MEDIA PENELITIAN DAN
PENGEMBANGAN KESEHATAN
Vol 35 No 4, Desember 2025

e-ISSN: 2338-3445
p-ISSN: 0853-9987

# STRAWBERRY POWDER IMPROVES TOTAL CHOLESTEROL, LDL, MDA, AND VISCERAL FAT MASS IN HFHFR-INDUCED OBESE RATS

*Tepung Stroberi Memperbaiki Kadar Kolesterol Total, LDL, MDA dan Massa Lemak Visceral pada Tikus Obesitas yang Diinduksi HFHFr*

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***ABSTRAK***

*Obesitas merupakan masalah gizi global yang semakin meningkat, termasuk di Indonesia. Salah satu pendekatan nonfarmakologis untuk mengatasinya adalah intervensi nutrisi. Penelitian ini bertujuan mengevaluasi efek pemberian tepung stroberi terhadap kadar kolesterol total, LDL, malondialdehid (MDA), dan massa lemak viseral pada tikus model obesitas yang diinduksi diet high fat high fructose (HFHFr). Studi eksperimental ini melibatkan 6 kelompok tikus Wistar jantan dengan desain pre dan post test. Setelah induksi obesitas selama 4 minggu, intervensi tepung stroberi diberikan selama 4 minggu dengan tiga dosis berbeda (0,117 g, 0,234 g, 0,468 g/200 g BB/hari). Hasil menunjukkan bahwa diet HFHFr berhasil menginduksi obesitas ditandai dengan peningkatan berat badan, indeks Lee >300, serta kenaikan kadar kolesterol, LDL, dan MDA. Intervensi tepung stroberi yang dilakukan selama 4 minggu menunjukkan hasil terjadinya penurunan kadar kolesterol total (p<0,001), LDL (p<0,001), MDA (p<0,001), dan massa lemak viseral (p<0,001) secara signifikan. Dosis kedua (0,234 g) juga menunjukkan adanya efek serupa dengan obat orlistat yang mana menjadi obat standar dalam manajemen obesitas. Temuan ini menbuktikan tepung stroberi dapat digunakan sebagai terapi diet alternatif untuk memperbaiki profil lipid, menurunkan stres oksidatif, dan mengurangi lemak viseral pada kondisi obesitas. Penelitian lanjutan pada manusia disarankan untuk mendukung hasil ini dalam konteks klinis*

***Kata kunci**: Intervensi, LDL, massa lemak viseral, MDA, tepung stroberi, total kolesterol*

**ABSTRACT**

Obesity is an increasing global nutritional problem, including in Indonesia. One non-pharmacological approach to overcome it is nutritional intervention. This study aims to evaluate the effect of strawberry powder on total cholesterol, LDL, malondialdehyde (MDA), and visceral fat mass levels in obesity model rats induced by a high-fat, high-fructose (HFHFr) diet. This experimental study involved six groups of male Wistar rats, utilizing a pre- and post-test design. After obesity induction for 4 weeks, strawberry powder intervention was given for 4 weeks with three different doses (0.117 g, 0.234 g, 0.468 g/200 g BW/day). The results showed that the HFHFr diet successfully induced obesity, characterized by increased body weight, a Lee index greater than 300, and elevated levels of cholesterol, LDL, and MDA. After 4 weeks strawberry powder intervention showed significant decrease in total cholesterol ($p < 0.001$), LDL ($p <$



https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

0.001), MDA ($p < 0.001$), and visceral fat mass levels ($p < 0.001$). The second dose (0.234 g) also showed a similar effect to orlistat, a standard drug in obesity management. These findings suggest that strawberry powder can be use as an alternative dietary therapy for improving lipid profiles, reducing oxidative stress, and decreasing visceral fat in individuals with obesity. Further human studies are recommended to support these results in a clinical context.

**Keywords:** Cholesterol total, Intervention, LDL, MDA, strawberry powder, intervention, visceral fat mass

## INTRODUCTION

Obesity is one of the biggest nutritional problems in the world. In 2022 there were approximately 2.5 billion cases of obesity recorded and as many as 1 in 8 people are obese on an international scale [1]. Indonesia is a developing country that has an obesity control program. Data show that the incidence of obesity has continued to increase over the last 15 years, reaching 2.3 times the 2018 rate. The latest data on the incidence of obesity, as of 2023, is 23.4% [2],[3]. Obesity is not only related to body weight. Still, it can also be related to metabolic disorders, such as lipid profile disorders, oxidative stress, and increased visceral fat mass, which can cause metabolic syndrome [4].

