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Post Prandial Blood Glucose Control Through the Consumption of Moringa Leaf-Based Snacks

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ABSTRACT

This study aims to determine the effect of snacks made from Moringa leaves on blood glucose in DM patients. This research was conducted at the Health Polytechnic of Mataram's Food Technology Laboratory and the Mataram City Hospital, using a quasi-experimental design involving 30 subjects aged >30 years. The subjects' average blood glucose level was >200 mg/dl, were consuming oral hypoglycemic medication, and had been treated at the Mataram City Hospital. Also, the subjects were type 2 DM patients, and were divided into control and treatment groups with an equal number at 15 per group. In the treatment group, three types of *Moringa oleifera* food made from fresh Moringa leaves were given for 15 days. The three types of snack that were made were cupcake, pudding, and tea. The measurements of blood glucose level were done pre- and post-intervention.The statistical analysis was performed which includes normality test, independent t-test, and paired t-test. The paired t-test, through the Wilcoxon Rank Test of the mean Preprandial Glucose Level (Preprandial GL), shows the values of 231±98.4 mg/dl (treatment group) and 310±117 mg/dl (control group) which indicates that there is not any difference between the two groups with p=0.245. In contrast, the Post Prandial Glucose level (Postprandial GL) which were 267±94.3 mg/dl (treatment group) and 330±127 mg/dl (control group) showed a difference between the two groups at p=0.001. Therefore, snacks made from Moringa leaves lowered Postprandial GL and have implications in the subjects' glucose control.

Keywords: glucose level, moringa leaf, postprandial glucose, snacks

INTRODUCTION

Within five years, Diabetes Mellitus (DM) prevalence in West Nusa Tenggara (NTB), referring to year 2013, experienced an increase of 0.8%, i.e., from 0.8% to 1.6% within the ≥15 years old population group (Ministry of Health Republic of Indoensim 2018). Meanwhile, in 2019, DM cases at Mataram City Hospital amounted to 111 cases, a significantly larger amount compared to 2018 at 75 cases. The patients were treated through diet therapy due to the absence of side effects. Also, diet therapy is chosen because it is relatively easy and inexpensive (Yusasrini & Jambe 2018). One of the nutritional therapies used in DM treatment is the provision of functional food. Moringa leaves are considered to be among functional food ingredients (BB-Pascapanen 2020). In Mataram, Moringa is normally used as a hedge plant, and its leaves are only occasionally processed elaborately into food by the community. *Moringa oleifera* leaf extract has an anti-hyperglycemic activity by inhibiting the alpha glucosidase enzyme on the surface of the small intestine. Moreover, monosaccharide is a simple carbohydrate that is absorbed by the small intestine. Meanwhile, slowing the breakdown of carbohydrates into monosacharides can reduce hyperglycemia, especially in two hours after eating (postprandial) (Adisakwattana 2011; Alethea & Ramadhian 2015). The Moringa leaves contain various polyphenols and flavonoids, including quercetin-3- glycoside (Q-3-G: 1494.2 μmol/100 g dry weight, everyday (1446.6 μmol/100 g dry weight), kaempferol glycosidase (394.4 μmol/100 g dry weight) and chlorogenic acid (134.5 μmol/100g dry weight). Q-3-G polyphenol is able to influence blood glucose regulation by changing the input of glucosamine in the small intestinal mucosa, prolonging glucose absorption, and thereby lowering the level of glucose which enters the blood (Gopalakrishnan *et al.* 2016). Studies on experimental animals have reported that Moringa

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leaf extract significantly reduced the blood glucose of mice (Radiansah *et al.* 2013). Complementary food, according to PERKENI (2015), needs to contribute 10–15% of the total calories needed per day. Nevertheless, complementary food which are made from vegetables are still lacking in numbers and varieties, especially those designed to be consumed by people with diabetes mellitus. Therefore, complementary food production that is made specifically for people with diabetes is important to be explored. It could provide tasty and safe food that can be used as a treatment to control the blood glucose level. Therefore, this study aims to determine the effect of Moringa leaf-based complementary food on (fasting and 2 HPP) blood glucose (levels) of Type 2 Diabetes Mellitus patients at Mataram City Hospital.

METHODS

Design, location, and time

The present study entails a quasi-experimental design where subjects were selected through purposive sampling based on criteria established by the authors. The subjects were divided into two groups, namely the control and the treatment. Furthermore, this study was conducted at the Laboratory of Food Technology, Nutrition Department of Health Polytechnic of Mataram and Mataram City Hospital in July-November 2019.

