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Purple Sweet Potato Extract and Aerobic Exercise Reduce Lipid Profiles in Hyperlipidemic Rats Model
El extracto de batata morada y el ejercicio aeróbico reducen los perfiles lipídicos en un modelo de ratas hiperlipidémicas

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Abstract. Obesity and dyslipidemia are the major risk factors for cardiovascular disease. It has been shown that dietary supplementation combined with exercise at appropriate intensity improves lipid profile and reduces the risk of cardiovascular disease. This study investigates the effect of purple sweet potato extract and swimming training on the lipid profile of a hyperlipidemic rat model. Twenty-five male Wistar rats were grouped into standard diet and high-fat diet and given their respective diet for two weeks. Afterward, they were randomly divided into five weight-matched groups; normal control (C; n=5), high-fat diet (HF; n=5), exercise (E; n=5), purple sweet potato extract (PSP; n=5), and exercise combined with purple sweet potato extract (EPSP; n=5). Purple sweet potato extract was given 100 mg/day through oral gavage for three weeks. Swimming exercise was performed for 30 minutes/day, five days a week, for three weeks at an intensity of 6% of body weight. At the end of the experimental period, intracardiac blood samples were drawn to measure lipid profiles. Data analysis technique using a one-way ANOVA test with a significant level of 5%. The findings revealed that the concentration of TC and LDL was highest in HF. The combination of exercise and purple sweet potato extract significantly reduced LDL and increased HDL levels compared to exercise or PSP alone ($p \leq 0.05$). It indicates that purple sweet potato extract combined with swimming exercise is shown to be effective in improving lipid profiles in hyperlipidemic rat models.
Keyword: Aerobic exercise, hyperlipidemia, lipid profile, purple sweet potato.

Resumen. La obesidad y la dislipidemia son los principales factores de riesgo de enfermedad cardiovascular. Se ha demostrado que la suplementación dietética combinada con ejercicio de intensidad adecuada mejora el perfil lipídico y reduce el riesgo de enfermedad cardiovascular. Este estudio investiga el efecto del extracto de batata morada y el entrenamiento de natación sobre el perfil lipídico de un modelo de rata hiperlipidémica. Se agruparon veinticinco ratas Wistar macho en una dieta estándar y una dieta alta en grasas y se les administró su dieta respectiva durante dos semanas. Luego, se dividieron aleatoriamente en cinco grupos del mismo peso; control normal (C; n=5), dieta alta en grasas (HF; n=5), ejercicio (E; n=5), extracto de batata morada (PSP; n=5) y ejercicio combinado con batata morada extracto (EPSP; n=5). Se administró extracto de batata morada 100 mg/día mediante sonda oral durante tres semanas. El ejercicio de natación se realizó durante 30 minutos al día, cinco días a la semana, durante tres semanas a una intensidad del 6% del peso corporal. Al final del período experimental, se extrajeron muestras de sangre intracardíaca para medir los perfiles de lípidos. Técnica de análisis de datos mediante prueba ANOVA unidireccional con un nivel de significancia del 5%. Los hallazgos revelaron que la concentración de CT y LDL era más alta en HF. La combinación de ejercicio y extracto de batata morada redujo significativamente el LDL y aumentó los niveles de HDL en comparación con el ejercicio o la PSP solo ($p \leq 0.05$). Indica que el extracto de batata morada combinado con ejercicio de natación ha demostrado ser eficaz para mejorar los perfiles de lípidos en modelos de ratas hiperlipidémicas.
Palabras clave: Ejercicio aeróbico, hiperlipidemia, perfil lipídico, batata morada.

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Introduction

Cardiovascular disease is a common and deadly disease in the world (Reamy et al., 2018). It is estimated that in 2017, the death rate from cardiovascular disease will reach 17.8 million people (Kaptoge et al., 2019). Meanwhile, the annual average mortality from cardiovascular disease reaches 17.3 million, with an estimate of 23.6 million in 2030 (Verma, 2016). This disease generally attacks countries with medium-low income, including Indonesia (Nugraheni et al., 2023). Several efforts to combat this disease in Indonesia are still low so many cases still occur up till now (Maharani et al., 2019). In particular, the purple sweet potato, a food rich in nutrients and bioactive compounds like anthocyanins (Sun et al., 2018), has been found to possess properties that can improve lipid profiles and prevent hyperlipidemia (Chen et al., 2011), a condition that can lead to atherosclerosis and cardiovascular diseases (Karam et al., 2017). Additionally, regular aerobic exercise has been shown to improve lipid profiles and reduce the risk of cardiovascular diseases (Stanton et al., 2022). Previous studies found that the percentage of the global risk of death, due to cardiovascular disease caused by hypertension was 13%, smoking was 9%, diabetes was 6%, physical inactivity was 6%, overweight and obesity were 5% (WHO, 2009). One of the major contributors to this disease is hyperlipidemia.