Adiposity that occurs in this condition stimulates the release of inflammatory adipokines which causes increased oxidative stress and inflammation [5], one of the biomarkers of oxidative stress is malondialdehyde (MDA) levels [6]. A study showed that obese and overweight groups had higher MDA levels compared to normal weight groups [7]. Excessive fat accumulation also results in accumulation in visceral fat tissue which can disrupt the body's metabolic regulation [8]. This can increase the risk of developing degenerative diseases such as coronary heart disease, diabetes mellitus, hypertension, stroke, and others [9],[10],[11],[12]. A study showed that overweight groups had higher total cholesterol levels and low-density lipoprotein compared to normal weight groups [13],[14].

The high-fat, high-fructose (HFHFr) diet is an experimental model commonly used in animal models of obesity [15]. Literature studies show that giving an HFHFr diet can cause weight gain in experimental animals to become obese, lipid profile disorders, and oxidative stress [16]. Many non-pharmacological therapies can be used in obesity management, one of which is lifestyle changes that include a healthy diet, physical activity, and weight management [17],[18]. A healthy diet, in the form of nutritional intervention, is one of the approaches recommended by the Ministry of Health for obesity management [19]. Fruit is one element in balanced nutrition guidelines, the recommended consumption of fruit and vegetables is 1/3 of the serving plate [20]. But, it has been recorded that 96.7% of the population consumes insufficient amounts of fruit and vegetables [3].

Strawberries are one of the fruits with a high content of bioactive compounds, including flavonoids, anthocyanins, and vitamin C, and possess antioxidant properties [21]. Anthocyanins are antioxidants belonging to the flavonoid family of the anthocyanidin subclass found in strawberries [22]. Anthocyanins can reduce fatty acid levels in the body, resulting in decreased low-density lipoprotein (LDL) and increased high-density lipoprotein (HDL), which can reduce the risk of obesity [23]. Antioxidants are associated with the modulation of chronic diseases related to oxidative stress as well as for maintaining body health, a study shows that antioxidants found in food have an important role in inflammation, obesity, and modulation of gut microbiota [24]. The anthocyanins in strawberries have also been shown to affect malondialdehyde and lower lipid peroxide levels [25]. Other research states that consumption of strawberries has benefits for visceral fat tissue in obesity-induced groups [26].


https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

Studies have shown that consuming strawberries can improve lipid profiles [27] and reduce oxidative stress [28], which may have a positive effect on individuals with obesity. Unfortunately, fresh strawberries are susceptible to physical damage and cannot be stored for long periods of time [29]. Strawberries processed into dry products offer advantages in terms of nutritional stability and food security compared to fresh strawberries [30]. A study shows that processing strawberries into powder does not significantly change the content [31]. Therefore, this research aims to see the effect of giving strawberry powder on cholesterol levels, LDL, malondialdehyde (MDA), and visceral fat mass in experimental animal models of obesity induced by HFHFr.

## METHODS

This study used an experimental design with a pre and post-approach. Sample distribution was carried out using the randomization method, with 30 rats randomly divided into 6 groups, with each group consisting of 5 rats. The rats used in this study were the Wistar strain, male, and 2 months old before starting adaptation. For the normal control group, HFHFr induction was not carried out as a differentiator between the healthy group and the group that was successfully induced. Induction was carried out for 28 days, HFHFr feed was given ad libitum, and 10% fructose fluid via tube.

When obesity modeling was complete, the intervention process was continued for 4 weeks. A rats is considered obese if its index value is more than 300. The negative control group and normal control were not given treatment; the positive control group was given orlistat 2.16 g/200 g/day, and the treatment groups were given strawberry powder at a dose of 0.117 g for treatment group 1, a dose of 0.234 g for treatment group 2, and a dose of 0.468 g for treatment group 3 per 200 grams body weight per day. Normal dosage refers to previous studies [27] and the treatment dose refers to the Dose Ranging Study, which is a dose test at various levels, with normal dose levels (medium dose), half dose (low dose), and double dose (high dose) [32]. Strawberry powder was dissolved in distilled water and administered orally using a tube. Strawberry powder is made through a drying process using a cabinet dryer for 2 x 8 hours at a temperature ranging from 50-60°C and grinding using a flour grinder. After analysis, the strawberry powder contains 34.12 kcal, 0.64 grams of protein, 0.32 grams of fat, and 7.17 grams of carbohydrates per 10 grams of powder. It also contains 397.72 mg of vitamin C, 18.83 mgQe/g of flavonoids, and 555.1 ppm of anthocyanin [31]. Administration was carried out in the morning during the intervention. During the intervention, all groups were given standard feed and raw water ad libitum.

