

Antioxidant activities of soybean (*Glycine max* L.), sweet potato leaves (*Ipomoea batatas* L.) and red yeast rice (*Monascus purpureus*) functional drink in managing hyperlipidemia

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Article history:

Received: 13 July 2023

Received in revised form: 4 September 2023

Accepted: 4 September 2024

Available Online: 22 April 2025

Keywords:

Antioxidant activity,

Functional beverage,

Red yeast rice,

Soybean,

Sweet potato leaves

DOI:

[https://doi.org/10.26656/fr.2017.9\(2\).229](https://doi.org/10.26656/fr.2017.9(2).229)

Abstract

Antioxidant activity is important in fighting oxidative damage caused by a high-fat diet. Dietary fat is associated with increased oxidative stress and risk of degenerative diseases. Soybean (*Glycine max* L.), sweet potato leaves (*Ipomoea batatas* L.) and red yeast rice (*Monascus purpureus*) contain phytochemical compounds that have strong antioxidant activities. This study aimed to evaluate the antioxidant activity of soybean, sweet potato leaves, and red yeast rice functional beverage (SSR) by measuring the activity of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and the level of oxidative product malondialdehyde (MDA) in rats fed a high-fat diet. Mice were divided into five groups: normal control, negative control, and positive control which was given Nutrive Benecol 3.6 mL/day, and two treatment groups with doses of 1250 mg/kg BW and 2500 mg/kg BW. The results showed that the high-fat diet treatment decreased the endogenous antioxidant activities (SOD, CAT and GPx) and increased the MDA level significantly ($p < 0.05$) compared to normal. The administration of SSR at a dose of 2500 mg/kg BW reduced MDA levels and increased the activity of the enzymes SOD, CAT and GPx significantly ($p < 0.05$) compared to the negative control. These findings demonstrated the potential of SSR in reducing oxidative stress induced by a high-fat diet, which contributes to the prevention of degenerative diseases.

1. Introduction

Unhealthy eating habits, particularly high-fat diets, have grown to be a serious global issue in recent decades. Consumption of high in fat foods is associated with an increased risk of obesity, cardiovascular disease and other degenerative diseases (Lasker *et al.*, 2019). Oxidative stress is one mechanism that is believed to be involved in the link between a high-fat diet and degenerative disease. Oxidative stress occurs when there is an imbalance between the production of reactive oxygen species (ROS) and the antioxidant defense system. Antioxidants protect cells and tissues from damage caused by ROS. The mechanism of action of antioxidants involves capturing free radicals or inhibiting oxidation reactions induced by ROS (Kunwar and Priyadarsini, 2011). A high-fat diet is known to increase ROS production in the body, which then can damage cell important molecules, including DNA, proteins, and lipids. When oxidative stress occurs in the long term, this can trigger degenerative diseases such as heart disease,

diabetes (Feldeisen and Tucker, 2007) and cancer (Hu *et al.*, 2013).

Natural ingredients containing antioxidant compounds have become the focus of research to reduce the risk of degenerative diseases. Some of the natural ingredients that have been studied include soy (*Glycine max* L.), sweet potato (*Ipomoea batatas* L.) leaves and red yeast rice (*Monascus purpureus*). These three materials contain phytochemical compounds with strong antioxidant activity. Several active compounds contained in these ingredients have been linked to antioxidant effects and protection against oxidative damage (Agboyibor *et al.*, 2018).

Soybeans contain isoflavonoid compounds such as genistein and daidzein which have been shown to have antioxidant activity and reduce the development of chronic diseases including obesity and cardiovascular disease (Muji *et al.*, 2011; Chatterjee *et al.*, 2018). These

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compounds can protect body cells from oxidative damage by capturing free radicals and inhibiting lipid oxidation reactions (Banach *et al.*, 2020). *In vitro* and *in vivo* studies have demonstrated that soybean extract has the potential to protect body tissues from oxidative stress.

Sweet potato leaves contain anthocyanins, betacyanins, and flavonoids which give the leaves a purple color. These compounds have strong antioxidant properties and have been known to protect the body's cells from oxidative damage (Zhang *et al.*, 2019). Several studies have also shown that sweet potato leaf extract can increase the activity of antioxidant enzymes such as SOD, catalase, and GPx (Lin *et al.*, 2012).

