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EFFECT OF ARROWROOT COOKIES WITH PORANG (*AMORPHOPHALLUS ONCOPHYLLUS*) GLUCOMANNAN ADDITION ON ATHEROGENIC INDEX OF PLASMA IN TYPE 2 DIABETES

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Abstrak

Latar belakang dan tujuan: Pasien diabetes melitus tipe 2 (DMT2) memiliki risiko tinggi mengalami penyakit kardiovaskular (PKV). *Cookies* berbahan dasar garut dengan penambahan glukomanan porang kaya akan serat pangan dan berpotensi menurunkan risiko PKV. Penelitian ini bertujuan untuk mengevaluasi pengaruh konsumsi *cookies* selama 8 minggu terhadap indeks atherogenik plasma (IAP) pada pasien DMT2. **Metode:** Sebanyak 24 subjek DMT2 direkrut dari puskesmas di Yogyakarta dan dibagi menjadi kelompok kontrol yang menerima edukasi gizi (n=12) serta kelompok intervensi yang menerima edukasi gizi dan cookies sebanyak 65 g/hari selama 8 minggu (n=12). IAP [log(TG/HDL-C)], antropometri, dan asupan makan diukur pada awal dan akhir penelitian. **Hasil:** Nilai IAP pada kelompok intervensi menurun dari 0,189 menjadi 0,164, sedangkan pada kelompok kontrol meningkat dari 0,075 menjadi 0,111, namun perbedaannya tidak signifikan (p>0,05). Tidak terdapat perubahan signifikan pada parameter antropometri. Asupan serat meningkat pada kedua kelompok (p<0,05), tetapi tidak berbeda bermakna antar kelompok. Kesimpulan: Konsumsi 65 g cookies garut dengan glukomanan porang selama 8 minggu tidak berpengaruh signifikan terhadap IAP pada pasien DMT2, namun cenderung mempertahankan IAP pada kategori risiko sedang PKV.
Kata Kunci: diabetes melitus tipe 2, serat pangan, umbi garut, indeks aterogenik plasma

Abstract

Background and aims: Patients with type 2 diabetes (T2D) are at increased risk of cardiovascular disease (CVD). Arrowroot cookies enriched with porang glucomannan are high in dietary fiber and may reduce CVD risk. This study aimed to evaluate the effect of 8-week cookie consumption on the atherogenic index of plasma (AIP) in T2D patients.
Methods: Twenty-four T2D subjects from primary health centers in Yogyakarta were assigned to a control group receiving nutrition education (n=12) or an intervention group receiving nutrition education plus 65 g/day of cookies for 8 weeks (n=12). AIP [log(TG/HDL-C)], anthropometric measurements, and dietary intake were assessed at baseline and week 8.
Results: AIP decreased in the intervention group from 0.189 to 0.164, while it increased in the control group from 0.075 to 0.111; however, differences were not statistically significant (p>0.05). No significant changes were observed in anthropometric measures. Dietary fiber intake increased in both groups (p<0.05), with no significant difference between groups.
Conclusion: Consumption of 65 g arrowroot cookies with porang glucomannan for 8 weeks did not significantly affect AIP in T2D patients but tended to maintain AIP at a medium CVD risk level

Keywords: *type 2 diabetes, dietary fiber, arrowroot, atherogenic index of plasma*

INTRODUCTION

Type 2 diabetes (T2D) patients are at risk of developing cardiovascular disease (CVD) related to atherogenic dyslipidemia. Atherogenic dyslipidemia is a condition marked by a high level of triglycerides (TG), small-dense low-density lipoprotein cholesterol (sdLDL-C), and low high-density lipoprotein cholesterol (HDL-C) (Fernández-Macías et al., 2019; Hermans et al., 2012). The sdLDL-C level is increased in T2D patients because of insulin resistance and is more atherogenic than in non-diabetic patients (Hirano, 2018; Suh et al., 2011).