This research was conducted at the Center for Food and Nutrition Studies (PSPG) Universitas Gadjah Mada Yogyakarta, the research was conducted from December 2024 to February 2025. Total cholesterol, LDL, and MDA levels were measured before starting the intervention (pre-test); after the intervention (post-test), cholesterol, LDL, and MDA levels were measured again. The method used in examining total cholesterol levels is the CHOD PAP enzymatic determination method; LDL examination using the CHOD PAP enzymatic precipitation method (DiaSys®); MDA examination using the Thiobarbituric Acid Reactive Substances (TBARS) assay (Merck KgaA®); then surgery to weigh visceral fat mass was carried out after the euthanasia process was carried out.

The statistical test used in this study was a one-paired t-test to examine the effect of strawberry powder administration on total cholesterol, LDL, and MDA before and after the intervention, if the data is not normally distributed, use the non-parametric test: Wilcoxon. A one-way ANOVA statistical test was also conducted to examine differences in examination results between treatment groups and to examine differences in visceral fat mass after the intervention in all groups, if the data is not normally distributed, use the non-parametric test: Kruskal Wallis. A Post Hoc test was conducted to determine specific differences between groups. This study has obtained


https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

ethical clearance with number 5430 / B.1 / KEPK-FKUMS / XII / 2024 from the ethics commission of the Faculty of Medicine, Muhammadiyah University of Surakarta.

## RESULT

HFHFr induction was carried out for 4 weeks in groups modeled as obese, namely the negative control group, positive control, treatment 1, treatment 2, and treatment 3. Table 1 shows data that the average body weight after induction did not differ significantly between groups, indicating that the weight gain in the group given the HFHFr diet was successful. Obesity induction was also said to be successful, as seen from the Lee index value in the induction group >300, which means that the rats already had an obesity status. After testing the comparison of mouse body weight between groups, there was a significant difference (p<0.05) before and after induction.

**Table 1. Body Weight and Lee Index Values Indicating Successful Obesity Induction**

| Group | Mean ± SD | | Mean ± SD Lee Index | Mean Difference BW | p-value[axy] |
|---|---|---|---|---|---|
| | x̄ BW Before[x] | x̄ BW After[y] | | | |
| NC* | 181,6 ± 5,857 | 211,0 ± 5,385 | 274,9 ± 3,248 | 29,4 ± 1,517 | <0,001 |
| C (-) | 179,8 ± 2,775 | 272,8 ± 4,024 | 315,9 ± 3,471 | 93,0 ± 1,414 | <0,001 |
| C (+) | 183,8 ± 3,271 | 277,0 ± 2,915 | 318,1 ± 3,099 | 93,2 ± 1,304 | <0,001 |
| T1 | 185,4 ± 3,209 | 277,8 ± 3,356 | 319,9 ± 2,676 | 92,4 ± 0,894 | <0,001 |
| T2 | 179,8 ± 2,775 | 273,8 ± 3,114 | 313,6 ± 2,084 | 94,0 ± 0,707 | <0,001 |
| T3 | 183,4 ± 4,979 | 276,6 ± 4,979 | 316,3 ± 3,378 | 93,2 ± 1,095 | <0,001 |
| p-value[b] | 0,376 | 0,839 | 0,817 | | |
| p-value | 0,188[c] | <0,001[c] | <0,001[c] | 0,006[d] | |

Note : NC: normal control group (no induction*); C(-): negative control group (HFHFr inducted); C(+): Positive control group (HFHFr inducted); T1 : treatment 1 group; T2 : treatment 2 group (HFHFr inducted); T3 : treatment 3 group (HFHFr inducted); [a]) : One Paired T-test; [b]) : Homogeny test; [c]) : One Way ANOVA; [d]) : Kruskal Wallis; BW : body weight.