Red yeast rice is a fermented product of *Monascus purpureus* and contains red pigment compounds such as monacolin K and azo pigments which have strong antioxidant activity. The compound monacolin K has been shown to have the potential to inhibit lipid oxidation and reduce oxidative stress. In addition, several studies have also shown that red yeast rice can increase the activity of antioxidant enzymes and reduce levels of free radicals in the body (Kim and Lim, 2016; Wu *et al.*, 2019)

This study aimed to evaluate the antioxidant activity of functional powdered beverages containing soybeans, sweet potato leaves, and red yeast rice in rats fed a high-fat diet. This research focused on measuring the enzymes superoxide dismutase (SOD), catalase, glutathione peroxidase (GPx) and malondialdehyde (MDA) levels as an indicator of oxidative stress.

2. Materials and methods

2.1 Preparation of soybean, sweet potato leaves, and red yeast rice functional beverage

The soybean, sweet potato leaves, and red yeast rice functional beverage (SSR) was prepared from ingredients as presented in Table 1.

Table 1. Formula of SSR.

Materials	Weight (g)
Sweet potato Leaves	3.36
Red yeast rice	1.2
Soybean	20
Powdered skimmed milk	7
Powdered full-cream milk	3
Sugar	15
Maltodextrin	7.2
Xanthan gum	2.5
Total	59.26

2.2 Preparation of high-fat feed

A high-fat diet was created by combining 300 g of regular feed with 20 g of egg yolk, 100 g of butter, 10 g of beef fat and PTU (0.05%). The materials were then mashed, and mixed in a meat grinder before being shaped into a size resembling conventional feed. The diet was then dried for three days at 50°C in an oven.

2.3 Test animals

The study's subjects were male Wistar strain white rats (*Rattus norvegicus*), 2-3 months old and weighed between 150 and 250 g. They are kept in rooms that have adequate lighting, adequate ventilation, and maintained humidity. Prior to the start of treatment, rats were adapted for 7 days. All treatments were carried out with due regard to animal welfare and received ethical approval from the UAD Research Ethics Committee with number 012108049.

2.4 Hypercholesterolemia induction and experimental design

This study involved 30 Wistar rats which were then divided into 5 groups. Each group consists of 5 test animal subjects, according to calculations using the Federer formula (Ihwah *et al.*, 2018). The schedule for induction and treatment is illustrated in Figure 1. The body weight of the animal study was observed every week throughout the study.



Figure 1. The schedule of high-fat diet induction and treatment by feeding with SSR.

2.5 Blood sample preparation

The blood and liver samples were taken from the test animals on the 29th day. Blood samples were taken through the orbital sinus and then centrifuged at 4000 rpm for 15 mins to separate the serum from the red blood cells. A separate portion of blood serum was then taken and used for absorbance analysis using a UV spectrophotometer and the Diasys reagent kit.

2.6 Liver sample preparation

After the animal treatment was completed, the animals were sacrificed on day 29. The liver organ was washed and kept in a physiological solution. A total of 0.8 g of rat liver was added with 9 mL of phosphate buffer pH 7.4 then homogenized in an ice bath using a mortar and then centrifuged at 10,000 rpm for 10 mins at 4°C. The supernatant was taken to measure the activity of the SOD, CAT, GPx activities and level of MDA, by Elabscience kit reagent.

2.7 Measurement of protein concentration

Before the measurement of antioxidant activities, the protein concentration of liver homogenate was determined using the Bradford colorimetric method. The Bradford reagent (5 mL) was added to 0.1 mL of the supernatant and incubated at room temperature for 10-60 minutes. The absorbance of the protein sample solution was read at a wavelength of 595 nm (Walker, 2002).