The atherogenic index of plasma (AIP) is a novel predictor of the risk of atherosclerosis and CVD (Fernández-Macías et al., 2019; Nwagha et al., 2010). Established by Dobiasova M and Frohlich J in 2001, AIP is a logarithmic transformation of triglyceride and HDL-C ratio in molarity [log(TG/HDL-C)]. AIP is related to LDL-C particle size, and measures the balance between protective and atherogenic lipoproteins (Dobiásová et al., 2011; Dobiásová & Frohlich, 2001). Studies suggested that AIP is associated with obesity indices, blood glucose, and lipid profile (Shin et al., 2022; Zhu et al., 2018). T2D patients with metabolic syndrome have higher AIP than T2D patients without metabolic syndrome (Pourfarzam et al., 2016). Another study found that AIP was related to waist circumference, body mass index, blood pressure, blood glucose correlation index (FBG, PPBG, HbA1c), and insulin resistance index (HOMA-IR) in T2D patients (Li et al., 2018). The study also found that groups with higher AIP had an increased risk for hypertension and atherosclerotic plaques.

High fiber diets have been reported to be beneficial in reducing total cholesterol (TC) (Soliman, 2019), TG (Giacco et al., 2014; Velázquez-López et al., 2016), TC/HDL-C ratio [14], LDL-C/HDL-C ratio (Vuksan et al., 2000), and increase HDL-C (Velázquez-López et al., 2016). High fiber diets also found to reduce insulin resistance(Chen et al., 2016). Individuals with diabetes or at risk for metabolic syndrome are encouraged to increase dietary fiber intake to 25g/day for adult women and 38g/day for adult men (Evert et al., 2013). Dietary fibers including resistant starch are resistant to digestion but could be fermented by bacteria in the colon to short-chain fatty acids (SCFA) in the large intestine (Soliman, 2019), mainly acetate, butyrate, and propionate. SCFA was reported to have a role in lipolysis and improvement in insulin sensitivity (Chen et al., 2018; Mao et al., 2021). Dietary fiber also adds bulk to the diet, absorbs, and sequesters dietary cholesterol, therefore reducing hepatic absorption of cholesterol and increasing its excretion through bile and fecal lipids and bile acids (Soliman, 2019).

Arrowroot cookies with porang glucomannan are functional food made from several ingredients that could be beneficial for T2D patients, namely arrowroot (*Maranta arundinaceae*) and porang (*Amorphophallus oncophyllus*) glucomannan (Lestari et al., 2020). Arrowroot and porang are local commodity di Indonesia. Arrowroot is a tuber that has not been widely cultivated and usually used as tertiary food in Indonesia. However, this tuber has a low glycemic index and exported in the form of flour (Deswina & Priadi, 2020). Porang is another tuber and a main source of glucomannan, a soluble fiber that is very beneficial for weight loss and lipid profiles improvement (Sood et al., 2008; Vuksan et al., 2000; Yanai et al., 2015). Porang itself can not be eaten directly for it contains high level of calcium oxalate, so the glucommanan should be extracted through a complicated long process (Nimmanapalli et al., 2016).

In order to increase the utilization and economic value of those beneficial tubers, Lestari et al. (2020) develop a cookies made from arrowroot and porang's glucommanan. The study found that these cookies have a low glycemic index (48.2) and glycemic load (6.92), and also high in dietary fiber (Lestari et al., 2020). The low glycemic index and glycemic load of this cookies, as well as the high fiber content is thought be a potential snack for diabetes patients. Therefore, this study aimed to evaluate the effect of arrowroot cookies with porang glucomannan addition consumption on the atherogenic index of plasma in T2D patients.

METHOD

Study design and subjects

This is a quasi-experimental study with control group design. Subjects were T2D patients, aged 30-60 recruited from primary health centers in Yogyakarta, Indonesia, and were chosen purposively. The patients were treated with oral antidiabetic agents, were not consuming any antihypercholesterolemic agents, and were not menopause for women. Exclusion criteria were pregnancy, lactation, and complications such as retinopathy, nephropathy, neuropathy, and foot ulcer. The procedure and informed consent have been approved by the Medical and Health Research Ethics Committee, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta (Ref: KE/FK/1019/EC/2019). As many as 24 patients were included in this study and divided into 2 groups of 12 patients. Written informed consent was obtained from all patients.

Intervention

All patients included in this study received detailed nutrition education from experienced nutritionists for their diet. The intervention group received 65g or 5 pieces of cookies from arrowroot and porang glucomannan as daily snacks for 8 weeks. Subjects were encouraged to change their daily snacks to the cookies.

