Hormozgan Medical Journal
January 2024, Volume 28, Number 1

Review Paper

Investigating Effects of Rice Bran on Obesity, Oxidative Stress, Inflammation, and Physical Performance: A Narrative Mini-review

Nazanin Rahmannezhad[1], Mohammad Ali Azarbayjani[1], Saleh Rahmati[2*], Maghsoud Peeri[1], Hoseyn Fatolahi[2]

1. Department of Sports Physiology, Faculty of Physical Education and Sports Science, Central Tehran Branch, Islamic Azad University, Tehran, Iran.
2. Department of Physical Education, Pardis Branch, Islamic Azad University, Pardis, Iran.

Use your device to scan and read the article online

Citation Rahmannezhad N, Azarbayjani MA, Rahmati S, Peeri M, Fatolahi H. Investigating Effects of Rice Bran on Obesity, Oxidative Stress, Inflammation, and Physical Performance: A Narrative Mini-review. Hormozgan Medical Journal. 2024; 28(1):1-8. http://dx.doi.org/10.32598/hmj.28.1.8

http://dx.doi.org/10.32598/hmj.28.1.8

Article info:
Received: 22 Nov 2023
Accepted: 26 Dec 2023
Available Online: 01 Jan 2024

Keywords:
Rice bran, Gamma oryzanol, Physical performance, Oxidative stress, Inflammation

ABSTRACT

Context: Regular physical activity reduces oxidative stress by increasing the capacity of antioxidant defense, reducing pro-inflammatory mediators, and increasing anti-inflammatory mediators in healthy and obese conditions with chronic diseases. The role of physical activities in oxidative stress, and inflammation is dual and depends on the mood, intensity, and duration of the activity.

Evidence acquisition: One session of long-term and intense exercises can produce free radicals more than the capacity of antioxidant defense and cause oxidative stress. Medicinal plants also have anti-obesity, antioxidant, and anti-inflammatory properties due to their phytochemical compounds.

Results: Rice bran contains nutrients and bioactive compounds, such as phytosterols, phenolic acids, flavonoids, anthocyanins, proanthocyanins, tocopherols, tocotrienols, phytic acid, gamma-aminobutyric acid, and gamma oryzanol. These compounds have antioxidant, anti-inflammatory, anti-obesity, and anti-diabetic effects. The examination of studies with human and animal subjects show that rice bran, gamma oryzanol, and anthocyanins improve endurance and resistance performance. Evidence shows that rice bran improves endurance performance by reducing lactate accumulation, and increasing muscle glycogen content, increasing free fatty acids turnover, and increasing muscle oxidative capacity and antioxidant enzymes.

Conclusion: Anthocyanins improve physical performance by affecting blood flow, metabolic pathways, and muscle fatigue. Accordingly, rice bran can improve physical performance as an ergogenic factor and promote health development by reducing oxidative stress and inflammation. However, there is a need for more studies regarding the effect of rice bran on physical performance and health.

*** Corresponding Author:**
Saleh Rahmati, Assistant Professor.
Address: *Department of Physical Education, Pardis Branch, Islamic Azad University, Pardis, Iran.*
Tel: *+98 (21) 76281011*
E-mail: *salehrahmati@pardisiau.ac.ir*

[DOI: 10.32598/hmj.28.1.8]