2.8 Measurement of superoxide dismutase activity

The activity of the T-SOD (total SOD) enzyme was carried out using Superoxide Dismutase (SOD) Assay Kit (Elabscience E-BC-K-019S) by the spectrophotometric method. The SOD enzyme has an inhibitory effect on the superoxide anion radical (O_2^-) which can reduce the nitrite content, the nitrite itself will appear purplish after reacting with a chromogenic agent. The SOD activity was calculated using formula (1).

$$SOD\ Activity = \left(\frac{Abs\ C - Abs\ S}{Abs\ C} \times 100\% \right) \div 50\% \frac{V1}{V2} \times f \div C_{prot} \quad (1)$$

2.9 Catalase activity

Examination of the activity of the catalase enzyme was done using the Catalase (CAT) Assay Kit (Elabscience E-BC-K031-S) with the spectrophotometry method. The catalase enzyme works by decomposing, this reaction can be inhibited quickly by ammonium molybdate. Then the residue H_2O_2 will react with ammonium molybdate to produce a yellowish complex. The absorbance was observed at 405 nm. The activity of catalase was calculated using formula (2).

$$Catalase\ activity = \frac{\Delta A \times 32.5}{1 \times V} \times f \div C_{prot} \quad (2)$$

2.10 Measurement of glutathione peroxidase

GPx activity was measured from a liver homogenate using the Elabscience E-BC-K096-S assay kit. GPx can induce the reduction of H_2O_2 to produce H_2O . The activity of GPX can be expressed by the rate of enzymatic reaction and calculated by measuring the reduced glutathione. GSH can react with dinitrobenzoic acid to produce 5-thio-dinitrobenzoic acid anion which showed a stable yellow color. The absorbance was read by spectrophotometry at 412 nm and the activity was calculated using the following formula (3).

$$GSH-Px\ activity\ (U/mgprot) = \Delta A1 + \Delta A2 \times c \times f2 \times f \div (V \times Cpr) \quad (3)$$

2.11 Measurement of malondialdehyde levels

The MDA levels measurement was carried out using a liver homogenate using the Elabscience assay kit with the catalog number E-BC-K025-S. The catabolite of lipid peroxide (MDA) can react with thiobarbituric acid (TBA) and produce a red compound, which could be

determined by the spectrophotometric method. The absorbance will be observed at 532 nm, The MDA level was calculated using the following (4).

$$MDA\ content\ (nmol/mgprot) = (\Delta A1) / (\Delta A2) \times c \times f \div Cpr \quad (4)$$

2.12 Data analysis

The antioxidant activity in each group was calculated and statistically analyzed using SPSS 21 statistic software. The activity of the treated groups was compared to the negative control group.

3. Results and discussion

The induction of high-fat feed to test animals was carried out to provide an intake of fat that exceeds the normal requirement of standard food. The high-fat diet could cause hyperlipidemia conditions, and lead to the formation of high free radicals or reactive oxygen species (ROS) (Tan and Norhaizan, 2019). The high amounts of free radicals could suppress the activity of endogenous antioxidant enzymes.

3.1 Superoxide dismutase enzyme activity

SOD is an enzyme that works by catalyzing the reduction of superoxide anions to hydrogen peroxide (H_2O_2). The high-fat consumption was found to decrease the SOD activity significantly. This finding was in agreement with a previous study which reported decreasing SOD activity following the HFD induction (Mahfudh, Mantali and Sulistyani, 2022). The treatment of SSR was found to increase the SOD activity significantly (Figure 2). Quercetin was detected as one of the active compounds in sweet potato leaves and was also reported to have antioxidant activity in vivo (Mahfudh et al., 2021).

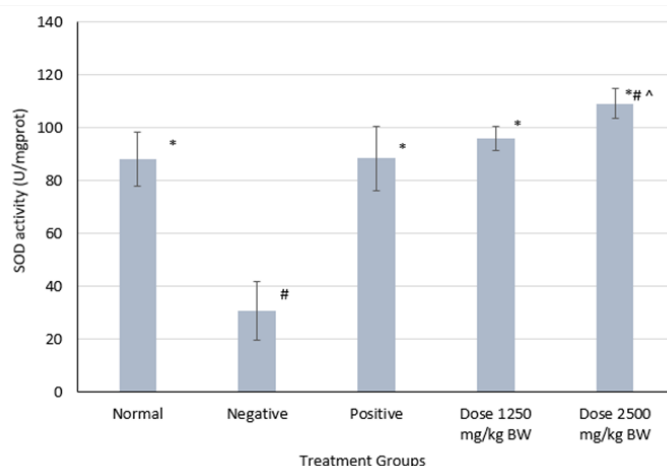


Figure 2. The treatment of SSR increases SOD activity in high-fat diet rats. *Significantly different from the negative control ($p < 0.05$), #significantly different from the normal control ($p < 0.05$), ^significantly different from the positive control ($p < 0.05$).