The cookies, named My Cookies© were limited commercial snacks made of a mixture of arrowroot flour, arrowroot starch, porang glucomannan, palm sugar, and cinnamon. A total of 100g cookies contains 500.56kcal energy, 7.66g protein, 28g fat, 54.49g carbohydrate, 16.37g fiber, 0.57g soluble fiber, 15.8g insoluble fiber, and 2.23g resistant starch. The glycemic index and glycemic load of the cookies were 48.2 and 6.91 respectively, which categorized as low (Lestari et al., 2020). Subjects were advised to eat the cookies as morning and afternoon snack, and also given logbook to record their daily cookies consumption and oral medicine independently. The logbooks were collected every 2 weeks to be checked.

Anthropometric, dietary, physical activity, and clinical data collection

All data were collected before (week 0) and after (week 8) the study. Bodyweight (BW), body mass index (BMI), waist circumference (WC), visceral fat (VF), and total body fat (TBF) data were collected. Omron HBF-375 Body Composition Monitor was used to measured body weight, BMI, visceral fat, and total body fat. Waist circumference was measured using a measurement tape (metline). Dietary intake data was collected with a semi-quantitative food frequency questionnaire (SQ-FFQ) by interview. Daily intake of energy, protein, fat, carbohydrate, dietary fiber, sugar, and saturated fatty acid (SFA) was measured by Nutrisurvey2007. The physical activity data was collected with the Short-Form International Physical Activity Questionnaire translated in Bahasa Indonesia. AIP was calculated by formula log(TG/HDL-C) which TG and HDL-C in mmol/L.

Biochemical analysis

To obtain blood serum, the blood sample was centrifuged for 15 minutes at room temperature. EDTA-serum was used to determine lipid profiles (TG and HDL-C). Lipid profiles were analyzed enzymatically using commercial Diasys kit (Diasys, Holzeim, Germany). The analysis was conducted in Clinical Pathology Laboratory, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada.

Statistical analysis

All parameters were measured twice, before (week 0) and after (week 8) study. The paired sample t-test was used to analyze the normally distributed data and the Wilcoxon signed *d*-rank test to analyzed abnormally distributed data in the control and intervention group. The independent t-test or Mann-Whitney test was used to analyze the difference in changes in all parameters between the two groups. We also analyzed the correlation between changes in AIP and changes in anthropometric measures and dietary intake using a Pearson correlation for normally distributed data and Spearman correlation for abnormally distributed data. All data analyses were performed using STATA version 13 (StataCorp, USA). Statistical testing was performed at the p=0.05 level of significance, two-sided

RESULT AND DISCUSSION

A total of 24 T2D patients consisted of 12 males and 12 females were included in this study, 6 males and 6 females each group. All participants in the intervention group followed the experimental protocol with good compliance with the average 93.3%. One subject stated feeling bloated in the beginning and adapted well to the cookies on the sixth day.

Table 1 shows the changes in anthropometric measures, dietary intake, physical activity, and lipid profiles in the control and intervention groups. After 8 weeks of study, there were no significant changes in anthropometric measures and physical activity. There were significant changes in dietary fiber intake in both the control and intervention groups, but it was not significantly different between groups. There were no differences in the other dietary component intake after study. On the lipid profile, there were also no significant changes in TG, HDL-C, and AIP on both groups. There was a slight decrease in AIP in the intervention group and a slight increase in the control group, but not significantly different between groups.

Table 1 Changes in anthropometric measures, dietary intake, and lipid profiles in the control and intervention groups