Introduction

Free radicals are continuously produced as part of natural metabolic processes. Free radicals are defined as molecules or molecular fragments with one or more unpaired electrons in an atomic or molecular orbital [1]. The most abundant type of free radicals is reactive oxygen species (ROS) [2]. Although free radicals in physiological doses have positive effects on immune reactions and cell signaling, in higher amounts, they have negative effects on cell structure and function, including oxidative damage to lipids, proteins, and nucleic acids, which can cause many diseases. When the production of free radicals increases and the antioxidant defense system cannot neutralize them, the accumulation of free radicals in the body creates a phenomenon called oxidative damage, which is also known as oxidative stress [1, 2]. Oxidative stress provides the molecular foundation for the initiation of several diseases and plays an important role in causing premature aging and chronic and degenerative disorders, such as arthritis, autoimmune disorders, cardiovascular and neurological diseases, inflammation, and cancer [3]. Due to the harmful effects of the pathological production of free radicals, organisms have antioxidant defense systems that protect cells against the toxic effects of free radicals. The antioxidant defense system includes enzymatic antioxidants, such as superoxide dismutase (SOD), catalase, and glutathione peroxidase, in addition to non-enzymatic antioxidants, such as vitamin C, vitamin E, glutathione, and bilirubin. These antioxidants play an important role in delaying or preventing the oxidation of intracellular and extracellular biological molecules [4]. Although a session of physical activity increases the production of free radicals due to the increase in metabolism and mitochondrial respiration, microscopic damage in active muscles, and the penetration of phagocytes, evidence shows that regular physical activity can increase the antioxidant defense capacity and reduce the harmful effects of free radicals [5]. In line with increasing the capacity of antioxidant defense, regular physical activities can reduce inflammation in healthy and patient subjects by stimulating the secretion of anti-inflammatory myokines [6-12]. On the other hand, due to the presence of various phytochemical compounds, such as phenols, polyphenols, and flavonoids, medicinal plants reduce oxidative stress and inflammation and protect tissues against the attack of free radicals and inflammatory mediators [13, 14]. Based on the search, two review studies have been conducted on the biological benefits of rice bran. Gul et al. have pointed out that rice bran is an important rich source of protein, B-complex vitamins, and fiber, which is better used in enriching industrial foods; however, it is still necessary to conduct more cellular and laboratory studies in this field [15]. In addition, Sapwarobol et al. have pointed out that rice bran has anti-inflammatory effects, lowers blood sugar, lowers cholesterol, and improves digestive system health, with no side effects reported [16]. Nevertheless, there is no accurate information about its daily consumption. No studies have been done on the simultaneous absorption of rice bran with sports activities, and limited original studies are also available. Rice bran is one of the medicinal plants that has antioxidant and anti-inflammatory effects and has been used for therapeutic purposes for a long time. Recently, the ergogenic effect of rice bran has attracted the attention of sports nutritionists. Since both physical activity and rice bran have antioxidant and anti-inflammatory effects, in this study, a review of the studies is conducted regarding the simultaneous effect of physical exercises and rice bran on indicators of oxidative stress, inflammation, and physical performance.

Materials and Methods

The present study utilized three widely recognized academic databases, namely PubMed, Scopus, and Google Scholar, to gather relevant literature on the topic of interest. The search was conducted using a combination of keywords, including “rice bran,” “obesity,” “oxidative stress,” “inflammation,” and “physical performance,” to ensure a comprehensive exploration of the subject matter. The initial search yielded a substantial number of articles, which were then subjected to a careful screening process. Firstly, unrelated studies that did not directly address the research objectives were excluded. This step was vital in maintaining the focus and relevance of the review. Secondly, duplicate studies were identified and subsequently removed to avoid repetition and duplication of findings. By implementing these criteria, a refined selection of 47 articles was obtained for in-depth analysis and evaluation. These chosen articles represented a diverse range of research methodologies, including experimental studies, clinical trials, observational studies, and systematic reviews. This heterogeneity allowed for a comprehensive examination of the available evidence, enabling a more robust understanding of the relationship between rice bran consumption and its potential impact on obesity, oxidative stress, inflammation, and physical performance. The review process involved a careful assessment of each article’s methodology, objectives, results, and conclusions. Through this scrutiny, important patterns and trends began to emerge, shedding light on the potential benefits of rice bran in various aspects of human health.

[DOI: 10.32598/hmj.28.1.8]

The systematic approach employed in this study, coupled with the thorough review of the 47 selected articles, establishes a solid foundation for the subsequent analysis and interpretation of the findings. By synthesizing and critically evaluating the available literature, this study contributes valuable insights to the existing body of knowledge and provides a comprehensive understanding of the potential effects of rice bran on obesity, oxidative stress, inflammation, and physical performance.

Nutritional values of rice bran

Rice (*Oryza sativa*) is one of the main grains (the third most consumed grain in the world) and provides the main food for half of the world's population [17]. Rice bran is a byproduct of rice whitening processing and is rich in protein [18]. About 10% to 20% of rice bran consists of protein [19]. Evidence shows that rice bran contains a variety of nutrients and bioactive compounds that have beneficial effects on health [20]. About 10% of rice is made up of bran, which is separated from it during the rice milling process [21, 22]. Rice bran is the brown outer layer of the rice kernel, which contains 50% carbohydrates, 20% fat, 15% protein, and 15% dietary fiber (mainly insoluble fiber) [15]. In the rice milling process, about 85% of fat, 15% of protein, 75% of phosphorus, 90% of calcium, and 70% of B vitamins (including B1, B2, and B3) are removed from rice, which shows that rice bran has nutritional value [15, 23, 24]. By increasing the degree of rice milling, significant amounts of phytochemical compounds useful for health are removed from rice and its antioxidant activity decreases due to the decrease in the content of phenolic compounds. Based on this, with a lower degree of rice grinding, more health-enhancing phytochemical compounds of rice are created. Apart from micro and micronutrients (vitamins, minerals, fats, and amino acids), brown rice contains rich phytochemical compounds, including phytosterols, phenolic acids, flavonoids, anthocyanins, proanthocyanins, tocopherols, tocotrienols, phytic acid, gamma-aminobutyric acid, and gamma oryzanol [25, 26].