This study found that a functional beverage dose of 1250 mg/kg BW and a dose of 2500 mg/kg BW can increase the activity of SOD. The results of this study concurred with the explanation that soybeans contain flavonoid compounds in the form of isoflavones which have antioxidant activity by binding to free radicals and preventing their chain reaction (Yoon, 2014). Isoflavones maintain the activity of the SOD enzyme due to the role of genistein by inducing the genes responsible for the synthesis of the SOD enzyme. Genistein upregulates antioxidant gene expression by involving estrogen receptors, ERK1/2 (extracellular-signal-regulated kinase), and NFκB (nuclear factor κB). In addition, isoflavones help the enzyme superoxide dismutase (SOD) work in destroying free radicals by donating an electron to radical compounds so that the radical compounds turn into non-radical compounds or compounds that are harmless to cells. So that the levels of the superoxide dismutase enzyme in the cells can be maintained (Suarsana and Suprayogi, 2013).

3.2 Catalase activity

Figure 3 shows the CAT activities in the high-fat diet rats fed with SSR. The CAT activity was found to decrease after induction of a high-fat diet. The CAT activity was found to increase following the 14-day treatments of functional powdered beverages. The previous study also found that a high-fat diet decreases catalase activity and is a predictor of oxidative stress (Aguilar *et al.*, 2016). The increase in the catalase enzyme in the functional drink treatment group was due to the content of antioxidant compounds found in soybeans, sweet potato leaves and red yeast rice. Antioxidant compounds in the flavonoid group found in soybeans are isoflavones (Muji *et al.*, 2011), in purple sweet potato leaves are quercetin (Nguyen *et al.*, 2021), and red yeast rice can be in the form of anthocyanins, besides that there are also monacolin K and dimerumic acid compounds (Zhang *et al.*, 2016). Flavonoid group compounds work as antioxidant agents by directly capturing free radicals, preventing free radical regeneration, and indirectly increasing the activity of cellular antioxidant enzymes (Akhlaghi and Brian, 2009).

The study showed that high-fat feeding reduces the activity of GPx enzymes. The mechanism for the decreased activity of GPX enzymes in the liver is due to the high concentration of fat in the hyperlipidemic conditions, thereby increasing the synthesis of bile acids and causing more oxygen and NADPH to be used, as well as an increase in cytochrome P-450 oxidase activity (Borza *et al.*, 2013). Cytochrome P450 oxidase also plays a role in mediating endoplasmic reticulum metabolism which produces O_2^- superoxide anion

radicals. Increased activity of cytochrome P-450 oxidase enzymes will produce excessive free radicals and lead to oxidative stress where the number of free radicals exceeds the amount and antioxidant capacity (Banerjee and Ghosh, 2016).

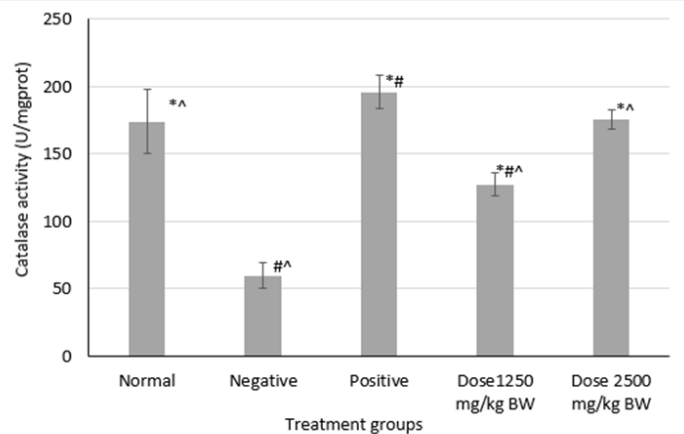


Figure 3. The treatment of SSR increases Catalase activity in high-fat diet rats. *Significantly different from the negative control ($p < 0.05$), #significantly different from the normal control ($p < 0.05$), ^significantly different from the positive control ($p < 0.05$).