To ascertain that the reduction in glucose level was due to the research intervention, the difference between the reduction in glucose level before and after the intervention in the control and treatment group was calculated. When the number is higher in the treatment group, then the intervention is proven to reduce blood glucose level.

The preparation of moringa leaf-based complementary food

Fresh Moringa leaves were obtained from Moringa gardens located in the village of Gebang, Mataram City. Furthermore, snacks processing and production were performed at the Laboratory of Food Technology, Nutrition Department of Health Polytechnic of Mataram. The types of food that were made from Moringa leaves were cupcake, pudding, and tea. Fresh leaves were integrated into each serving of the complementary snacks were as much as 150 g, which is equivalent to 20 g of dried Moringa leaf powder. Subsequently, the leaves were processed into cupcake, pudding, and tea. The snacks were given daily for 15 days, and their nutritional compositions were measured based on the recommended snack serving of 10–15% of total daily calorie needs.

Sampling

Prior to the intervention, this study was assessed, approved, and issued an Ethical Approval (LB) license number LB.01.03/1.1/3356/2019 from the Mataram Medical Polytechnic Health Research Ethics Commission as well as 079/06/KEP/2019 of the Mataram City Hospital Ethics Commission. The subjects were 30 people who were selected with the criteria of >30 years old and had blood glucose level of >200 mg/dl. They had a history of being treated at Mataram City Hospital in 2019 and were selected from outpatients records in July–September 2019. Furthermore, the subjects were grouped into treatment and control group by employing simple random sampling. The subjects in the treatment group resided in one sub-district (Selaparang), and the control subjects were from another sub-district (Sandubaya). All subjects had consumed anti-hyperglycemia drugs (metformin, glibenclamide, sitagliptin) regularly and consistently.

Data collection

The data collection was done through interviews to obtain personal data (age, medicine, consumption), measurements of weight and height to determine the nutritional status and needs, as well as the measurement of preprandial (fasting blood glucose) and postprandial glucose levels (blood glucose 2 hours postprandial). The glucose level was evaluated using the enzymatic method, where the subjects were encouraged to fast for 8–10 hours before the preprandial glucose examination. The enzymatic method is a method that is commonly used in checking blood glucose levels. The method uses GOD-PAP with DialLINE brand. At a wavelenght of 546 nm, the absorbance reading was measured using premium Biolis 24i (Tokyo Boeki Machinery LTD).

The subjects were immediately served breakfast and took the oral medication. Two hours after having their breakfast, a postprandial glucose examination was carried out. Meanwhile, the provision of the snacks for the treatment group was carried out after the postprandial examination. The treatment group consumed the snacks every day for 15 days. In the first 5 days, the food that was consumed was Moringa leaf cupcake. Then, on the 6th to 10th day, Moringa pudding was supplied. Consequently, on 11th to 15th day, Moringa tea was given. The subjects' fasting blood glucose level and 2 hours postprandial blood glucose level were measured prior to the treatment by drawing the venous blood using needle/venipuncture. Furthermore, the glucose level was determined using a spectrophotometer with a sample blood serum. In addition, the blood glucose measurements were also conducted on the last day of the intervention.

Data analysis

The characteristics data of the subjects: age, sex, occupational, and nutritional status were collected through a questionnaire and later was tabulated. Meanwhile, the data on blood sugar levels consisted of Preprandial (Preprandial GL) and Postprandial Glucose Level (Postprandial GL) before and after the intervention. This data were subsequently analyzed using the normality test. This study used a two-dependent sample difference test with the Wilcoxon test and Mann Whitney test. This is because when the amount of data is small (<30 samples). The statistical method that was used was a non-parametric statistical method. Therefore, when $p<0.05$, a significant difference between the two groups is indicated. Moreover, the Effect Size (ES) was also tested, which is said to be meaningful when ES>0.3.

RESULTS AND DISCUSSION

The production of moringa leaf-based snacks

Snacks are the important part of a diabetics' diet. One of the ways to control the blood glucose levels in DM patients is the careful attention paid to the snacks they consume. Snacks, according to PERKENI (2015), account for 10–15% of the total calories needed per day. Based on an in vivo study by Leone *et al.* (2018) that observed 17 people with type 2 Diabetes Mellitus in Italy, it was found that the chemical composition of Moringa leaf powder produced in Saharawi inhibited amylase activity and its sensory reception in food.