Health benefits of rice bran

Due to having phytochemical compounds (the items mentioned in the previous sections), rice bran has a high capacity for health development, which can be mentioned for its anti-diabetic effects, blood lipid reduction, blood pressure reduction, antioxidant, and anti-inflammatory effects. One of the most important compounds in rice bran is gamma oryzanol. Gamma oryzanol exists in the form of steryl ferulates, which is a mixture of sterol ferulic acid esters and triterpene alcohols. In addition, the amount and composition of gamma oryzanol in rice bran varies depending on the rice variety and extraction method. Gamma oryzanol has antioxidant activity, anti-diabetic activity, fat-reducing effect, and anti-cancer properties [16, 24]. Other phytochemical compounds in rice bran include anthocyanins, which have antioxidant, anti-angiogenic, cardiovascular disease prevention, anticancer, anti-diabetes, anti-obesity, antimicrobial, and neuroprotective effects [27]. The phytochemical compounds of rice bran and its therapeutic effects are presented in Figure 1.

Effects of rice bran on inflammation, oxidative stress, and obesity markers

Phytochemical compounds of rice bran exert their anti-obesity effects through various biochemical mechanisms. Accordingly, rice bran as a medicinal plant with anti-obesity effects has attracted the attention of researchers. For this reason, researchers studied the effect of rice bran on obesity markers in in vitro and in vivo conditions. The results of in vitro studies demonstrate that rice bran reduces the number of fat cells and triglyceride accumulation by reducing preadipocyte number, reducing transcription factors (PPARγ, C/EBPα, and C/EBPβ) and their target genes [28]. Also, rice bran can exert its anti-obesity effects by inhibiting pancreatic lipase, inhibiting the differentiation of fat cells, and stimulating the lipolysis of fat cells [29]. In vivo studies have also confirmed the anti-obesity effects of rice bran. Justo et al. reported a reduction in markers of metabolic syndrome, including dyslipidemia, high blood pressure, and insulin resistance in obese rats after receiving rice bran [30]. In another study, Justo et al. [31] investigated the effect of rice bran on inflammation, macrophage permeability, and white adipose tissue size in mice fed a high-fat diet. The results of this study showed that rice bran decreased insulin resistance, serum triglycerides, total cholesterol, IL-6, and IL-1β pro-inflammatory indicators, the size of white fat cells, and the permeability of M1 family macrophages in adipose tissue. These findings show that rice bran can reduce the negative effects of the high-fat diet in mice and exert its protective effect on subcutaneous white fat tissue [31]. In this regard, Duansak et al. showed that rice bran significantly reduced body weight, adipose tissue mass, and blood vessel density in adipose tissue of obese rats fed with a high-fat diet [32]. In addition, rice bran reduced VEGF and MMP-2 mRNA levels in visceral adipose tissue. These results show that rice bran significantly reduces adipose tissue mass and prevents obesity in high-fat diet-fed mice, which may partially exert its anti-obesity effect through an anti-angiogenic mechanism [32]. Rice bran reduces the absorption of fats

[DOI: 10.32598/hmj.28.1.8]