Hyperlipidemia is one of the causes of atherosclerosis and cardiovascular disease (Karam et al., 2017). The term hyperlipidemia refers to high levels of lipids (triglycerides, cholesterol, or both) in the blood, while the term hypertriglyceridemia refers to high blood triglyceride levels and the term hypercholesterolemia refers to high blood cholesterol levels (Xu et al., 2014). Hyperlipidemia or dyslipidemia is a condition caused by the increase of plasma cholesterol, Low-Density Lipoprotein (LDL), triglycerides, and a decrease in High-Density Lipoprotein (HDL) levels or a combination of these abnormalities (Karr, 2017; Musunuru, 2010). Hyperlipidemia is also caused by disorders of lipoprotein metabolism including excess or deficiency (Preta, 2023). These lipoproteins are stored in the interstitial spaces of the arteries, blocking blood flow to the heart (Di Fusco et al., 2023). This can lead to atherosclerosis and myocardial infarction, resulting in heart attacks (Shattat, 2014). Measurement of total cholesterol, LDL, HDL, and lipid ratio is important for early screening of cardiovascular risk (Madhu et al., 2013).

Common causes of hyperlipidemia are due to unhealthy eating habits, obesity, and lack of physical activity (Verma, 2016). Purple sweet potatoes are a healthy food that contains essential nutrients and bioactive compounds (Curayag et al., 2019). Purple sweet potatoes contain an important source of nutrients such as dietary fiber, minerals, vitamins, anthocyanins, and so on (Teow et al., 2007). Anthocyanin compounds in purple sweet potato are natural pigments that are allowed for consumption by the WHO and the US Food and Drug Administration (FDA) (Mattoo et al., 2022). The anthocyanin content in purple sweet potato is well distributed in almost all parts of the plant, from leaves, skin, and tubers, and its properties have been studied in mice, rats, and plant rabbits (Sun et al., 2018). Purple sweet potato is more often used for diet therapy, because anthocyanins have many functions, including anti-oxidants, anti-tumor, antimutagenic, anti-inflammatory, and disease prevention cardiovascular, diabetes prevention, weight loss, and other effects (Xu et al., 2015; Jiao et al., 2012; De Pascual-Teresa & Sanchez-Ballesta, 2008).

In addition, purple sweet potato was able to improve blood lipid profiles in rabbits fed a high-cholesterol diet, in addition to reducing Malondialdehyde (MDA) levels and increasing total antioxidant levels (Chen et al., 2011). Purple sweet potato has also been shown to increase the expression of SOD-2 and SOD-3 in vascular endothelial cells (Sutirta-Yasa & Jawi, 2017). The extract of purple sweet potato also contains anthocyanins, which are exogenous antioxidants that can reduce MDA levels (Cuevas et al., 2011; Sutirta-Yasa & Jawi, 2017). These compounds are also thought to be able to improve lipid profiles, which in turn can prevent hyperlipidemia conditions (Xu et al., 2021).

Apart from diet therapy, hyperlipidemia can also be reduced by doing exercises (Wang, & Xu, 2017). Stanton et al. (2022) stated that exercise with appropriate exercise programs can improve plasma lipid profiles and reduce the risk of cardiovascular disease. Kannan et al. (2014) also revealed that changes in lipid profiles are influenced by exercise intensity. Total food intake and exercise intensity are important factors influencing changes in lipid profiles (Kannan et al., 2014).

Aerobic exercise is a physical activity that increases heart rate and breathing volume to meet the oxygen needs of active muscles (Wang & Xu, 2017). The American College of Sports Medicine (ACSM) recommends good aerobic exercise of 150-300 minutes per week of moderate-intensity (60-70% HR_{max}) (Garber et al., 2011; Rejeki et al., 2023; Pranoto et al., 2023; Merawati et al., 2023). Chiu et al. (2017) in their study revealed that aerobic exercise in 60 minutes-duration of 3 times a week for 12 weeks can reduce body weight and body fat. Aerobic exercise increases the sensitivity of β-adrenergic receptors in adipose tissue (Chiu et al., 2017). Interestingly, in women trained in resistance, β-adrenergic sensitivity was increased, whereas anti-lipolytic α-2 receptor sensitivity was reduced (Boutcher, 2011). Increased physical activity will increase basal metabolism in body cells, this facilitates the mobilization and oxidation of fat, especially in visceral adipose tissue which will cause a decrease in body fat levels (Dewi & Kania, 2016).

This study utilizes an animal model, specifically rats, to understand the impact of physical exercise and a purple sweet potato diet on lipid profiles. It aims to investigate how the combination of aerobic exercise and purple sweet potatoes can influence lipid profiles in a high-fat-induced hyperlipidemic rat model. This approach is based on previous research indicating that both exercise and dietary interventions can have significant effects on lipid profiles. However, the combined effect of these interventions has not been extensively studied, particularly in the context of a high-fat diet-induced hyperlipidemic rat model. Therefore, this study will contribute to the existing body of knowledge by exploring this under-researched area.