After successful induction, intervention was continued in each treatment group. The negative control group was a group that was induced to obesity and given standard feed during the intervention process, while in the positive control group, treatment groups one, two, and three showed an effect, and there was a significant difference before and after the intervention (p<0.05). Table 2 shows the results of a significant difference in total cholesterol levels in the normal control group before and after the intervention (p<0.05). The results of the pre- and post-difference tests in the negative control group showed no significant difference between cholesterol levels before and after the intervention (p>0.05). The results of the ANOVA test also showed a significant difference in total cholesterol levels after the intervention for 4 weeks (p<0.05).

**Table 2. Impact of Strawberry Powder on Total Cholesterol Levels**

| Group | Mean ± SD | | Mean Difference TC | p-value[a] |
|---|---|---|---|---|
| | x̄ TC (mg/dL) Before | x̄ TC (mg/dL) After | | |
| NC | 86,47 ± 2,158 | 88,64 ± 2,574 | 2,20 ± 0,507 | 0,001 |
| C (-) | 200,9 ± 3,858 | 202,5 ± 4,938 | 1,51 ± 1,422 | 0,760 |
| C (+) | 201,2 ± 1,677 | 108,2 ± 3,121 | -93,05 ± 4,379 | <0,001 |
| T1 | 207,1 ± 2,799 | 123,3 ± 2,250 | -83,82 ± 3,836 | <0,001 |
| T2 | 200,5 ± 4,699 | 106,7 ± 2,673 | -93,82 ± 3,604 | <0,001 |
| T3 | 201,6 ± 4,221 | 99,20 ± 4,289 | -102,4 ± 0,963 | <0,001 |
| p-value[b] | <0,001 | <0,001 | <0,001 | |

Note : NC: normal control group (Healthy Rats + standard feed); C(-): negative control group (Obese Rats + standard feed); C(+): Positive control group (Obese Rats + standard feed + orlistat); T1 : treatment 1 group (Obese Rats + standard feed + strawberry powder low doses); T2 : treatment 2 group (Obese Rats + standard feed + strawberry powder normal doses); T3 : treatment 3 group (Obese Rats + standard feed +



https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

strawberry powder high doses); [a]) : One Paired T-test; [b]) : One Way ANOVA; TC : total cholesterol

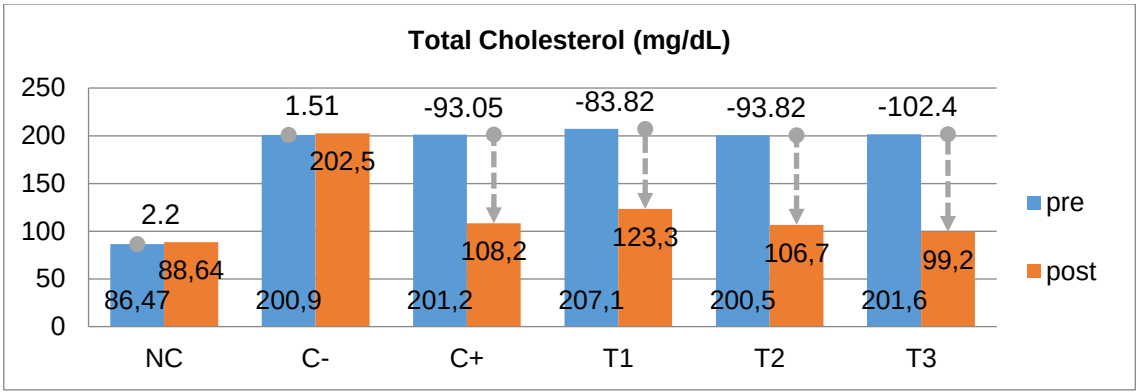


**Figure 1. Difference in Total Cholesterol Before and After Intervention**

Figure 1 shows a decrease in cholesterol levels in the groups given the strawberry powder intervention. Treatment group 1 experienced a 40.5% decrease, treatment group 2 experienced a 46.8% decrease, and treatment group 3 experienced a 50.8% decrease in cholesterol levels after being given strawberry powder. Each group showed different values, and treatment group 3 was the group that experienced a greater decrease compared to the other treatment groups.

The results of the ANOVA test on the post-test value of LDL levels showed a significant difference in LDL-C levels in the normal control group, negative control, positive control, treatment groups one, two, and three after being given an intervention for 4 weeks ($p<0.05$). The paired t-test data also showed an effect and a significant difference before and after the intervention ($p<0.05$).