3.3 Glutathione peroxidase activity

Figure 4 shows the GPx activities in the high-fat diet rats fed with SSR. The GPx activity was found to decrease after induction of a high-fat diet. The GPx activity was found to increase following the 14-day treatments of functional powdered beverages. The GPx activity in treated groups was significantly increased compared to the negative control group ($p < 0.05$). However, the GPx activity in the dose of 2500 mg/kg BW was not significantly different from the dose of 1250 mg/kg BW. The treated groups were also found not significantly different from positive control groups ($p > 0.05$).

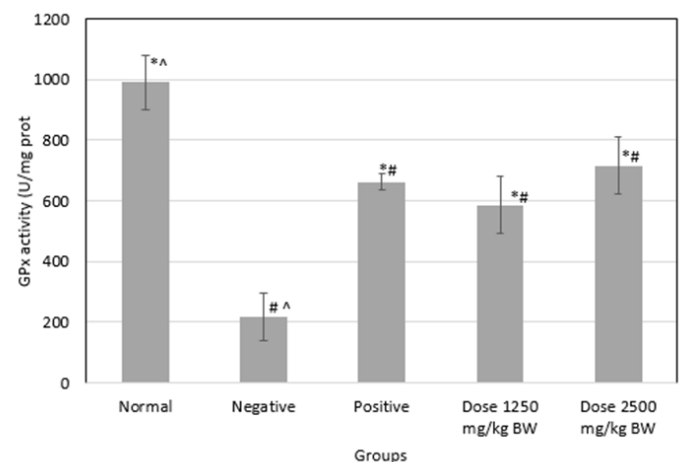


Figure 4. The treatment of SSR increases GPx activity in high-fat diet rats. *Significantly different from the negative control ($p < 0.05$), #significantly different from the normal control ($p < 0.05$), ^significantly different from the positive control ($p < 0.05$).

Sweet potato leaves contain a lot of antioxidant compounds in the form of flavonoids, including quercetin and anthocyanins. The mechanism of action of flavonoids as antioxidants can be direct or indirect. Flavonoids as antioxidants directly donate hydrogen ions and neutralize the toxicity effects of free radicals (Mahfudh, Mantali and Sulistyani, 2022). Flavonoids act as antioxidants indirectly by increasing the expression of endogenous antioxidant genes through several mechanisms. One mechanism for increasing antioxidant gene expression is through activation of nuclear factor erythroid 2 related factor 2 (Nrf2) increasing genes that play a role in the synthesis of endogenous antioxidant enzymes such as SOD and catalase (Agbo et al., 2020).

Antioxidants in red yeast rice consist of several compounds such as flavonoids, polyphenols, carotenoids, alkaloids and vitamins (Egea et al., 2023). One of the *Monascus* secondary metabolites is an antioxidant compound in the form of dimeric acid which will inhibit NADPH and iron which cause fat peroxidation and can stop chain reactions due to free radicals (Walter, 2011; Oboh et al., 2013). Prevention of lipid peroxidation will increase the activity of endogenous antioxidant enzymes such as GTS enzymes (Glutathione S-transferase), SOD, and catalase. In addition, red yeast rice also has a compound called monacolin K (lovastatin) which can play a role by activating the antioxidant system and reducing hydrogen peroxide (H₂O₂).

3.4 Malondialdehyde levels

Figure 5 shows the MDA level in the high-fat diet rats fed with SSR. The MDA level was found to increase after induction of a high-fat diet and decrease following the 14-day treatments of functional powdered beverages. The MDA level in treated groups significantly decreased compared to a negative control group ($p < 0.05$). The MDA level in the dose of 2500 mg/kg BW was significantly lower than the dose of 1250 mg/kg BW. The treatment of a dose of 2500 mg/kg BW was similar (not significantly different) from positive control groups ($p > 0.05$).

High MDA concentration indicates an oxidation process in the cell membrane. Elevated MDA levels in animals fed a high-fat diet have previously been reported. Increasing MDA levels are positively correlated with stress oxidative (Hassan et al., 2011). The high level of MDA could be used as a biomarker for the pathological conditions of various diseases (Khoubnasab Jafari et al., 2015). Hypercholesterolemia also causes an imbalance between oxidative compounds and endogenous antioxidant components leading to a decrease in endogenous antioxidant activity and increasing in MDA level (Setiawan et al., 2016). The

results obtained are in agreement with previous research, that the administration of a combination of sweet potato leaf extract (quercetin) and red yeast rice (monacolin k) in high-fat diet rats can increase GPx activity and reduce MDA levels (Mahfudh et al., 2022).