Subsequently, an evaluation was made to find out its effect on the post prandial glucose response which was performed through random administration on two different days. Also, Moringa powder was mixed into the food of 17 Saharawi diabetics and ten healthy subjects. Then, their fasting as well as 2 hours postpandrial blood glucose level was measured. The decrease in glucose levels occurred gradually at 90, 120, and 150 minutes compared to the anti-glycemic drugs. These findings implied that Moringa leaf powder could be used as a hypoglycemic agent (Leone *et al.* 2018). Based on the above references, current study produced three types of snack or complementary food that was made from fresh moringa leaves with nutritional value as presented in Table 1.

The serving size of each product is presented in Figure 1. *Moringa oleifera* leaf, both in dry and fresh forms, has many uses.

Tab1e 1. Moringa based complementary food products

Type complementary food	Composition main ingredients	Nutrition content (per serving)					
		Energy (kkal)	Protein (g)	Carbohydrate (g)	Fat (g)	Fiber (g)	Na (mg)
Moringa leaf cupcake	Moringa leaves 150 g Yellow pumpkin 20 Egg white 10 g	161.3	20.3	63.3	6.51	4.76	40.6
Pudding kelor	Moringa leaves 150 g Flour agar 4g	156.4	24.7	26.65	6.5	5.3	26.9
Kelor tea	Dry moringa leaves 20 g	2	16.0	12.3	1.38	11.5	0

Left to right: Moringa cupcake (serving size: 160 g); Moringa pudding (serving size: 230 g); Moringa tea (serving size: 60 g)

Figure 1. Moringa leaf-based complementary food products

The leaves can be used as a medicine or food ingredient when it is incorporated into products such as yoghurt, cakes, bread, biscuits, and soup according to Daba (2016) in Nurminah *et al.* (2019). Furthermore, Moringa leaves can be processed into cupcakes which would provide not only macro and micronutrients for DM patients, but the leaves also offer an enjoyable culinary experience without feeling excessively full or heavy when digested despite it is a calorie dense food.

The fiber content of the snacks is sufficient to meet the daily requirement. Meanwhile, pudding is a food that is made from hydrocolloid agar with the addition of water to produce a soft texture. It is a popular food because it tastes sweet, has a soft texture, quick, and easy to prepare. Moringa leaf pudding does not only help increasing fiber intake, but it also provides micro nutrient contents such as Fe, Mg, Ca, and Vitamin C that are easily consumed (Martatino *et al.* 2014).

Research on Moringa leaf tea consumption have been previously conducted and had proven to have a hypoglycemic effect. A study by Fombang and Willy (2016) found that blood glucose levels in normal or non-treated subjects did not show any significant change after 2 hours of Moringa leaf tea consumption. Comparatively, in subjects with hyperglycemia, blood glucose levels dropped significantly after 2 hours of consumption (Mujianti & Sukmawati 2018; Villarruel-López *et al.* 2018).

Subjects characteristics

This study was conducted on subjects who were registered as type 2 DM patients at the Mataram City Hospital. The subjects' characteristics include, age, sex, occupation, and nutritional status as presented in Table 2. In this table, all the characteristics have been tested for differences between the two sample groups (Mann Whitney test). The test results showed that there is not any significant difference ($p>0.05$). It means that the characteristics of the two groups are assumed to be the same. This is a requirement for a different test between the two sample groups during the post-test (after the intervention).

Age. Age can indicate the organs' working condition in the body. Accordingly, insulin resistance is a challenge a person needs to confront as age increases and the organ functions decrease gradually. Older people are faced with more possibility of experiencing hyperglycemia which also incurs the risk of developing type 2 diabetes (International Diabetes Federation 2019). As human gets older, body tissue increasingly deteriorates and blood glucose absorptions processes becoming less optimal (International Diabetes Federation 2019). In fact, the increase in age causes the pancreas to experience a faster decline in insulin secretion as well as decreased