**Table 3. Impact of Strawberry Powder on Low Density Lipoprotein Levels**

| Group | Mean ± SD | | Mean Difference LDL-C | p-value[a] |
|---|---|---|---|---|
| | x̄ LDL-C (mg/dL) Before | x̄ LDL-C (mg/dL) After | | |
| NC | 23,53 ± 1,090 | 25,04 ± 1,428 | 1,51 ± 0,395 | 0,001 |
| C (-) | 76,81 ± 1,622 | 78,08 ± 1,704 | 1,26 ± 0,397 | 0,002 |
| C (+) | 76,95 ± 1,419 | 34,67 ± 3,029[d] | -42,29 ± 3,375 | <0,001 |
| T1 | 77,78 ± 2,275 | 49,33 ± 1,535 | -28,45 ± 3,528 | <0,001 |
| T2 | 78,89 ± 2,680 | 33,78 ± 2,262[d] | -45,11 ± 3,358 | <0,001 |
| T3 | 76,68 ± 2,559 | 31,70 ± 2,739[d] | -44,98 ± 0,179 | <0,001 |
| p-value | <0,001[b] | <0,001[b] | <0,001[c] | |

Note: NC: normal control group (Healthy Rats + standard feed); C(-): negative control group (Obese Rats + standard feed); C(+): Positive control group (Obese Rats + standard feed + orlistat); T1 : treatment 1 group (Obese Rats + standard feed + strawberry powder low doses); T2 : treatment 2 group (Obese Rats + standard feed + strawberry powder normal doses); T3 : treatment 3 group (Obese Rats + standard feed + strawberry powder high doses); [a]) : One Paired T-test; [b]) : One Way ANOVA; [c]) : Kruskal Wallis; [d]) : not significantly different (Post Hoc); LDL-C : low density lipoprotein-cholesterol

Figure 2 shows a decrease in LDL levels in the groups given the strawberry powder intervention. Treatment group 1 experienced a 36.6% decrease, treatment group 2 experienced a 57.2% decrease, and treatment group 3 experienced a 58.7% decrease in LDL levels after being given strawberry powder. Each group showed different values, and treatment group 3 was the group that experienced a greater decrease compared to the other treatment groups.



https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

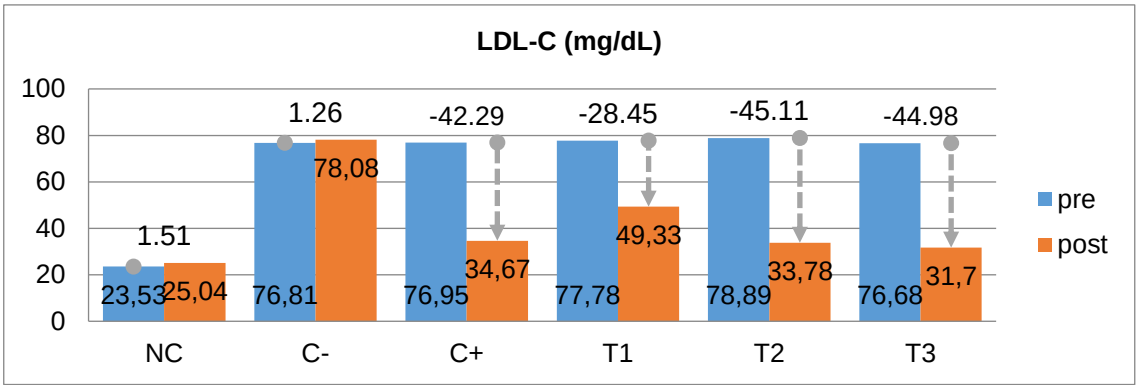


**Figure 2. Difference in LDL Level Before and After Intervention**

The results of the Kruskal-Wallis test in Table 4 show a significant difference in MDA levels in the normal control group, negative control, positive control, treatment groups one, two, and three after being given an intervention for 4 weeks (p <0.05). The paired t-test conducted on the normal control group, positive control, treatment groups one, two, and three also showed an effect and significant differences before and after the intervention (p <0.05). The pre- and post-test results of the negative control group showed the Wilcoxon test results showing a significant difference in MDA levels (p <0.05) before and after the intervention.

