125 mg/dL, so the number of subjects in the treatment group was 27 and in the control group was 25 (Table 1). The subjects were evenly distributed and there were no significant differences between the two groups.

Characteristics of blood glucose levels

The results of the examination of blood glucose levels for both groups are presented in Table 2. All subjects in the treatment group and 100% of subjects in the control group had fasting glucose levels less than 126 mg/dL. Both participants in the control and treatment groups had postprandial glucose levels less than 200 mg/dL. The mean fasting glucose level was 89.49 mg/dL in the treatment group and 91.12 mg/dL in the control group.

Body mass index

The average BMI in the treatment group was 22.39 kg/m^2 and in the control group was 22.45 kg/m^2 with the category of normal nutritional status. There was no difference in BMI between the two groups ($p>0.000$).

Macronutrient and fiber intake

Macronutrient and fiber intake before treatment was collected by interview using a 24-hour recall method. Table 3 shows the intake of macronutrients and fiber in both groups. The mean energy intake for the treatment group was 1,498 kcal and for the control group was 1,455 kcal. Energy adequacy based on the Recommended Dietary Allowances (RDA) means that the energy requirement for women between 20 and 30 years of age is 2,250 kcal. In terms of energy adequacy based on the RDA, both the treatment and control groups met about 65–67% of the RDA. The protein intake of the treatment group was 58.6 g and that of the control group was 56.0 g. The

Table 1. Characteristics of subjects

Variable	Treatment group (n=27)	Control group (n=25)	*p*
	n (%)	n (%)	
History of nutritional counselling			
Yes	11 (40.7)	11(44)	
No	16 (59.3)	14 (56)	
History of Diabetes			
Yes	4 (14.8)	3 (12)	
No	23 (85.2)	22 (88)	
Frequency of exercise			
<3 times/week	25 (92.6)	25 (100)	
≥3 times/week	2 (7.4)	0 (0)	
Nutritional status (by BMI)	22.38±3.56	22.30±3.36	0.931
Underweight	2 (7.4)	4 (16)	
Normal	14 (51.9)	11 (44)	
Overweight	7 (25.9)	4 (16)	
Obesity	4 (14.8)	6 (24)	

BMI: Body Mass Index

protein adequacy based on the RDA is 60 g, so the protein intake of the treatment and control groups was 93–97%.

Effect of healthy boba pearl drink consumption on postprandial glucose levels

The results of the study on the effect of consumption of the drink containing boba pearls on postprandial glucose levels in the control and treatment groups are presented in Table 4. The results reported that the treatment group that consumed healthy boba drink had a lower average postprandial glucose level than the control group. The statistical test results revealed that there was a significant effect of healthy boba drink consumption on postprandial glucose levels in the treatment group ($p<0.000$).

Boba drink is a type of modern drink that has emerged among Indonesians in recent years. It is a drink made of black tea mixed with fruit and milk flavors, and topped with small, chewy, dark tapioca pearls called boba, which is usually drizzled with brown sugar. Boba milk tea is served with high-calorie sugar, with sugar content ranging from 38 to 96 g of granulated sugar and energy content ranging from 299 to 515 kcal, depending on size and additional toppings. Moreover, some boba drinks contain additional sugar in the form of sweeteners such as High Fructose Corn Syrup (HFCS) or sucrose, which are commonly found in Sugar-Sweetened Beverages (SSBs). High Fructose Corn Syrup (HFCS) is particularly 55% fructose and 45% glucose, while sucrose is 50% fructose and 50% glucose. Increased intake of added sugars is the leading cause of metabolic diseases, such as type 2 diabetes. Unfortunately, sweetened drinks are high in sugar, so they are high in calories, but they reduce satiety and have low nutritional value (Veronica & Ilmi 2020).

Porang, or Amorphophallus muelleri Blume, has tubers that contain glucomannan,

Table 2. Characteristics of blood glucose levels

Glucose levels (mg/dL)	Treatment group (n=27)	Control group (n=25)	*p*
	Mean±SD	Mean±SD	
Fasting glucose levels	89.49±5.12	91.12±7.44	0.000
Postprandial glucose levels	83.67±4.89	94.40±17.84	0.000

SD: Standard Deviation

Table 3. Characteristics of macronutrient and fiber intake

Intake	Treatment group (n=27)		Control group (n=25)		*p*
	Mean±SD	Min–Max	Mean±SD	Min–Max	
Energy (kcal)	1,498±413.8	980–2,559	1,437±413.8	918.40–2,410.6	0.581
Protein (g)	58.6±24.9	7.2–107.5	56.0±22.9	22.80–134.78	0.740
Fat (g)	54.5±21.9	21.4–111.4	52.5±28.6	21.70–160.20	0.595
Carbohydrates (g)	170.8±73.6	24.6–377.1	177.3±58.8	85.00–344.10	0.784
Fiber (g)	7.02±3.46	1.1–12.3	4.7±2.7	0.10–13.10	0.012*

SD: Standard Deviation; Min: Minimum; Max: Maximum

Table 4. Postprandial glucose levels after consuming boba

Glucose levels (mg/dL)	Treatment group (n=27)	Control group (n=25)	*p*
	Mean±SD	Mean±SD	
Fasting glucose levels - Before intervention	89.49±5.12	91.12±7.44	0.000
Postprandial glucose levels - After intervention	83.67±4.89	94.40±17.84	0.000
p	0.000	0.380	

SD: Standard Deviation

a water-soluble fiber that can lower blood cholesterol and blood glucose levels and reduce body weight (Nissa & Madjid 2016). This fiber has health benefits and can serve as a dietary replacement for individuals dealing with obesity, type 2 diabetes, and dyslipidemia. Porang flour, a low-fat, high-fiber food ingredient, contains 64.98% glucomannan, 2.5% dietary fiber, and 0.02% fat (Thelmalina & Wirasuta 2023; Mahirdini & Afifah 2016; Fatchiyah *et al.* 2019). Glucomannan, a highly soluble dietary fiber with a dry matter content of 15–64%, could lower blood glucose levels by forming a thick gel that slows gastric emptying in the small intestine. This fiber fermentation, facilitated by the colonic microbiome, stimulates the production of GLP-1, an incretin hormone (Thelmalina & Wirasuta 2023).