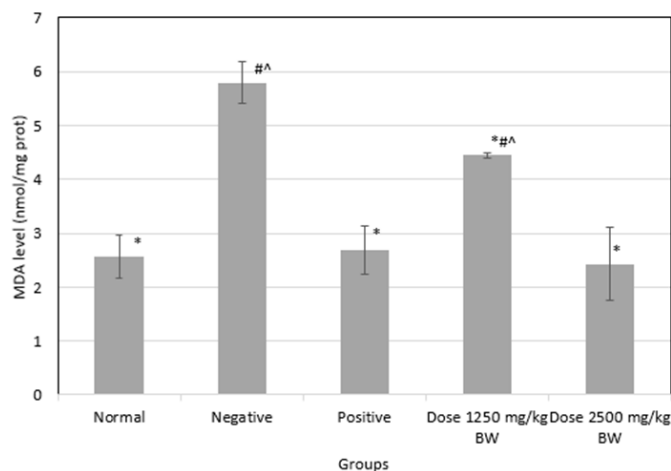


Figure 5. The treatment of SSR decreases MDA levels in high-fat diet rats. *Significantly different from the negative control ($p < 0.05$), #significantly different from the normal control ($p < 0.05$), ^significantly different from the positive control ($p < 0.05$).

4. Conclusion

Provision of functional powdered beverages containing soybean (*Glycine max* L.), sweet potato leaves (*Ipomoea batatas* L.), and red yeast rice were able to significantly exert pharmacological effects on SOD, catalase, GPx, and MDA activities ($p < 0.05$) in rats treated with a high-fat diet. The result recommended the use of functional powdered beverages in the diet for dyslipidemic conditions.

Conflict of interest

The authors declare no conflict of interest in this work.

Acknowledgements

The authors would like to thank the Ministry of Education, Culture, Research, and Technology for funding this study through the Fundamental Research Excellence in Higher Education grant scheme, with grant number 071/E5/PG.02.00.PT/2022.

References

- Agbo, E.A., Kouassi, K. and Gbogouri, A.G. (2020). Antioxidant Activities in Sweet Potatoes Leaves Steamed with Spices. *Journal of Food Research*, 9 (4), 41-49. <https://doi.org/10.5539/jfr.v9n4p41>
- Agboyibor, C., Kong, W.-B., Chen, D., Zhang, A.-M. and Niu, S.-Q. (2018). *Monascus* pigments