**Table 4. Impact of Strawberry Powder on MDA Levels**

| Group | Mean ± SD | | Mean Difference MDA | p-value[a] |
|---|---|---|---|---|
| | x̄ MDA (nmol/mL) Before | x̄ MDA (nmol/mL) After | | |
| NC* | 1,172 ± 0,146 | 1,340 ± 0,176 | 0,168 ± 0,069 | 0,006[a] |
| C (-) | 10,250 ± 0,375 | 10,442 ± 0,364 | 0,192 ± 0,116 | 0,042[d] |
| C (+) | 10,046 ± 0,162 | 3,122 ± 0,178 | -6,924 ± 0,138 | <0,001[a] |
| T1 | 10,608 ± 0,267 | 4,032 ± 0,339 | -6,576 ± 0,454 | <0,001[a] |
| T2 | 9,980 ± 0,448 | 3,070 ± 0,101 | -6,910 ± 0,479 | <0,001[a] |
| T3 | 10,082 ± 0,399 | 2,018 ± 0,146 | -8,064 ± 0,502 | <0,001[a] |
| p-value | <0,001[b] | <0,001[c] | <0,001[c] | |

Note : NC: normal control group (Healthy Rats + standard feed); C(-): negative control group (Obese Rats + standard feed); C(+): Positive control group (Obese Rats + standard feed + orlistat); T1 : treatment 1 group (Obese Rats + standard feed + strawberry powder low doses); T2 : treatment 2 group (Obese Rats + standard feed + strawberry powder normal doses); T3 : treatment 3 group (Obese Rats + standard feed + strawberry powder high doses); [a]) : One Paired T-test; [b]) : One Way ANOVA; [c]) : Kruskal Wallis; [d]) : Wilcoxon; MDA: malondialdehyde.

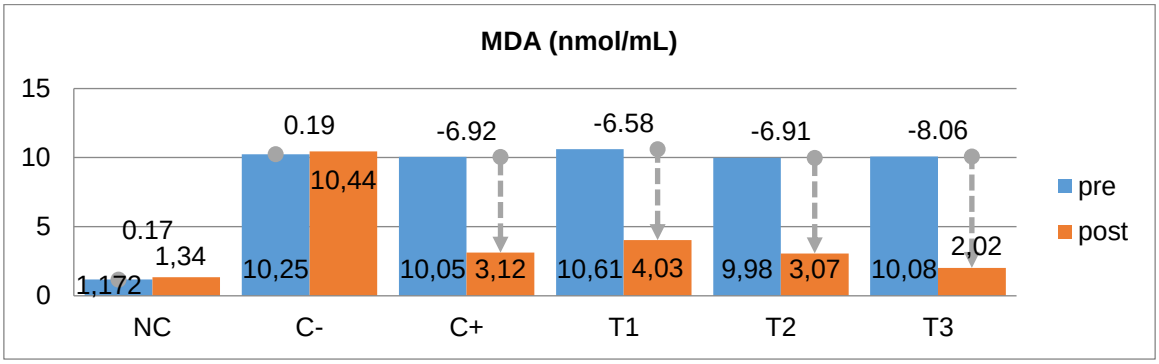


**Figure 3. Difference in MDA Levels Before and After Intervention**

Figure 3 shows a decrease in MDA levels in the groups given the strawberry powder intervention. Treatment group 1 experienced a 62% decrease, treatment group 2 experienced a 69.2% decrease, and treatment group 3 experienced a 79.9% decrease



https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

in MDA levels after being given strawberry powder. Each group showed different values, and treatment group 3 was the group that experienced a greater decrease compared to the other treatment groups.

It should also be noted that in Tables 2, 3, and 4, the normal and negative control groups showed significant changes in results, as these groups were not given any intervention other than a standard diet. This change in the normal control group could be due to the growth and developmental factors of mice in the early adult phase. This could be a factor in the natural changes in lipid profiles in the uninterrupted group. In the early adult phase, rats can experience increased metabolic activity and hormonal changes that affect lipid profiles and MDA levels [33]. Meanwhile, in the negative control group, pathological obesity, a consequence of HFHFr induction that occurred before the intervention, may have been affected. This could also be an indicator of metabolic syndrome in the obesity-induced group but not given any intervention.