Table 2. Distribution of characteristics of research subjects

Characteristic	Treatment		Control		p
	n	%	n	%	
Age					
30–50 years old	3	20	5	33	
>50 years old	12	80	10	67	0.140
Total	15	100	15	100	
Sex					
Male	6	40	7	46.7	
Female	9	60	8	53.3	0.717
Total	10	100	15	100	
Professional status					
Employed	8	53.3	8	53.3	
Unemployed	7	46.7	7	46.7	1.00
Total	15	100	15	100	
Total	10	100	10	100	
Educationlevel					
No formal education	4	26.7	8	53.3	
Primary school	3	20.0	3	20.0	
High school	4	26.7	2	13.3	0.299
Higher education	4	26.7	2	13.3	
Total	15	100	15	100	
Nutritional status					
Underweight	2	13.3	0	0	
Normal	4	26.7	10	66.7	
At risk	2	13.3	0	0	0.493
Obese 1	4	26.7	3	20	
Obese 2	3	20	2	13.3	
Total	15	100	15	100	
Type of anti-hyperglycemia oral					
Glimepiride	3	20	5	33.3	
Glipalamide	7	46.7	3	20	
Metformin	3	20	3	20	0.25
Glimepiride metformin	2	13.3	4	26.7	
Total	15	100	15	100	

receptor sensitivity. This often occurs at the age of 40 (Lachmandas *et al.* 2018).

Sex. In this study, females dominate both groups with 9 people in the treatment group and 8 in the control. This is different compared to Yanto and Setyawati (2017) where 46% of the samples were female.

Female DM patients have low levels of estrogen hormone, especially for those who are 40–50 year-old (menopause). Furthermore, they have two hormones which increase insulin response, namely estrogen and progesterone. The estrogen which is systematically regulated in the monthly cycle contributes to the distribution of fat cells in women. Once the fertile period has passed, insulin production would become lower (International Diabetes Federation 2019).

Nutritional status. Nutritional status was determined by calculating the Body Mass Index (BMI) and about 60% of the samples were included within the at risk and obese categories. This case is highly similar to Suryanti *et al.* (2019) in which as many as 49.5% of the samples were at risk and obese. In fact, Isnaini and Hikmawati (2016) showed that 62.5% of the samples were at risk of obese, as well as in Hasanah (2018) at 63.5%.

Body Mass Index is a measure used to determine the nutritional status of a person at age over 18 years. In addition to assessing nutritional status, waist circumference measurements were also used to determine central obesity (Isnaini & Hikmawati 2016; Suryanti *et al.* 2019). Meanwhile, obesity implies strongly on the evidence of non-communicable diseases such as Diabetes Mellitus (DM), Coronary Heart Disease (CHD), Chronic Kidney Disease (CKD), and Osteoarthritis (Workneh *et al.* 2017). When combined with a decrease in insulin production there is a change in glucose uptake. The absorbed glucose will turn into fatty acid. With this condition, further or worse decrease in pancreas function and insulin production will manifest (Workneh *et al.* 2017).

Oral anti-hyperglycemia medication. All subjects routinely took oral anti-hyperglycemic drugs once a day after meals. The types of the drug used include: metformin, glibenclamide, and sitagliptin. Meanwhile, the drugs that were consumed by the subjects function as the inhibitor of DPPIV. Hence, GLP-1 (Glucagon like peptide-1) would continue to work in high concentrations in its active form. This increases insulin secretion and suppresses glucagon. Anti-hyperglycemic drugs work after meal. Also, there are some medications that work by reducing the glucose production in the liver (gluconeogenesis) and improving the glucose uptake in the peripheral tissues (PERKENI 2015).

Effect analysis of moringa leaf-based snacks on the blood glucose of thesubjects

Average preprandial glucose level (Preprandial GL). The average Preprandial GL was measured twice from both groups (treatment and control), before and after the intervention. The average (Preprandial GL) before and after the intervention, as well as the change experienced in each group, can be seen in Table 3. Accordingly, the average Preprandial GL before the intervention

Table 3. Average pre-prandial glucose level pre and post intervention

Variable	Intervention (n=15)	Control (n=15)
	Mean±SD	Mean±SD
Initial Pre-prandial glucose level (mg/dl)	247±94	226±106
Final Pre-prandial glucose level (mg/dl)	231±98.4	310±117
ΔPre-prandial glucose level	16±4.4	-104±11
p	0.245	0.41

for the treatment and control groups were 247±94 mg/dl and 226±106 mg/dl, respectively. Post-intervention, these values changed to 231.10±98.4 mg/dl for the treatment group and 330+127 mg/dl for the control. Meanwhile, the average change or difference was 16 mg/dl (decreased) and 104 mg/dl (increased). The test results for the control and treatment groups with the Wilcoxon rank test for mean fasting blood (Preprandial GL) showed that there is not any difference in the two sample groups (p=0.24 in the intervention group and p=0.41 in the control).