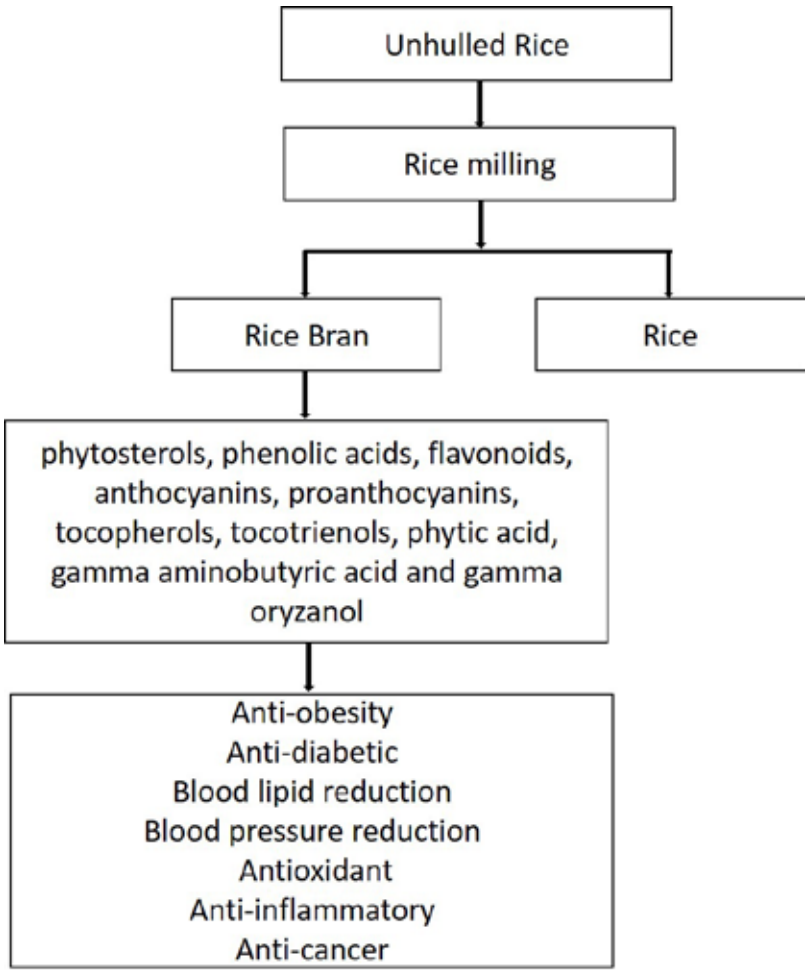

Figure 1. Phytochemical compounds of rice bran and its therapeutic effects [15, 16, 22-24]

in the intestine by affecting the digestive enzymes in this way. The individual can control obesity caused by eating a high-fat diet. Munkong et al. showed that rice bran reduces fat hypertrophy, fat accumulation, inflammation, and the expression of adipogenesis genes in intra-abdominal epididymal white adipose tissue in mice fed with a high-fat diet. Evidence shows that the presence of phenolic compounds, including flavonoids, anthocyanins, and proanthocyanidins in rice bran, has anti-fat and anti-hypertrophic effects on fat cells and reduces the negative effects of eating a high-fat diet [33].

Rice bran, oxidative stress, and physical performance

In the last decade, the attention of researchers has been drawn to the ergogenic effects of rice bran. Bioactive substances in rice bran can improve physical performance by stimulating messenger molecules, especially hormones. Seesen et al. investigated the effect of rice sprouts and bran on markers of inflammation, muscle strength, and physical performance in the elderly [34]. Elderly people trained for 24 weeks and received rice sprouts and bran along with it. The combination of exercise and rice bran significantly reduced inflammatory biomarkers including CRP and interleukin-6, and significantly increased the level of insulin-like growth factor 1. A significant improvement in physical performance and muscle strength was observed. The results of this study show the synergistic effect of resistance training and rice bran on the sustainable improvement of physical performance, lower limb muscle strength, and modulation of inflammatory and endocrine biomarkers [34]. Anthocyanins in rice bran have reduced inflammatory factors in this study [35]. On the other hand, the increase in muscle strength in this study can be attributed to the effect of resistance training on the stimulation of IGF-1 secretion and the presence of proteins in rice bran. γ-oryzanol, a powerful antioxidant in rice bran, is used by bodybuilders and athletes to enhance strength and muscle hypertrophy, without major side effects. Eslami et al. (2014) studied the effect of gamma oryzanol and resistance training on anthropometric characteristics and

[DOI: 10.32598/hmj.28.1.8]