The results in Table 5 show significant differences in visceral fat mass between groups (p=0.001). The data show that the normal control group had smaller visceral fat mass measurements compared to the other groups, while the visceral fat in the negative control group was greater than the other groups. When compared to the group given strawberry powder, the visceral fat mass in the obese intervention group showed that treatment group 3 was smaller than the other obese groups.

**Table 5. Impact of Strawberry Powder on Visceral Fat Mass**

| Group | Mean ± SD Visceral Fat Mass (g) |
|---|---|
| NC | 1,890 ± 0,229 |
| C (-) | 5,740 ± 0,600 |
| C (+) | 2,446 ± 0,042 |
| T1 | 3,080 ± 0,062 |
| T2 | 2,092 ± 0,129[b] |
| T3 | 1,922 ± 0,195[b] |
| p-value[a] | <0,001 |

Note : NC: normal control group (Healthy Rats + standard feed); C(-): negative control group (Obese Rats + standard feed); C(+): Positive control group (Obese Rats + standard feed + orlistat); T1 : treatment 1 group (Obese Rats + standard feed + strawberry powder low doses); T2 : treatment 2 group (Obese Rats + standard feed + strawberry powder normal doses); T3 : treatment 3 group (Obese Rats + standard feed + strawberry powder high doses); [a]) : One Way ANOVA; [b]) : not significantly different (Post Hoc).

When viewed from the three treatment effects, the dose in the third treatment group showed a greater decrease compared to treatment groups 1 and 2. However, further tests conducted (Post Hoc test) on the results of LDL and visceral fat measurements showed that the effect of the strawberry powder dose in treatment group 3 was not significantly different from the effect produced by the second dose in treatment group 2. This may indicate a dose response in the body that is given a high dose.

## DISCUSSION

This study shows that the use of the HFHFr diet for 4 weeks can cause experimental animals to become obese, indicated by a Lee index >300 [34]. The group given the HFHFr diet had an average Lee index >300. The selection of HFHFr induction refers to the habit of eating high-fat and high-sugar, which can cause weight gain, and when it lasts for a long time, it can cause obesity in individuals. A study shows that the habit of eating high-fat and sugar is common in the obese group [35]. In addition to increasing body weight, HFHFr induction can also cause other disorders, as shown in the table. There is an increase in total cholesterol, LDL, and MDA levels when compared to the normal control group (tables 2, 3 and 4). This is in line with other studies, which also prove that HFHFr induction can cause disorders in the lipid profile [36]. High MDA


https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

levels in the group given HFHFr induction can also be a marker of oxidative stress in the obese group given HFHFr induction [6].

After being given strawberry powder intervention for 4 weeks, the results of the study showed a significant decrease in total cholesterol in treatment group 2 (P2) and treatment group 3 (P3). The reduction in total cholesterol levels that occurred in groups P2 and P3 approached and exceeded the effectiveness of the orlistat drug given to the positive control group. This proves that the content in strawberry powder such as flavonoids, anthocyanins, and vitamin C has a hypolipidemic effect [37]. which bioactive content can reduce cholesterol levels by reducing fat absorption and inhibiting the HMG-CoA reductase enzyme, which plays a role in cholesterol synthesis [38].

LDL levels also experienced a significant decrease in the group given strawberry powder. LDL, known as bad fat, is one of the biomarkers of cardiovascular disease risk [39]. The decrease in LDL levels in the group given strawberry powder shows that this can reduce complications or the risk of cardiovascular disease related to obesity [40]. The antioxidant activity contained in strawberry powder can improve lipid profiles and prevent LDL oxidation, which is an important factor in the development of atheroma plaque [41].

MDA levels as a marker of oxidative stress in the obesity group also showed a significant decrease after being given strawberry powder. Increased MDA levels in the obesity modeling group indicate an increase in lipid peroxidation due to oxidative stress associated with visceral fat accumulation and metabolic disorders [42]. The significant decrease in MDA levels that occurred in the group given strawberry powder indicates a protective effect against oxidative damage; this is most likely due to the presence of anthocyanin and vitamin C as free radical scavengers in the body [43]. In addition to being a sign of reduced oxidative stress, the decrease in MDA that occurred in the group given strawberry powder indicates that strawberry powder can suppress systemic inflammation and cell damage that often occurs in the obese group. This proves that strawberry powder can be a source of nutraceuticals in weight control and metabolic health.