Monitoring preprandial glucose level for DM patients is important to evaluate the glycemic control. However, in practice, preprandial monitoring was often neglected and therefore the patients were unable to assess their response upon the glycemic target. Meanwhile, the preprandial target that needs to be achieved by patients is <126 mg/dl (Al-Rifai *et al.* 2017; PERKENI 2015).

In fasting state, the digestive tract tends to work slower when digesting food, likewise with the absorption of nutrients. In both groups, there were decreases in blood sugar levels, but they were not significantly different. This suggests that gastric emptying during fasting (no food consumption for eight hours), which should lower the blood glucose, did not happen in such case. One of the possible causes is the consumption of food with a high glycemic load. Also, when DM patients experience insulin resistance, the body responds to the glycemic load by increasing the insulin secretion. This results in fatigue in pancreatic beta cells due to continuous insulin synthesis. Ultimately, the beta cells are unable to meet insulin needs, and therefore blood glucose remains high (Wang *et al.* 2019).

Average postprandial glucose level (Postprandial GL). Like the Preprandial above, Postprandial GL examination was done prior and post the intervention. The average Postprandial GL and the changes or differences of each group are shown in Table 4. Based the table, the average Postprandial GL before the study in the treatment group was 353±117 mg/dl, while it was 226±106 mg/dl for the control. Subsequently, the average Postprandial GL after the study in the treatment and the control groups were 267±94.3 mg/dl and 330±127 mg/dl respectively. Furthermore, the average difference in the Postprandial GL in the treatment group was 86 mg/dl (decrease) while the control was 104 mg/dl (increased). Statistical test results for the average Postprandial GL showed difference in the two samples p=0.001 (p<0.001). It implies that the provision of Moringa leaf-based complementary food has an effect on the Postprandial GL of the subjects.

In line with research on snacks for diabetics, it is stated that snacks for diabetics should contain fiber, especially resistant fiber. Many resistant fibers are contained from plant food such as soybeans which can be processed into tempeh (Maya *et al.* 2020).

Effect Size (ES) analysis was conducted to determine the extent of the intervention effect within the two groups. The analysis results are shown in Table 5. Moringa leaves have been shown to have a hypoglycemic effect, which is attributed to the Q-3-G type polyphenols content

Table 4. Average postprandial glucose level pre and post intervention

Variable	Intervention (n=15)	Control (n=15)
	Mean±SD	Mean±SD
Postprandial glucose level prior intervention	353±112	226±106
Postprandial glucose level post intervention	267±94.3	330±127
ΔPostprandial glucose level	86±17.7	-104±-21
p	0.001	0.062

Table 5. Effect size analysis results

Group	Effect size	Results
Control	Pre-prandial glucose level	-0.87
	Postprandial glucose level	-0.63
Treatment	Pre-prandial glucose level	0.113
	Postprandial glucose level	0.584

which is 1494.2 μmol/100g in dry ingredient. Its works by influencing the glucose intake in the small intestinal mucosa, which in turn slow down the time taken to absorb the glucose into the blood. Thereby, it reduces the glucose levels.

In contrast to the test results obtained in the earlier measurement (Prepandrial GL) within this study, the measurement of posprandial GL showed that there is an influence of Moringa leaf-based complementary food on the Postprandial GL of the subjects (p=0.001). Concurrently, Taweerutchana *et al.* (2017) reported that dried and extracted Moringa leaves were more effective in reducing glucose levels compared to Glipizide. It is thought that the Moringa leaf extract has a direct effect on glucose intake by inhibiting the gluconeogenesis in the liver and decreasing the glucose absorption in muscle and adipose tissues (Taweerutchana *et al.* 2017).

Meanwhile, the trend of decreasing postprandial GL in the treatment group has not yet led to normal levels. Therefore, further research is needed to determine the optimum duration and dosage of Moringa leaves consumption for improving blood glucose control in DM patients.

CONCLUSION

Consumption of Moringa based complementary food as a snack helps to reduce the postprandial blood glucose levels in patients with type 2 Diabetes Mellitus.

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AUTHOR DISCLOSURES

The authors declare that there is no conflict of interest.

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