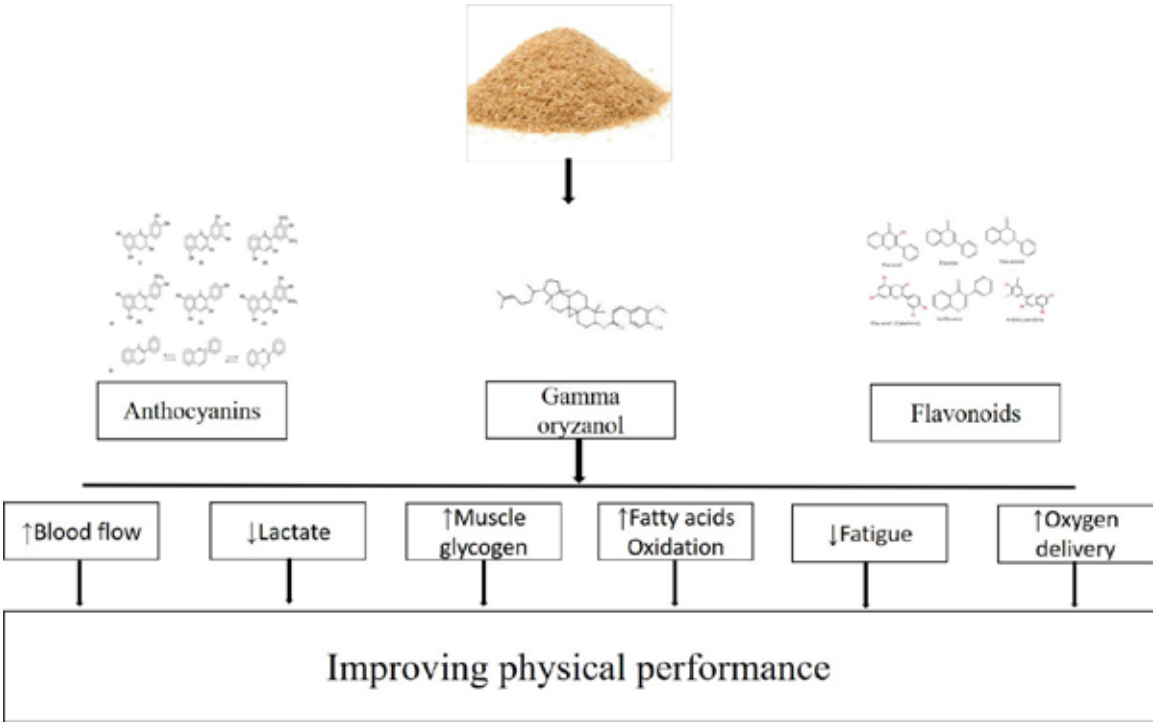

Figure 2. Effect of rice bran on physical performance

Notes:↑=increase, ↓=decrease [34, 37, 38, 42, 45].

muscle strength in healthy men. Subjects received 600 mg of gamma oryzanol daily and performed four resistance training sessions for 9 weeks. Although the consumption of gamma oryzanol had no significant effect on anthropometric characteristics, it significantly increased muscle strength, which indicates the ergogenic effect of γ-oryzanol [36]. Fry et al. reported no effect of 500 mg of gamma oryzanol daily for 9 weeks on muscle strength and concentration of testosterone, cortisol, estradiol, growth hormone, insulin, and beta-endorphin hormones in trained men [37]. Anthocyanins are other compounds found in rice bran. This family of phytochemical compounds can exert their ergogenic effect through various mechanisms. In this regard, reported that anthocyanins can improve physical performance by affecting blood flow, metabolic pathways, and muscle fatigue [38]. On the other hand, the consumption of medicinal plants containing anthocyanins, in addition to reducing oxidative stress, inflammation, and muscle damage, increases the oxygen supply to muscles increases the oxidation of fatty acids, and improves aerobic performance by increasing the production of nitric oxide [39]. Yarahmadi et al. reported an increase in maximum oxygen consumption after six weeks of receiving anthocyanins, which indicates the ergogenic effect of anthocyanins [40]. Bloedon et al. in a systematic review and meta-analysis article showed that the consumption of anthocyanins reduces oxidative stress and inflammation caused by physical activities [41]. The results of animal studies are also consistent with the results obtained from human studies. Kim et al. showed that consuming 1 g/kg for 21 days increases endurance activity time in rats, increasing endurance performance by reducing lactate concentration and increasing serum-free fatty acids, muscle glycogen content, and the activity of antioxidant enzymes was accompanied [42]. These findings show that rice bran increases endurance performance by reducing lactate, increasing muscle glycogen content, and increasing free fatty acids and antioxidant enzymes [42]. In this regard, Kim et al. investigated the anti-stress and anti-fatigue effects of rice bran in rats in two studies. The findings of these two studies showed that receiving 1 g/kg of body-weight rice bran for two weeks increased the swimming time and delayed the time to reach stagnation in rats, which indicates the anti-fatigue effect of rice bran [43, 44] (Figure 2).

Ahn et al. studied the effect of gamma oryzanol on endurance and strength performance in aged rats. γ-oryzanol did not cause significant changes in muscle weight; however, it increased the amount of running and also improved grip strength. Gamma oryzanol inhibited the TGF-β-Smad-NADPH oxidase 4 pathway and inflammatory cytokines, including TNF-α, IL-1β, IL-6, and p65 NF-κB, which cause muscle weakness. These re-

[DOI: 10.32598/hmj.28.1.8]

searchers concluded that gamma oryzanol increases the oxidative capacity of the muscle, which helps to increase the strength and the oxidative capacity in the muscles, thereby increasing the physical performance capacity in aged rats [45]. Rice bran affects physical performance and its simultaneous consumption with physical activity strengthens the health-enhancing effects of physical activity. Ismail et al. showed that ten weeks of consumption of gamma-oryzanol fraction along with swimming training leads to positive regulation of antioxidant gene expression and negative regulation of oxidative gene expression [46]. Similar results were obtained by Mowry et al. in horses. Competitions were observed. A total of 60 days of receiving sunflower oil and rice bran decreased interleukin 1β and creatine kinase after exercise, which indicates the anti-inflammatory effect of these two oils [47].