Visceral fat mass also showed a decrease in the group given strawberry powder when compared to the negative control group. Visceral fat has a role in the pathophysiology of metabolic syndrome and insulin resistance [44]. so that reducing visceral fat mass through a nutritional diet can reduce the risk associated with metabolic syndrome and insulin resistance. The reduction in visceral fat in the group given strawberry powder can be caused by the ability of the content in strawberry powder to suppress lipogenesis and increase fat oxidation through the lipid metabolism pathway. Overall, the results of this study indicate the potential of strawberry powder as a non-pharmacological therapy that can reduce total cholesterol, LDL, MDA, and visceral fat mass in the obese group. The third dose showed the best results during treatment, and the dose in treatment group 2 had a significant effect with the group given standard drugs, namely orlistat. This shows that the use of strawberries processed into powder can be used as a long-term dietary approach in obesity management.

Compared to the effects given to treatment groups 2 and 3, it does appear that the dose in treatment group 3 (0.468 g/200 g bb/day) is superior, but in several examination indicators such as LDL levels and visceral fat, it shows that the dose in group 3 is not significantly different from group 2. This finding is in line with the concept of a dose-response plateau, which is an indication that the active effect that occurs in strawberry powder may have reached the peak of dose effectiveness in the second treatment. So that when using a higher dose it no longer provides an improvement effect on the body [45]. Therefore, strawberry powder at a normal dose of 0.234 g/200


https://doi.org/10.34011/jmp2k.v35i4.3316

e-ISSN: 2338-3445
p-ISSN: 0853-9987

g bw/day is recommended for diet therapy, as it has almost the same results or is not significantly different from the control group given standard medication

Powdered strawberries have been shown to maintain the stability of the flavonoids they contain, such as anthocyanins [31]. Similar research has been conducted by maintaining the phytochemical content in mulberry fruit which is made into powder, the results of the intervention showed an improvement in the lipid profile in a group of obese rats after being given mulberry powder [46]. The results of the literature review also gathered evidence that anthocyanins found in plants and fruits such as Clitoria ternatea flower, raspberry, lingonberry, black rice, black soybean, blackberry, blueberry and cherry can reduce oxidative stress in groups with obesity [47].

Furthermore, powdered strawberries can be an alternative preservation process without the addition of other ingredients. Strawberry powder is an innovative approach to long-term nutraceutical development, offering the added advantage of flexibility in its use in various dosage forms [48]. Strawberry powder is a product that is easy to apply to other food products such as drinks, supplements, toppings, and cereal mixes without reducing antioxidant activity which can improve taste and nutrition [49]. This indicates potential as a functional ingredient in the prevention and management of metabolic diseases such as obesity.

This study shows that strawberry powder also has an effect in preventing or reducing oxidative stress that occurs in obese groups and can be a functional food and has the potential as a nutraceutical agent that is beneficial for obese groups. This study certainly has limitations during the research process, the small number of samples, the sample with only male gender, and the duration of the intervention are some of the reasons why the results of this study cannot be fully generalized. The use of strawberry powder for clinical interventions on human subjects needs to consider the calculation of human equivalent doses, and must pay attention to a person's daily needs in consuming fruit, especially strawberries. This study also requires further research to ensure the safety and appropriateness of consumption by a large population. This includes examining the side effects of long-term strawberry powder use and also monitor the effects after the intervention, to see whether the effects of giving strawberry powder are temporary or sustainable

## CONCLUSION

Based on the results of this study, it was concluded that consuming strawberry powder can significantly reduce total cholesterol, LDL, MDA, and visceral fat mass in HFHFr-induced obesity model rats. The presence of bioactive compounds from strawberry powder can improve lipid profiles, oxidative stress biomarkers, and reduce visceral fat accumulation, and show positive effects for the obesity group. Administration of strawberry powder at the highest dose produced optimal results; however, the second dose (treatment 2) which showed effects comparable to the standard drug orlistat across all biomarkers measured. Thus, a dose of strawberry powder of 0.234 g/200 g body weight/day shows potential as a dietary adjuvant therapy for obesity management. Although strawberry powder shows positive effects, this study is still pre-clinical and limited by gender, age, and time period. Which certainly requires further research, both long-term animal trials and clinical trials with human subjects.

## ACKNOWLEDGMENT

This research was funded by Universitas Sebelas Maret Strengthening Research Group Capacity (PKGR-UNS A) Grant number 3371/UN27.22/PT.01.03/2025.

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