- production, composition, bioactivity and its application: A review. *Biocatalysis and Agricultural Biotechnology*, 16, 433-447. <https://doi.org/10.1016/j.bcab.2018.09.012>
- Aguilar, T.A.F., Navarro, B.C.H. and Pérez, J.A.M. (2016). Endogenous Antioxidants: A Review of their Role in Oxidative Stress. In Morales-Gonzalez, J.A., Moreales-Gonzalez, A., Madrigal-Santillan, E.O. (Eds.) A Master Regulator of Oxidative Stress - The Transcription Factor Nrf2. InTech Open E-Book. <https://doi.org/10.5772/65715>
- Akhlaghi, M. and Brian, B. (2009). Mechanisms of flavonoid protection against myocardial ischemia-reperfusion injury. *Journal of Molecular and Cellular Cardiology*, 46(3), 309-317. <https://doi.org/10.1016/j.yjmcc.2008.12.003>
- Banach, M., Wiloch, M., Zawada, K., Cyplik, W. and Kujawski, W. (2020). Evaluation of Antioxidant and Anti-Inflammatory Activity of Anthocyanin-Rich Water-Soluble Aronia Dry Extracts. *Molecules*, 25 (18), 4055. <https://doi.org/10.3390/molecules25184055>
- Banerjee, S. and Ghosh, J. (2016). Drug Metabolism and Oxidative Stress: Cellular Mechanism and New Therapeutic Insights. *Biochemistry and Analytical Biochemistry*, 5(1), 1000255. <https://doi.org/10.4172/2161-1009.1000255>
- Borza, C., Borza, C., Muntean, D., Dehelean, C., Săvoiu, G., Șerban, C., Simu, G., Andoni, M., Butur, M. and Drăgan, S. (2013). Oxidative Stress and Lipid Peroxidation – A Lipid Metabolism Dysfunction. In Baez, R.V. (Ed.) Lipid Metabolism, p. 185-211. InTech Open E-Book. <https://doi.org/10.5772/51627>
- Chatterjee, C., Gleddie, S. and Xiao, C.W. (2018). Soybean bioactive peptides and their functional properties. *Nutrients*, 10(9), 8-11. <https://doi.org/10.3390/nu10091211>
- Egea, M.B., Dantas, L.A., Sousa, T.L. de, Lima, A.G. and Lemes, A.C. (2023). The potential, strategies, and challenges of Monascus pigment for food application. *Frontiers in Sustainable Food Systems*, 7, 1141644. <https://doi.org/10.3389/fsufs.2023.1141644>
- Feldeisen, S.E. and Tucker, K.L. (2007). Nutritional strategies in the prevention and treatment of metabolic syndrome. *Applied Physiology, Nutrition, and Metabolism*, 32(1), 46-60. <https://doi.org/10.1139/h06-101>
- Hassan, S., El-Twab, S.A., Hetta, M. and Mahmoud, B. (2011). Improvement of lipid profile and antioxidant of hypercholesterolemic albino rats by polysaccharides extracted from the green alga *Ulva lactuca* Linnaeus. *Saudi Journal of Biological Sciences*, 18(4), 333-340. <https://doi.org/10.1016/j.sjbs.2011.01.005>
- Hu, F., Zhang, Y. and Song, Y. (2013). Lipid Metabolism, Metabolic Syndrome, and Cancer. In Baez, R.V. (Ed.) Lipid Metabolism, p. 185-211. InTech Open E-Book. <https://doi.org/10.5772/51821>
- Ihwah, A., Deoranto, P., Wijana, S. and Dewi, I. (2018). Comparative study between Federer and Gomez method for number of replication in complete randomized design using simulation : study of Areca Palm (*Areca catechu*) as organic waste for producing handicraft paper Comparative study between Federer and Gomez. *IOP Conference Series: Earth and Environmental Science*, 131, 012049. <https://doi.org/10.1088/1755-1315/131/1/012049>
- Khoubnasab Jafari, M., Ansarin, K. and Jouyban, A. (2015). Comments on “use of malondialdehyde as a biomarker for assessing oxidative stress in different disease pathologies: A review.” *Iranian Journal of Public Health*, 44(5), 714-715.
- Kim, S.-M. and Lim, S.-T. (2016). Enhanced antioxidant activity of rice bran extract by carbohydrase treatment. *Journal of Cereal Science*, 68, 116-121. <https://doi.org/10.1016/j.jcs.2016.01.006>
- Kunwar, A. and Priyadarsini, K. (2011). Free radicals, oxidative stress and importance of antioxidants in human health. *Journal of Medical and Allied Sciences*, 1(2), 53-60.
- Lasker, S., Rahman, M., Parvez, F., Zamila, M. and Miah, P. (2019). High-fat diet-induced metabolic syndrome and oxidative stress in obese rats are ameliorated by yogurt supplementation. *Scientific Reports*, 9, 20026. <https://doi.org/10.1038/s41598-019-56538-0>
- Lin, M.H., Yang, H.L., Wang, C.C. and Chen, J.C. (2012). The effect of purple sweet potato leaves consumption on exercise-induced oxidative stress and IL-6 and HSP72 expressions. *Journal of Applied Physiology*, 112(11), 1777-1785. <https://doi.org/10.1152/jappphysiol.00205.2010>
- Mahfudh, N., Sulistyani, N., Syakbani, M. and Dewi, A.C. (2021). The antihyperlipidaemic and hepatoprotective effect of *Ipomoea batatas* L. leaves extract in high-fat diet rats. *International Journal of Public Health Science*, 10(3), 558-564. <https://doi.org/10.11591/ijphs.v10i3.20777>
- Mahfudh, N., Mantali, M.F. and Sulistyani, N. (2022). The Antihyperlipidemic Effect of Purple Sweet Potato Leaf Extract (*Ipomoea batatas* L.) and Red Yeast Rice Combination on Hypercholesterol Rats. *Indonesian Journal of Pharmacy*, 33(1), 93-99.