Hyperlipidemia, characterized by an increase in cholesterol and triglycerides in the blood, is a significant risk factor for cardiovascular diseases. Despite the availability of pharmaceutical treatments, these often come with side effects and do not always address the root cause of the condition. Therefore, there is a growing interest in exploring alternative treatments that are safe, effective, and can be incorporated into daily life. This study investigates the potential of Purple Sweet Potato Extract and Aerobic Exercise in reducing lipid profiles in a hyperlipidemic rat model, offering a natural and accessible approach to managing hyperlipidemia. To the best of our knowledge, studies on the hypolipidemic benefits of purple sweet potato in improving lipid profile have been carried out, however, few studies on the effect of purple sweet potato extract combined with regular exercise in improving lipid profile have not been widely studied. Thus, the purpose of this present study was to investigate the effect of purple sweet potato and aerobic exercise on lipid profile in a high-fat-induced hyperlipidemic rat model.

Materials and methods

Study design

The method used in this research was the experimental method. The present study used a randomized control post-test-only group design. A total of twenty-five healthy male *Rattus norvegicus* strain Wistar weighing between 150-200 grams were used in this study. *Rattus norvegicus* strain Wistar was obtained from the Faculty of Veterinary Medicine, Airlangga University, Indonesia. Sample size calculation using the Federer formula (1967) to obtain a minimum sample size and 25 *Rattus norvegicus* strain Wistar were taken. Afterward, they were randomly divided into five weight-matched groups; normal control (C; n=5), high-fat diet (HF; n=5), exercise (E; n=5), purple sweet potato extract (PSP; n=5), and exercise combined with purple sweet potato extract (EPSP; n=5). The positive control group in this study (C) represents the normal variation from the observation after the treatment is given, while the negative control group consists of HF, E, PSP, and EPSP which represents the normal variation from the observation before the treatment was done. The present study followed animal welfare principles in experimental science published by the European Convention for the Protection of Vertebrate Animals and has received approval from the Health Research Ethics Committee of the Faculty of Public Health, Airlangga University, Surabaya, Indonesia, number: 328-KEPK.

Extraction of purple sweet potato

Purple sweet potato es (*Ipomoea batatas L. var Ayamurasaki*) were sorted to obtain high-quality tubers. One kilogram of sorted tuber was peeled out, then rinsed with clean water, and chopped at 2-3 cm of thickness. It was dried using a drying cabinet with the temperature set to 60 ºC for 8 hours to obtain simplicia. The simplicia was then crushed and macerated by ethanol 96% at room temperature for 24 hours to produce crude extract. The crude extract was then filtered using filter paper to obtain anthocyanin filtrate. The anthocyanin filtrate was mixed with maltodextrin and then emulsified by adding 10% egg white. The mixture was then stirred manually for ± 2 minutes. Afterward, the mixture was dried using a drying cabinet and crushed with mortal and then sieved in 80 mesh size.

Animal care and exercise protocol

All rats were placed at room temperature of 26 ± 2°C with 50-60% humidity (Yuliastrid et al., 2024), and the lighting was regulated by a light-dark cycle with 12-hour light and 12-hour dark cycles (08:00–20:00) (Antoni et al., 2022; Rejeki et al., 2021). During one week of the acclimatization period, they were fed a normal diet and tap water *ad libitum*. Afterward, they were divided into two weight-matched groups; standard diet (n=5) and high-fat diet (n=20), and given their respective diet for two weeks. Standard rat chow diet consists of 20-25% protein, 45-50% starch, 5% fat, 5% ash, 5% crude fiber, vitamins, and minerals. The high-fat diet was prepared by adding 10% of a liquid mixture of reused cooking oil and duck egg yolk to standard rat chow, resulting in ~30-40% added cholesterol.

After two weeks, rats in the high-fat diet group were randomly divided into four groups consisting of five rats each; HF (high-fat diet only), E (high-fat diet and exercise), PSP (high-fat diet and purple sweet potato extract), and EPSP (high-fat diet and exercise combined with purple sweet potato extract). Rats in PSP and EPSP were given purple sweet potato extract daily at a dose of 100 mg/day through oral gavage for three weeks. Moreover, rats in E and EPSP were subjected to swimming exercises regularly every morning. Swimming exercise was performed for 30 minutes/day, five days a week, for three weeks at an intensity of 6% of body weight (Sholikhah & Ridwan, 2021; Antoni et al., 2022). The swimming session was done in a tank filled with water that was sufficient for rats to swim simultaneously without touching the bottom of the tank. The training in the first week began with acclimatization in the water for 15 minutes. Then, the duration was increased by 5 minutes every day until each rat could swim continuously for 30 minutes. After each swimming session, rats were hair-dried to prevent hypothermia stress. During the experimental period, the average food intake of each group was recorded daily and body weight was measured weekly. Two measurements were done consecutively and the average was then taken as the final reading for body weight. Body weight measurements were using a HL-3650 heles digital scale (0-5kg scale) (Sari et al., 2023).