	Control (n=12)		Intervention (n=12)				
	Before mean ± SD	After mean ± SD	p value	Before mean ± SD	After mean ± SD	p value	p value[a] (control vs intervention)
Age (years)	49.16 ± 5.29			46.75 ± 6.17			
Anthropometric measures							
BW (kg)	70.05 ± 14.02	70.57 ± 14.23	0.138[b]	67.18 ± 17.43	68.34 ± 4.95	0.130[b]	0.664
BMI (kg/m^2)	28.74 ± 5.20	28.97 ± 5.22	0.119[b]	26.61 ± 5.46	26.82 ± 5.53	0.140[b]	0.965
WC (cm)	94.10 ± 11.76	94.67 ± 15.00	0.723[b]	91.46 ± 12.14	91.87 ± 15.25	0.749[b]	0.921
TBF (%)	30.99 ± 7.25	30.95 ± 8.60	0.972[b]	30.07 ± 6.24	30.18 ± 6.25	0.759[b]	0.751
VF	14.04 ± 6.17	14.45 ± 6.51	0.075[b]	11.21 ± 6.43	11.42 ± 6.57	0.175[b]	0.435
Dietary Intake							
Energy (kcal)	1344.44 ± 348.97	1405.71 ± 213.22	0.441[b]	1558.89 ± 421.87	1630.99 ± 369.27	0.583[c]	0.947
Protein (g)	51.07 ± 27.08	52.16 ± 18.39	0.388[c]	65.51 ± 26.02	53.39 ± 15.03	0.189[b]	0.130
Fat (g)	42.61 ± 25.37	43.71 ± 11.84	0.432[c]	51.67 ± 19.49	58.21 ± 10.58	0.324[b]	0.525
Carbohydrate (g)	199.83 ± 36.64	199.78 ± 41.93	0.998[b]	223.97 ± 50.09	255.28 ± 61.02	0.099[c]	0.246
Dietary fiber (g)	13.67 ± 5.89	22.88 ± 12.06	0.018[b]	18.23 ± 8.22	25.17 ± 9.92	0.049[c]	0.623
Sugar (g)	30.3 ± 17.57	25.9 ± 9.2	0.339[b]	33.45 ± 12.41	43.63 ± 18.12	0.209[c]	0.094
SFA (g)	16.65 ± 8.40	11.9 ± 4.93	0.073[b]	15.58 ± 9.37	14.92 ± 7.34	0.753[c]	0.274
Lipid Profile							
TG (mg/dL)	132.33 ± 22.19	144.67 ± 40.72	0.286[b]	156.58 ± 50.49	169.17 ± 89.58	0.445[b]	0.989
HDL-C (mg/dL)	48.33 ± 6.98	47.92 ± 7.79	0.862[b]	43.00 ± 8.79	45.33 ± 10.01	0.499[b]	0.507
AIP	0.075 ± 0.08	0.111 ± 0.14	0.264[b]	0.189 ± 0.18	0.164 ± 0.31	0.668[b]	0.359
Physical activity (METs-min/wk)	2155.25 ± 3165.25	1232.25 ± 1539.86	0.389[c]	1187.17 ± 1119.45	1060.12 ± 1291.68	0.556[c]	0.538

Abbrevation: Data are represented as mean ± s.d.
BW, body weight; BMI, body mass index; WC, waist circumference; TBF, total body fat; TG, triglyceride; HDL-C, high density lipoprotein-cholesterol; AIP, atherogenic index of plasma.
[a]Comparison of changes between control and intervention groups.
[b]Paired *t* test for normally distributed data.
[c]Wilcoxon signed d-rank for abnormally distributed data.

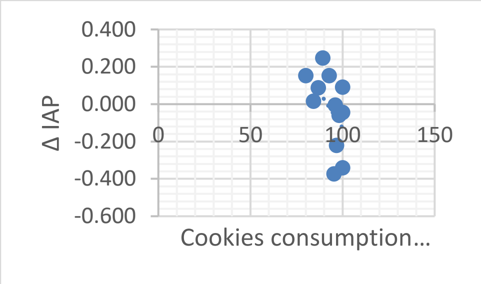

Figure 1. Correlation between changes in AIP and compliance of cookies consumption (r=-0.523, p=0.081)

We found a strong inverse correlation between changes in AIP and compliance of cookies consumption, although it was not significantly different (Figure 1). We also found a strong correlation between changes in WC and AIP (r=0.515, p=0.086), but it was not significantly different.

T2D patients are at risk of developing atherosclerosis (La Sala et al., 2019; Poznyak et al., 2020). Insulin resistance stimulates circulating free fatty acid, causes atherogenic dyslipidemia, marked by a high level of TG, sdLDL-C, and low level of HDL-C (Hirano, 2018; Nimmanapalli et al., 2016). The sdLDL-C is easier to enter and pile up in arterial wall than LDL-C, thus cause atherosclerosis. The sdLDL-C was found to higher in T2D patients than control. TG is strongly correlated with the sdLDL-C, and AIP has a strong inverse correlation with LDL-C particle size (Suh et al., 2011; Zhu et al., 2018).

A high dietary fiber diet is reported to be beneficial to prevent dyslipidemia. Dietary fiber reduced cholesterol absorption and increase its excretion through bile acid and fecal lipid (Gusti Ayu Nyoman Danuyanti & Ahmad Fahrurrozi, 2022; Soliman, 2019). Dietary fiber could be fermented by gut bacteria in the large intestine to SCFA and may have a role in lipolysis and insulin sensitivity improvement which beneficial to prevent atherosclerosis and T2D (Mao et al., 2021; Soliman, 2019). T2D patients are recommended to increase their fiber intake to 14g/1000 kcal to prevent dyslipidemia (Evert et al., 2013).