Conclusion

Further research is needed to explore the potential benefits of incorporating rice bran into exercise programs. The combination of physical activity and the phytochemical compounds found in rice bran has shown promising results in improving health indicators and reducing the negative effects of intense training. By harnessing the antioxidant, anti-inflammatory, and anti-obesity properties of rice bran, individuals can enhance their endurance performance, increase muscle glycogen content, and reduce lactate levels. These effects can contribute to overall improved sports performance and recovery. Additionally, the use of rice bran as a by-product with high nutritional value presents an opportunity to optimize athletic performance while minimizing the potential side effects of intense training. The various phytochemical compounds present in rice bran, such as gamma oryzanol and anthocyanins, have been shown to have positive effects on oxidative stress and inflammation. These compounds work in synergy with regular physical activity to enhance the health-enhancing effects of exercise programs. However, it is important to note that more studies are needed in this field to fully understand the potential benefits and mechanisms of action of rice bran in sports performance. Further research can provide valuable insights into the optimal dosage, timing, and duration of rice bran supplementation for athletes. Additionally, studies exploring the long-term effects and potential risks associated with rice bran consumption are necessary to ensure its safe and effective use in the athletic community. The combination of physical activity and the phytochemical compounds found in rice bran hold promise for improving sports performance and reducing the side effects of intense training. The antioxidant, anti-inflammatory, and anti-obesity properties of rice bran make it a suitable candidate for enhancing endurance, promoting muscle glycogen synthesis, and reducing lactate levels. However, further research is needed to fully understand the potential benefits and risks associated with rice bran supplementation in athletes.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

All authors contributed equally to preparing this article.

Conflict of interest

The author declared no conflict of interest.

Acknowledgments

The authors would like to thank all the students who helped them in this study.

References

[1] Halliwell B. Biochemistry of oxidative stress. Biochem Soc Trans. 2007; 35(Pt 5):1147-50. [DOI:10.1042/BST0351147] [PMID]

[2] Halliwell B, Gutteridge JMC. Free radicals in biology and medicine. Oxford: Oxford University Press; 2015. [Link]

[3] Sharma V, Collins LB, Chen TH, Herr N, Takeda S, Sun W, et al. Oxidative stress at low levels can induce clustered DNA lesions leading to NHEJ mediated mutations. Oncotarget. 2016; 7(18):25377-90. [DOI:10.18632/oncotarget.8298] [PMID]

[4] Birben E, Sahiner UM, Sackesen C, Erzurum S, Kalayci O. Oxidative stress and antioxidant defense. World Allergy Organ J. 2012; 5(1):9-19. [DOI:10.1097/WOX.0b013e3182439613] [PMID]

[5] Bouzid MA, Filaire E, Matran R, Robin S, Fabre C. Lifelong voluntary exercise modulates age-related changes in oxidative stress. Int J Sports Med. 2018; 39(1):21-8. [DOI:10.1055/s-0043-119882] [PMID]

[DOI: 10.32598/hmj.28.1.8]

[6] Azizbeigi K, Azarbayjani MA, Atashak S, Stannard SR. Effect of moderate and high resistance training intensity on indices of inflammatory and oxidative stress. Res Sports Med. 2015; 23(1):73-87. [DOI:10.1080/15438627.2014.975807] [PMID]

[7] Dolati S, Namiranian K, Amerian R, Mansouri S, Arshadi S, Azarbayjani MA. The effect of curcumin supplementation and aerobic training on anthropometric indices, serum lipid profiles, C-Reactive protein and insulin resistance in overweight women: A randomized, double-blind, placebo-controlled trial. J Obes Metab Syndr. 2020; 29(1):47-57. [DOI:10.7570/jomes19055] [PMID]

[8] Golbidi S, Badran M, Laher I. Antioxidant and anti-inflammatory effects of exercise in diabetic patients. Exp Diabetes Res. 2012; 2012:941868. [DOI:10.1155/2012/941868] [PMID]

[9] Nikseresht M, Agha-Alinejad H, Azarbayjani MA, Ebrahim K. Effects of nonlinear resistance and aerobic interval training on cytokines and insulin resistance in sedentary men who are obese. J Strength Cond Res. 2014; 28(9):2560-8. [DOI:10.1519/JSC.0000000000000441] [PMID]

[10] Pedersen BK. Muscles and their myokines. J Exp Biol. 2011; 214(Pt 2):337-46. [DOI:10.1242/jeb.048074] [PMID]

[11] Abedi B, Fatolahi H, Kouhidehkordi S, Zolfaghari GA. The effects of copenhagen football test on glutathione reductase and catalase activity in female football players. Asian J Sports Med. 2017; 8(1):e41473. [DOI:10.5812/asjsm.41473]

[12] Darani MSM, Abedi B, Fatolahi H. The effect of active and passive recovery on creatine kinase and C-reactive protein after an exercise session in football players. Int Arch Health Sci. 2018; 5(1):1-5. [Link]

[13] Adegbola P, Aderibigbe I, Hammed W, Omotayo T. Antioxidant and anti-inflammatory medicinal plants have potential role in the treatment of cardiovascular disease: A review. Am J Cardiovasc Dis. 2017; 7(2):19-32. [PMID]

[14] Prasad S, Kulshreshtha A, Lall R, Gupta SC. Inflammation and ROS in arthritis: Management by Ayurvedic medicinal plants. Food Funct. 2021; 12(18):8227-47. [DOI:10.1039/D1FO01078F] [PMID]