Biochemical analysis

All rats were euthanized following a 12-hour fasting period (Pranoto et al., 2020). Intracardiac blood was collected to measure the lipid profiles of each rat. The serum concentration of total cholesterol (T-C), LDL-cholesterol, and HDL-cholesterol levels were measured enzymatically by colorimetric method (Shrivastava et al., 2015).

Data analysis

Data were analyzed with SPSS software and were presented as mean values and standard deviation (SD). Normality and homogeneity tests were applied using Shapiro-Wilk and Levene's test. Paired sample t-test was performed to compare the initial (first week) and final (third week) body weight. One-way ANOVA and the Least Significant Difference (LSD) post hoc test were performed to compare weight gain and lipid profiles between groups. All statistical analyses use a significant level of 5%.

Results

To observe the changes in lipid profiles during the experimental period, body weight in all groups was measured. Two measurements were done consecutively and the average was then taken as the final reading for body weight. The results of the average body weight are shown in Figure 1.

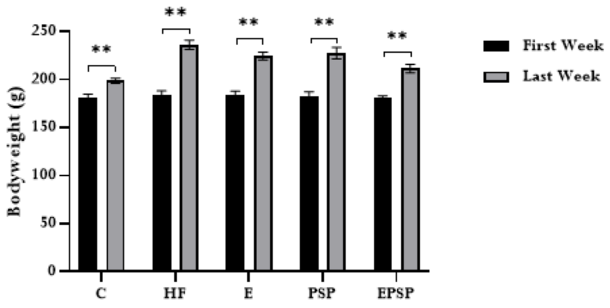

Figure 1. Effect of purple sweet potato extract and aerobic exercise with a high-fat diet on body weight change (g). Control (C), high-fat diet (HF), exercise (E), purple sweet potato extract (PSP), and exercise combined with purple sweet potato extract (EPSP). p-values are obtained with a paired sample t-test. Data presented as mean and standard deviation (SD). (**) A significant difference in the first week ($p \leq 0.001$).

Based on the results of the analysis, it showed that there was an increase in body weight between the first week and the last week in each group ($p \leq 0.001$). Meanwhile, the results of the analysis of differences in weight gain (g) between groups are presented in Figure 2.

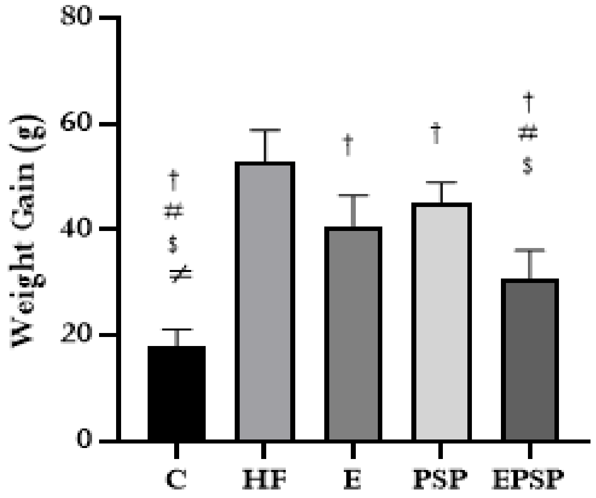

Figure 2. Effect of purple sweet potato extract and aerobic exercise with a high-fat diet on weight gain (g). (†) Significant difference at HF ($p \leq 0.05$). (#) Significant difference at E ($p \leq 0.05$). ($) Significant difference at PSP ($p \leq 0.05$). (≠) Significant difference at EPSP ($p \leq 0.05$). p-values are obtained with One-way ANOVA and LSD post hoc test. Data presented as mean and SD.

Based on Figure 2, rats in all groups gained significant weight in the last week compared first week including the control group (C) that was given a standard-normal diet. However, control group experienced the lowest weight gain compared to the other groups with an average weight gain was 18.04 ± 3.12 grams. Meanwhile, the highest weight gain among all groups was found in high-fat diet (HF) with the average weight gain was 52.86 ± 5.97 grams.

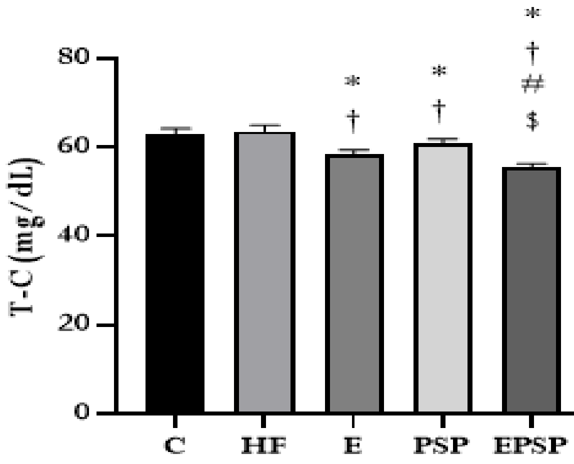

Figure 3. Effect of purple sweet potato extract and aerobic exercise with a high-fat diet on T-C levels (mg/dL). (*) Significant difference at C ($p \leq 0.05$). (†) Significant difference at HF ($p \leq 0.05$). (#) Significant difference at E ($p \leq 0.05$). ($) Significant difference at PSP ($p \leq 0.05$). p-values are obtained with One-way ANOVA and LSD post hoc test. Data presented as mean and SD.