Only a few studies have shown the effect of high fiber foods on AIP. In this study, high fiber arrowroot cookies with porang glucomannan addition for 8 weeks did not improve AIP, TG, HDL-C, and anthropometric measures. Fiber intake was higher after 8 weeks of study in the control and intervention groups, although the changes are not significantly different between groups. It was expected that the intervention group could improve the AIP level since the cookies contain high fiber (total dietary fiber 10.64g, soluble fiber 0.37g, insoluble fiber 10.27g) (Lestari et al., 2020). Increased dietary fiber intake in the control group could occur because of nutrition education provided to them before the study, so the subjects increase their fruits and vegetables intake.

In this study, we found a slight decrease in AIP after 8 weeks of arrowroot cookies consumption with porang glucomannan in the intervention group. This small and insignificant change might happen because soluble fiber in our study was a lot fewer than the insoluble fiber (0.37g vs 10.27g respectively).

One study found that consumption of 32g high-fiber snacks from the mixture of *Dioscorea esculenta,* arrowroot, cassava, and pumpkin containing 4.81g soluble fiber, 14.91 insoluble fiber, and 13.26g resistant starch for 28 days significantly reduced BW, BMI, WC, and CRP, and reduced AIP and non-HDL-C although not significantly on T2D patients (Sunarti et al., 2018). This study also did not find any significant changes in AIP, however in contrast, we did not see any changes in anthropometric measures. Soluble fiber in this study was higher than the current study. BW, BMI, and WC, and LV are strongly correlated with AIP (Bo et al., 2018). We found a strong correlation between changes in AIP and WC. Improvement in body composition may reduce the inflammatory of T2D patients that can cause atherosclerosis (Sunarti et al., 2018).

Soluble fiber consumption is reported to have several health benefits, such as improve blood lipid levels, lower blood pressure, improved blood glucose control and weight loss, reduced CVD risk, and minimal changes in TG and HDL-C, depending on the type of dietary fiber and the amount consumed (Surampudi et al., 2016). Soluble fiber is resistant to digestion by small intestines but is fermented by gut bacteria to SCFA in the colon. It also absorbs water, leading to gel formation which increases food transit time, delays emptying of gastric, slows digestions, and decreases nutrients absorption in the small intestine, including cholesterol absorption (Soliman, 2019).

Soluble fiber source on this study mainly from glucomannan from porang tuber which has a similar genus with konjac (*Amorphophallus konjac*) glucomannan. A study reported 36.8g/day konjac glucomannan (KJM) supplementation for 28 days reduced LDL-C, TC/HDL-C ratio, and apolipoprotein B (Chen et al., 2003). Unlike soluble fiber, insoluble fiber decreases transit time, and only a few can be fermented by gut bacteria to SCFA (Soliman, 2019). It is reported that SCFA, mainly propionate and butyrate, may contribute to hypocholesterolemia by attenuating cholesterol synthesis (Chen et al., 2018). However, we found a strong inverse correlation between changes in AIP and cookies compliance. Although AIP changes were not significant, the cookies which high in insoluble fiber may still have a beneficial effect in decreasing AIP. An epidemiological study found that increased insoluble fiber intake, mainly from whole grain is more beneficial in improving insulin sensitivity and preventing T2D than soluble fiber, though the mechanism is still unclear (Galisteo et al., 2008). However, a meta-analysis also found that both soluble fiber and dietary fiber were beneficial for blood glucose control and improving insulin sensivity (Mao et al., 2021).

A potential limitation of this study is that we did not set the daily energy intake for subjects. We only advised them not to change their eating habit and for intervention group to change their daily snacks to arrowroot cookies with porang glucomannan addition. The sample size was small, which could affect the significancy of the results. Even with the existing shortcomings, this study could be a starting point in the development of healthy snacks for diabetes patients from local comodity in Indonesia, which could also increase its selling value

CONCLUSION

Consumption of arrowroot cookies with porang glucomannan addition which high in dietary fiber for 8 weeks did not affect the atherogenic index of plasma in T2D patients. However, it could maintain the AIP level in the intervention group in the medium-risk category. Additional studies on bigger samples and the effect on SCFA are needed to better understand the effect of arrowroot cookies with porang glucomannan addition consumption on atherosclerosis risks.

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