Soy is a low-glycemic food ingredient with isoflavones, dietary fiber and antioxidant properties. It helps control blood glucose levels, protects pancreatic cells from oxidation, and regenerates damaged cells. Soy milk has been shown to help control blood glucose levels in people with T2DM (Pramono *et al.* 2020; Yulifianti *et al.* 2018). Soy protein contains glycine and arginine, amino acids that stimulate pancreatic beta cells to regulate blood glucose levels. These amino acids increase insulin secretion and glucose transport to the body's cells. The main isoflavones, genistein and daidzein, act as antioxidants and inhibitors of enzymes that prevent rapid glucose absorption. However, some studies have suggested that the effect of soy isoflavones on glucose levels is not statistically significant (Pertiwi & Murbawani 2012; Barańska 2021). Red dragon fruit could be used as a substitute food to lower blood glucose levels and inhibits oxidative reactions because it contains high levels of vitamins and antioxidants. Its flavonoid content prevents damage to beta-cells and increases insulin sensitivity. The fruit's fiber binds water, reducing glucose levels and triggering insulin production. Several studies showed that red dragon fruit was effective in reducing fasting blood glucose levels in individuals with overnutrition (Ayuni 2020; Fadlilah *et al.* 2020).

The results of the reduction of postprandial glucose levels in this study are presented in Table 4. There was a significant effect of consuming healthy boba drink on postprandial glucose levels in the treatment group ($p<0.000$), as indicated by the mean fasting glucose level of the treatment group being 89.49 mg/dL, and the mean postprandial glucose level after consuming healthy boba drink being 83.67 mg/dL, so there was a decrease in blood glucose by 5.82 mg/dL. This is directly proportional to the study results of Thelmalina and Wirasuta (2023), which found the average initial fasting blood glucose level in the treatment group that received a high fructose diet and 200 mg of porang flour. The results showed that there was a decrease of 176 mg/dL (57.7%)

in mice given a high fructose diet and 200 mg porang flour group, which was a quite significant decrease in blood glucose levels (Thelmalina & Wirasuta 2023). A study conducted by Laboro *et al.* (2023) proved that the administration of 200 mL of soy milk for seven days resulted in the reduction of blood glucose in diabetic patients in the treatment group, as evidenced by the results of the average blood glucose in the treatment group before the initial treatment from 213.30 mg/dL to 105.40 mg/dL after the initial treatment (Laboro *et al.* 2023). Apart from that, a study on dragon fruit conducted by Nisa *et al.* (2021) found that administration of dragon fruit juice for seven days resulted in significant changes in blood glucose levels in people with diabetes mellitus (p=0.026), where the average blood glucose level before treatment was 305.7 mg/dL and decreased to 241.7 mg/dL after treatment. It is also known that 9 out of 15 subjects (60%) had normal blood glucose levels after consuming dragon fruit for seven days (Nisa *et al.* 2021).

For people with diabetes mellitus, it is recommended to consume 20 g–35 g of fiber per day, with a minimum recommendation of 25 g per day. Consumption of less than 25 g of fiber per day is considered low fiber intake, while consumption of 25 g or more of fiber per day is considered adequate fiber intake (Soviana & Maenasari 2019). An analysis of 11 pooled RCTs (13 comparisons) with a minimum 8-weeks duration examined the effect of dietary fiber on glycemic control in T2DM patients. The inclusion of fiber-rich foods or fiber supplements in the diet resulted in a significant 0.55% reduction in HbA1c levels, equivalent to an average reduction of 4.75%. In addition, fasting plasma glucose levels lowered by 10 mg/dL. Soluble fiber's physiological effects include modulation of the postprandial glycemic response through gastric and small bowel functions. These effects include delayed gastric emptying, altered gastrointestinal myoelectric activity, delayed small bowel transit, decreased glucose diffusion through the unstirred water layer, and decreased α-amylase accessibility to substrates due to increased gut viscosity (Sillva *et al.* 2013). The reduction in blood glucose levels in this current study is related to the use of alternative food ingredients to make a healthy boba drink to reduce blood glucose levels, which contains fiber per serving of 1.808 g (9.04% of the daily fiber requirement).

CONCLUSION

The results of this study showed that the administration of healthy boba pearl drink to the treatment group resulted in a significant reduction in postprandial glucose levels of the group (p<0.000). The average fasting glucose levels of the treatment group before the intervention was 89.49 mg/dL, and after the administration of healthy boba pearl drink, the average postprandial glucose level decreased to 83.67 mg/dL. There was a 5.82 mg/dL decrease in postprandial glucose levels after the initial treatment.

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DECLARATION OF CONFLICT OF INTERESTS

Authors declares no conflicts of interests.

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