Based on Figure 3, it shows that there is a significant difference in average T-C levels (mg/dL) between groups (C: 63.01±1.21 mg/dL vs. HF: 63.54±1.41 mg/dL vs. E: 58.20±1.14 mg/dL vs. PSP: 60.85±0.99 mg/dL vs. EPSP: 55.60±0.72 mg/dL; p=0.001).

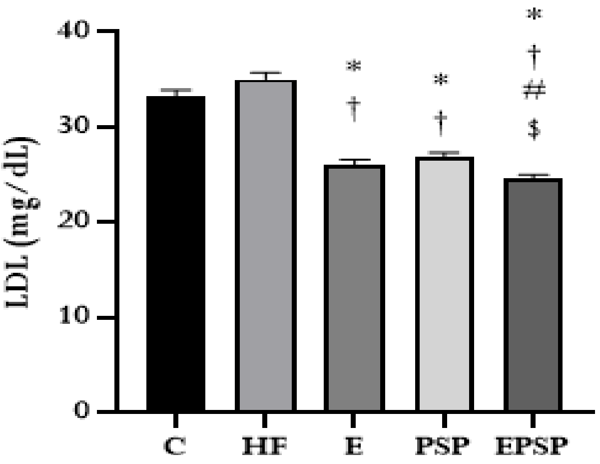

Figure 4. Effect of purple sweet potato extract and aerobic exercise with a high-fat diet on LDL levels (mg/dL). (*) Significant difference at C ($p \leq 0.05$). (†) Significant difference at HF ($p \leq 0.05$). (#) Significant difference at E ($p \leq 0.05$). ($) Significant difference at PSP ($p \leq 0.05$). p-values are obtained with One-way ANOVA and LSD post hoc test. Data presented as mean and SD.

Based on Figure 4, it shows that there is a significant difference in average LDL levels (mg/dL) between groups (C: 33.25±0.66 mg/dL vs. HF: 35.03±0.69 mg/dL vs. E: 26.01±0.56 mg/dL vs. PSP: 26.93±0.40 mg/dL vs. EPSP: 24.50±0.48 mg/dL; p=0.001).

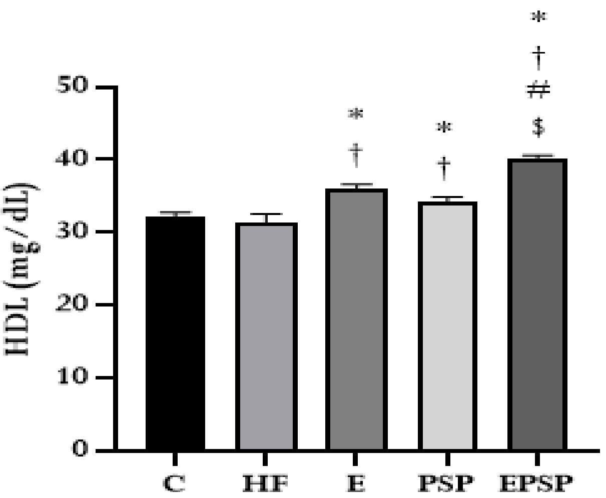

Figure 5. Effect of purple sweet potato extract and aerobic exercise with a high-fat diet on HDL levels (mg/dL). (*) Significant difference at C ($p \leq 0.05$). (†) Significant difference at HF ($p \leq 0.05$). (#) Significant difference at E ($p \leq 0.05$). ($) Significant difference at PSP ($p \leq 0.05$). p-values are obtained with One-way ANOVA and LSD post hoc test. Data presented as mean and SD.

Based on Figure 5, it shows that there is a significant difference in average HDL levels (mg/dL) between groups (C: 32.15±0.64 mg/dL vs. HF: 31.42±1.15 mg/dL vs. E: 35.99±0.62 mg/dL vs. PSP: 34.23±0.67 mg/dL vs. EPSP: 40.09±0.54 mg/dL; p=0.001).