[15] Gul K, Yousuf B, Singh AK, Singh P, Wani AA. Rice bran: Nutritional values and its emerging potential for development of functional food-A review. Bioact Carbohydrates Diet Fibre. 2015; 6(1):24-30. [DOI:10.1016/j.bcdf.2015.06.002]

[16] Sapwarobol S, Saphyakhajorn W, Astina J. Biological functions and activities of rice bran as a functional ingredient: A review. Nutr Metab Insights. 2021; 14:11786388211058559. [DOI:10.1177/11786388211058559] [PMID]

[17] Muthayya S, Sugimoto JD, Montgomery S, Maberly GF. An overview of global rice production, supply, trade, and consumption. Ann N Y Acad Sci. 2014; 1324:7-14. [DOI:10.1111/nyas.12540] [PMID]

[18] Kadowaki M, Kubota M, Watanabe R. Physiological multifunctions of rice proteins of endosperm and bran. J Nutr Sci Vitaminol (Tokyo). 2019; 65(Supplement):S42-S7. [DOI:10.3177/jnsv.65.S42] [PMID]

[19] Shobako N, Ohinata K. Anti-hypertensive effects of peptides derived from rice bran protein. Nutrients. 2020; 12(10):3060. [DOI:10.3390/nu12103060] [PMID]

[20] Faustino M, Veiga M, Sousa P, Costa EM, Silva S, Pintado M. Agro-food byproducts as a new source of natural food additives. Molecules. 2019; 24(6):1056. [DOI:10.3390/molecules24061056] [PMID]

[21] Esa NM, Ling TB, Peng LS. By-products of Rice Processing: An Overview of Health Benefits and Applications. J Rice Res. 2013; 1:107. [Link]

[22] Tan BL, Norhaizan ME. Rice by-products: Phytochemicals and food products application. Berlin: Springer; 2020. [Link]

[23] Ravichanthiran K, Ma ZF, Zhang H, Cao Y, Wang CW, Muhammad S, et al. Phytochemical profile of brown rice and its nutrigenomic implications. Antioxidants (Basel). 2018; 7(6):71. [DOI:10.3390/antiox7060071] [PMID]

[24] Rungratanawanich W, Abate G, Serafini MM, Guarienti M, Catanzaro M, Marziano M, et al. Characterization of the Antioxidant Effects of gamma-Oryzanol: Involvement of the Nrf2 Pathway. Oxid Med Cell Longev. 2018; 2018:2987249. [DOI:10.1155/2018/2987249] [PMID]

[25] Babu PD, Subhasree RS, Bhakyaraj R, Vidhyalakshmi R. Brown rice-beyond the color reviving a lost health food - A review. Am Eurasian J Agron. 2009; 2(2):67-72. [Link]

[26] Cho DH, Lim ST. Germinated brown rice and its bio-functional compounds. Food Chem. 2016; 196:259-71. [DOI:10.1016/j.foodchem.2015.09.025] [PMID]

[27] Khoo HE, Azlan A, Tang ST, Lim SM. Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. Food Nutr Res. 2017; 61(1):1361779. [DOI:10.1080/16546628.2017.1361779] [PMID]

[28] Kongthitilerd P, Suantawee T, Cheng H, Thilavech T, Marnpae M, Adisakwattana S. Anthocyanin-enriched riceberry rice extract inhibits cell proliferation and adipogenesis in 3T3-L1 preadipocytes by downregulating adipogenic transcription factors and their targeting genes. Nutrients. 2020; 12(8):2480. [DOI:10.3390/nu12082480] [PMID]

[29] Lim SM, Goh YM, Kuan WB, Loh SP. Effect of germinated brown rice extracts on pancreatic lipase, adipogenesis and lipolysis in 3T3-L1 adipocytes. Lipids Health Dis. 2014; 13:169. [DOI:10.1186/1476-511X-13-169] [PMID]

[30] Justo ML, Rodriguez-Rodriguez R, Claro CM, Alvarez de Sotomayor M, Parrado J, Herrera MD. Water-soluble rice bran enzymatic extract attenuates dyslipidemia, hypertension and insulin resistance in obese Zucker rats. Eur J Nutr. 2013; 52(2):789-97. [DOI:10.1007/s00394-012-0385-6] [PMID]

[31] Justo ML, Claro C, Zeyda M, Stulnig TM, Herrera MD, Rodriguez-Rodriguez R. Rice bran prevents high-fat diet-induced inflammation and macrophage content in adipose tissue. Eur J Nutr. 2016; 55(6):2011-9. [DOI:10.1007/s00394-015-1015-x] [PMID]

[32] Duansak N, Schmid-Schonbein GW, Srisawat U. Anti-obesity effect of rice bran extract on high-fat diet-induced obese mice. Prev Nutr Food Sci. 2022; 27(2):172-9. [DOI:10.3746/pnf.2022.27.2.172] [PMID]