- <https://doi.org/10.22146/ijp.2115>
- Mahfudh, N., Nanik Sulistyani, N.S., Fatihatul Khoirot, A., Tsanawiyah Indah Safira, T.I.S., Othman, F. and Zakaria, Z.A. (2022). Sweet Potato (*Ipomoea batatas* L.) Leaves Ethanol Extract Increases Endogenous Antioxidant Activities in Hyperlipidemic Rats. *Sains Malaysiana*, 51(9), 2873-2883. <https://doi.org/10.17576/jsm-2022-5109-11>
- Muji, I., Šertovi, E., Joki, S., Sari, Z., Alibabi, V., Vidovi, S. and Živkovi, J. (2011). Isoflavone content and antioxidant properties of soybean seeds. *Croatian Journal of Food Science and Technology*, 3 (1), 16-20. <https://hrcak.srce.hr/file/105559>
- Nguyen, H.C., Chen, C., Lin, K., Chao, P. and Lin, H. (2021). Bioactive compounds, antioxidants, and health benefits of Sweet Potato Leaves. *Molecules*, 26, 1820. <https://doi.org/10.3390/molecules26071820>
- Oboh, G., Ademosun, A.O., Odubanjo, O.V. and Akinbola, I.A. (2013). Antioxidative properties and inhibition of key enzymes relevant to type-2 diabetes and hypertension by essential oils from black pepper. *Advances in Pharmacological Sciences*, 2013, 926047. <https://doi.org/10.1155/2013/926047>
- Setiawan, D.I., Tjahyono, K. and Afifah, D.N. (2016). Pemberian kecambah kacang kedelai terhadap kadar malondialdehid (MDA) dan superoxide dismutase (SOD) tikus Sprague Dawley hiperkolesterolemia. *Jurnal Gizi Klinik Indonesia*, 13(1), 20-26. <https://doi.org/10.22146/ijcn.22815> [In Bahasa Indonesia].
- Suarsana, W.T. and Suprayogi, A. (2013). Respon Stres Oksidatif dan Pemberian Isoflavon terhadap Aktivitas Enzim Superoksida Dismutase dan Peroksidasi Lipid pada Hati Tikus. *Jurnal Ilmu Ternak dan Veteriner*, 18(2), 146-152. [In Bahasa Indonesia].
- Tan, B.L. and Norhaizan, M.E. (2019). Effect of high-fat diets on oxidative stress, cellular inflammatory response and cognitive function. *Nutrients*, 11(11), 2579. <https://doi.org/10.3390/nu11112579>
- Walker, J.M. (2002). *The Protein Protocols Handbook*. 2nd ed., p. 15-23. Totowa, New Jersey, USA: Humana Press.
- Walter, M. and Marchesan, E. (2011). Phenolic Compounds and Antioxidant Activity of Rice. *Asian Journal of Biotechnology and Genetic Engineering*, 54(2), 371-377. <https://doi.org/10.1590/S1516-89132011000200020>
- Wu, H.-C., Cheng, M.-J., Wu, M.-D., Chen, J.-J., Chen, Y.-L., Chang, H.-S. and Chen, K.-P. (2019). Secondary metabolites from the fermented rice of the fungus *Monascus purpureus* and their bioactivities. *Natural Product Research*, 33(24), 3541-3550. <https://doi.org/10.1080/14786419.2018.1488698>
- Yoon, G.P.S. (2014). Antioxidant action of soy isoflavones on oxidative stress and antioxidant enzyme activities in exercised rats. *Nutrition Research*, 8(6), 618-629. <https://doi.org/10.4162/nrp.2014.8.6.618>
- Zhang, Z., Ali, Z., Khan, S.I. and Khan, I.A. (2016). Cytotoxic monacolins from red yeast rice, a Chinese medicine and food. *Food Chemistry*, 202, 262-268. <https://doi.org/10.1016/j.foodchem.2015.12.039>
- Zhang, C., Liu, D., Wu, L., Jianming, Z., Li, X. and Wu, W. (2019). Chemical characterization and antioxidant properties of ethanolic extract and its fractions from sweet potato (*Ipomoea batatas* L.) leaves. *Foods*, 9, 15. <https://doi.org/10.3390/foods9010015>