Discussion

This research aims to investigate the effect of purple sweet potato extract and swimming training on the lipid profile of a hyperlipidemic rat model. Our results show that the combination of exercise with the addition of purple sweet potato extract significantly improves the lipid profile in the rat model. Rats were given a diet for two weeks. Our study showed body weight in all groups. The least weight gain occurred in the control group. The highest weight gain occurred in the high-fat diet group. All groups were given a standard diet consisting of 20-25% protein, 45-50% starch, 5% fat, 5% ash, 5% crude fiber, vitamins, and minerals. The high-fat diet was prepared by adding 10% of a liquid mixture of reused cooking oil and duck egg yolk to standard rat chow, resulting in ~30-40% added cholesterol. We have reported that this diet causes hyperlipidemia, characterized by high LDL levels in the control and high-fat diet groups. This shows that eating habits and type of food are factors causing increased body weight and hyperlipidemia. Hyperlipidemia is defined as levels of one or more lipids in plasma that are higher than normal, which are clinically classified as hypercholesterolemia, hypertriglyceridemia, mixed hyperlipidemia, and high-density lipoproteinemia (Li et al., 2022). LDL levels were lower in the intervention group (exercise, the group given intervention in the form of purple sweet potato extract, and the combination group exercise and given purple sweet potato extract) compared to the control and high-fat-diet groups, proving that the fat profile had improved, these data strengthened by higher HDL levels. HDL-C (High-density lipoprotein cholesterol) has for many years been thought to be inversely related to cardiovascular risk, a postulate based primarily on epidemiological studies showing that every 1 mg/dL increase in HDL-C is accompanied by a ~2% to 3% reduced risk of cardiovascular death (Trimarco et al., 2022; Wilson et al., 1988; Pekkanen et al., 1990; Sourlas & Kosmas, 2019; Casula et al., 2021; Gordon et al., 1989; Rader & Hovingh, 2014). Low LDL levels and increased HDL levels can be used as markers for an increased lipid profile.

This study shows the results of aerobic exercise by swimming 30 minutes at a frequency of 5 times per week for 3 weeks can improve lipid profiles. Aerobic exercise was significantly able to increase HDL levels and reduce weight gain, LDL levels, and total cholesterol. Exercise can have a positive effect on health and lipid profile, thereby reducing the risk of death. Inadequate exercise will be detrimental to a person because it increases the risk of cardiovascular disease due to impaired lipid metabolism and serum lipoprotein concentrations (Sung et al., 2017). Dyslipidemia patients are strongly advised to do aerobic exercise to improve their lipid profile because of their low-cost, low-risk, and non-drug intervention (Wang & Xu, 2017).

Exercise can maintain body weight due to the administration of a high-fat diet for 2 weeks (Figure 1). A previous study on the effect of aerobic exercise on 52 obese men with a mean BMI of 31.3 kg/m^2 stated that body weight decreased by 7.5 kg (8%) after aerobic exercise for 3 months (Ross et al., 2000). The study also states that aerobic exercise can prevent weight gain from returning. Tate et al. (2007) in their study involving 202 overweight men who were given aerobic exercise with a total calorie expenditure of 2500 kcal/week for 30 months revealed a significant weight loss of 3%.

The effect of exercise on the lipid profile is achieved through the action of lipoprotein and hepatic lipase enzymes and cholesterol esters (Wang & Xu, 2017). Aerobic exercise can increase HDL-C concentrations and reduce triglycerides, LDL-C levels, and total cholesterol (Tate et al., 2007). In 2018, Othman & Temur conducted a study on 20 men by doing 90 minutes of walking and running exercise for 8 weeks with a frequency of 3 times per week. The result was a reduction in cholesterol levels of 85.35 mg/dl (Othman & Temur, 2018). Fat deposits in the body are used as a source of energy when doing exercise. The process of lipolysis to break down fat as an energy source will increase when stimulated by increased sympathetic activity and decreased insulin secretion (Barjaktarović-Labović, 2015). Exercise can increase sympathetic nerve activity and decrease insulin secretion (Bird & Hawley, 2017; Iaccarino et al., 2021).

Exercise can reduce LDL-C levels in adults by an average reduction of 3-6 mg/dL (Members et al., 2014). Research by LeMura et al., (2000) stated that aerobic exercise for 6 weeks by healthy women can reduce LDL-C levels, triglycerides, and 13% body fat percentage. In addition, aerobic exercise also increases HDL-C levels and 25% VO_{2max} (LeMura et al., 2000). Varady et al. (2005) in their research on the effect of aerobic exercise on LDL particle size in hypercholesterolemic patients, stated that aerobic exercise was able to significantly reduce LDL. Albarrati et al. (2018) who reviewed 11 research articles on physical exercise on LDL levels concluded that aerobic exercise, both low and moderate intensity, was able to reduce total cholesterol and LDL levels.

The decrease in LDL-C due to aerobic exercise is thought to be due to the decrease in apolipoprotein (apoB) due to exercise (Wang & Xu, 2017). Apolipoprotein (apoB) is the main component of LDL particles. The concentration of apolipoprotein (apoB) indirectly reflects the concentration of LDL because approximately 95% of apolipoprotein (apoB) binds to LDL particles and one LDL particle binds to one apolipoprotein molecule (apoB) (Shelness & Sellers, 2001). Aerobic exercise that is performed for several months can reduce apolipoprotein (apoB) in hypercholesterolemic patients (Crouse et al., 1997). However, Leon et al. (2000) obtained different results in that there was no significant change in apolipoprotein levels (apoB) after aerobic exercise for 20 weeks. Thus, it is necessary to carry out further research on the effect of aerobic exercise on apolipoprotein (apoB) more deeply.