[33] Munkong N, Lonan P, Mueangchang W, Yadyookai N, Kanjoo V, Yoysungnoen B. Red rice bran extract attenuates adipogenesis and inflammation on white adipose tissues in high-fat diet-induced obese mice. Foods. 2022; 11(13):1865. [DOI:10.3390/foods11131865] [PMID]

[DOI: 10.32598/hmj.28.1.8]

[34] Seesen M, Semmarath W, Yodkeeree S, Sapbamrer R, Ayood P, Malasao R, et al. Combined Black Rice Germ, Bran Supplement and Exercise Intervention Modulate Aging Biomarkers and Improve Physical Performance and Lower-Body Muscle Strength Parameters in Aging Population. Int J Environ Res Public Health. 2020; 17(8):2931. [DOI:10.3390/ijerph17082931] [PMID]

[35] Limtrakul P, Yodkeeree S, Pitchakarn P, Punfa W. Suppression of inflammatory responses by black rice extract in RAW 264.7 macrophage cells via downregulation of NF-kB and AP-1 signaling pathways. Asian Pac J Cancer Prev. 2015; 16(10):4277-83. [DOI:10.7314/APJCP.2015.16.10.4277] [PMID]

[36] Eslami S, Esa NM, Marandi SM, Ghasemi G, Eslami S. Effects of gamma oryzanol supplementation on anthropometric measurements & muscular strength in healthy males following chronic resistance training. Indian J Med Res. 2014; 139(6):857-63. [PMID]

[37] Fry AC, Bonner E, Lewis DL, Johnson RL, Stone MH, Kraemer WJ. The effects of gamma-oryzanol supplementation during resistance exercise training. Int J Sport Nutr. 1997; 7(4):318-29. [DOI:10.1123/ijsn.7.4.318] [PMID]

[38] Cook MD, Willems MET. Dietary Anthocyanins: A review of the exercise performance effects and related physiological responses. Int J Sport Nutr Exerc Metab. 2019; 29(3):322-30. [DOI:10.1123/ijsnem.2018-0088] [PMID]

[39] Copetti CLK, Diefenthaeler F, Hansen F, Vieira FGK, Di Pietro PF. Fruit-Derived Anthocyanins: Effects on cycling-induced responses and cycling performance. Antioxidants (Basel). 2022; 11(2):387. [DOI:10.3390/antiox11020387] [PMID]

[40] Yarahmadi M, Askari G, Kargarfard M, Ghiasvand R, Hoseini M, Mohamadi H, et al. The effect of anthocyanin supplementation on body composition, exercise performance and muscle damage indices in athletes. Int J Prev Med. 2014; 5(12):1594-600. [PMID]

[41] Bloedon TK, Braithwaite RE, Carson IA, Klimis-Zacas D, Lehnhard RA. Impact of anthocyanin-rich whole fruit consumption on exercise-induced oxidative stress and inflammation: A systematic review and meta-analysis. Nutr Rev. 2019; 77(9):630-45. [DOI:10.1093/nutrit/nuz018] [PMID]

[42] Kim S, Park J, Kim K, Jun W. Effect of rice bran supplementation on endurance exercise capacity in mice. J Korean Soc Food Sci Nutr. 2019; 48(12):1317-22. [Link]

[43] Kim KM, Yu KW, Kang DH, Koh JH, Hong BS, Suh HJ. Anti-stress and anti-fatigue effects of fermented rice bran. Biosci Biotechnol Biochem. 2001; 65(10):2294-6. [DOI:10.1271/bbb.65.2294] [PMID]

[44] Kim KM, Yu KW, Kang DH, Suh HJ. Anti-stress and anti-fatigue effect of fermented rice bran. Phytother Res. 2002; 16(7):700-2. [DOI:10.1002/ptr.1019] [PMID]

[45] Ahn J, Son HJ, Seo HD, Ha TY, Ahn J, Lee H, et al. gamma-Oryzanol improves exercise endurance and muscle strength by upregulating PPARdelta and ERRgamma activity in aged mice. Mol Nutr Food Res. 2021; 65(14):e2000652. [DOI:10.1002/mnfr.202000652] [PMID]

[46] Ismail M, Al-Naqeeb G, Mamat WA, Ahmad Z. Gamma-oryzanol rich fraction regulates the expression of antioxidant and oxidative stress related genes in stressed rat's liver. Nutr Metab (Lond). 2010; 7:23. [DOI:10.1186/1743-7075-7-23] [PMID]

[47] Mowry KC, Thomson-Parker TL, Morales C, Fikes KK, Stutts KJ, Leatherwood JL, et al. Effects of crude rice bran oil and a flaxseed oil blend in young horses engaged in a training program. Animals (Basel). 2022; 12(21):3006. [DOI:10.3390/ani12213006] [PMID]

[DOI: 10.32598/hmj.28.1.8]