Exercise is believed to improve HDL levels and thus reduce the risk of cardiovascular disease (Albaghdadi et al., 2017). Several studies have shown that exercise has no significant effect on changes in HDL levels (Pattyn et al., 2013; Lemes et al., 2016). However, Members et al. (2014) revealed that HDL-C levels were better in adults doing aerobic exercise and could reduce the prevalence of coronary heart disease by 6%. Lemes et al. (2018) also stated that HDL-C levels increased by 3 mg / dL in adults after 12 weeks of aerobic exercise. Meanwhile, Banz et al. (2003) stated in their study of 11 obese men who exercised for 10 weeks 3 times a week caused an increase in HDL-C levels by 13%. Kesaniemi et al. (2001) who conducted 51 research articles also revealed that HDL levels increased by 4.6% as a result of aerobic exercise, while LDL and triglyceride levels were inconsistent. HDL, which is commonly referred to as good fat in the body, functions as a transport of cholesterol in the blood vessels to the liver so that it conflicts with the performance of LDL in clogging blood vessels which can cause atherosclerosis (Vickers et al., 2011; Vickers & Remaley, 2014). The mechanism by which aerobic exercise can increase HDL-C levels is not clear. However, Gordon et al. (2014) explain that aerobic exercise increases apolipoprotein A1 (ApoA1), decreases hepatic lipase activity, and decreases HDL-C catabolism. ApoA1 is a major protein component that synthesizes HDL-C (Klancic et al., 2016).

Almost all of the nutrients contained in purple sweet potatoes prevent coronary heart attacks. Several studies have also stated that these compounds can prevent obesity and diabetes, improve brain memory abilities prevent neurological diseases, and ward off free radicals in the body (Oki et al., 2002; Cevallos-Casals & Cisneros-Zevallos, 2003). Sweet potatoes contain lots of vitamins (B1, B2, C, and E), minerals (calcium, magnesium, potassium, and zinc), dietary fiber, and nonfibrous carbohydrates. In addition, purple sweet potato also contains other beneficial nutrients such as flavonoids, β-carotene, and anthocyanins (Suda et al., 2003). Various studies have shown that some of the flavonoids contained in purple sweet potatoes have antioxidant properties, because the micronutrients, which are phytochemical groups of various food ingredients derived from plants, are believed to protect against oxidative stress. One type of plant flavonoid that can function as an antioxidant is a natural dye called anthocyanin (Oki et al., 2002). Purple sweet potato contains 519 mg of anthocyanin/100 g fresh weight. The anthocyanin levels in purple sweet potatoes were greater than in red cabbage, elderberry, blueberries, and corn (Dwiyanti et al., 2018). Anthocyanin levels will increase significantly after 30 minutes to 8 hours of consuming purple sweet potato with a dose of 4 ml single dose (Sutirta-Yasa & Jawi, 2014). A group of anthocyanins stored in purple sweet potatoes can block the rate of free radical cell destruction caused by nicotine, air pollution, and other chemicals (Barrowclough, 2015). Anthocyanins play a role in preventing aging (Wallace et al., 2013), degenerative diseases (Jang et al., 2005), coronary heart disease (Wallace, 2011), cancer (Katsube et al., 2003), hypertension, and hypercholesterolemic effect (Hopkins et al., 2013).

The antioxidant function of anthocyanins can prevent atherosclerosis by reducing cholesterol levels in the blood caused by LDL oxidation. In other words, anthocyanins protect fat cell membranes from oxidation (Wallace, 2011). The cholesterol level that is lowered by anthocyanins in this case reaches up to 13.6% when taking anthocyanins for ± 12 weeks with an average consumption of anthocyanins in women between 19.8 - 64.9 mg and in men around 18.4 - 44, 1 mg daily (Priska et al., 2018). Purple sweet potatoes containing 0.07% anthocyanins can prevent atherosclerosis through the experimental inhibition of aortic VCAM by changing cholesterol levels and lipid levels (Satriyasa, 2017). The size of adipose cells affects the amount of free fatty acids released. Hypertrophic adipocytes excrete more free fatty acids than normal adiposity. The administration of purple sweet potato extract can reduce the accumulation of free fatty acids in adipose so that it can reduce the size of adipose (Tsuda et al., 2003; Ju et al., 2011).

The mechanism of anthocyanins in improving lipid profiles is described as follows: 1) Decreased cholesterol synthesis due to decreased activation of the HMG-CoA reductase gene, 2) Decreased LDL concentration due to inhibition of cholesteryl ester transfer protein (CETP), 3) decreased apolipoprotein B and apolipoprotein C-III, 4) Anthocyanin facilitates the excretion of cholesterol through feces (Shah, 2019). A study conducted by (Sutirta-Yasa &

Jawi, 2017) about the administration of purple sweet potato to 28 Wistar rats at a dose of 200 mg/day for 4 weeks was able to increase HDL levels and reduce total cholesterol, triglycerides, and LDL levels (Sutirta-Yasa & Jawi, 2017). (Ishiguro et al., 2016) also reported in their study of mice given sweet potatoes for 28 days that levels of VLDL, LDL, triglycerides, and leptin levels were significantly lower than the control group (Ishiguro et al., 2016). In 2007, Chang et al. also conducted a study where the consumption of purple sweet potato for 2 weeks as an anti-oxidant can improve lipid profiles in 15 elite basketball players (Chang et al., 2007).

Another mechanism of purple sweet potato in reducing total cholesterol, triglyceride, and LDL levels and increasing HDL according to Nagai et al. (2011) is the suppression of LDL oxidation due to the antioxidant properties of purple sweet potato. Purple sweet potatoes are also rich in polyphenols which can prevent oxidative stress such as cancer, aging, and cardiovascular disorders (Musilová et al., 2017). Polyphenols have been reported to reduce plasma LDL concentrations. The decrease in LDL concentration was followed by a decrease in the Apoprotein B concentration (Hernáez et al., 2015). Apolipoprotein B is the main protein in atherogenic lipoprotein particles and is mainly present in LDL particles. Each LDL particle contains one apo B molecule, thus the concentration of apoprotein B reflects the number of LDL particles in the body (Setiawan et al., 2017).

Purple sweet potato extract contains the flavonoid quercetin (Suárez et al., 2020). The mechanism of action of quercetin is to reduce total cholesterol levels and LDL cholesterol levels by inhibiting the secretion of Apo-B 100 in $CaCO_2$ cells and reducing MTP activity, which plays a role in the formation of lipoproteins by catalyzing the transfer of lipids to Apo-B molecules. Quercetin can also inhibit the activity of the enzyme HMG-CoA reductase, an enzyme that plays a role in cholesterol formation. Quercetin's antioxidant properties can prevent LDL oxidation by binding to free radicals and transitioning metal ions to inhibit lipid peroxidation (Bentz, 2017). Lipid peroxidation is the process of converting fatty acids through hydrogen abstraction. Lipid peroxidation can cause damage such as heart disease (Duarte et al., 2001).

The results of this study indicate that after being given a high-fat diet, the Exercise Combined with Purple Sweet Potato Extract (EPSP) treatment is better than giving purple sweet potato (PSP) or aerobic exercise (E) treatment alone on weight gain (Figure 2), total cholesterol (Figure 3), LDL level (Figure 4), HDL level (Figure 5). These results are in line with a study conducted by Son et al. (2015) who gave purple sweet potato to 24 obese students and 70 minutes of aerobic exercise with a frequency of 3 times per week for 12 weeks. The result is lean body mass, % body fat, triglycerides, and total cholesterol in participants who were given the Exercise Combined with Purple Sweet Potato Extract treatment had a significantly lower pre-post difference value than giving purple sweet potato or aerobic exercise alone. HDL levels also increased the best compared to participants given the Exercise Combined with Purple Sweet Potato Extract treatment which had a significantly lower pre-post value than giving purple sweet potato or aerobic exercise alone. However, there was no significant difference in LDL levels in all treatment groups (Son et al., 2015).

The Exercise Combined with Purple Sweet potato Extract treatment can improve lipid profiles in 2 ways. The first is due to the content of Purple Sweet Potato Extract such as anthocyanins. By consuming Purple Sweet Potato Extract, the anthocyanins contained in Purple Sweet Potatoes will reduce the cholesteryl ester transfer protein (CETP), thereby reducing the LDL level and increasing the HDL level (Qin et al., 2009). Anthocyanins work to inhibit the atherogenesis process by oxidizing bad fats in the body, namely LDL. Apart from that, anthocyanins also lower total cholesterol, and triglycerides and increase HDL levels (Liu et al., 2016). Anthocyanins also protect the integrity of the endothelial cells lining the walls of blood vessels so that no damage occurs (Shah, 2019).

Second, aerobic exercise treatment will reduce LDL-C levels due to decreased apolipoprotein (apoB) as the main component of LDL particles (Shelness & Sellers, 2001). In addition, aerobic exercise also increases apolipoprotein A1 (ApoA1), decreases liver lipase activity, and decreases HDL-C catabolism (Gordon et al., 2014). A limitation in this study is that we only focused on increasing the lipid profile from the fat profile composition level factor itself without controlling for other factors that could influence the lipid profile. Meanwhile, further research is recommended to control factors that can influence changes in lipid profiles, and compare different methods and media.

Conclusion

Purple sweet potato extract combined with swimming exercise is more effective in improving lipid profiles than exercise alone or purple sweet potato extract alone in the hyperlipidemic rats model.

Conflict of Interest

The authors declare that they have no conflict of interest in this study.

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