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MINI REVIEW: BLACK RICE (*Oryza sativa* L. Indica) AS POTENTIAL FOOD FOR ANTIHYPERGLYCAEMIC

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ABSTRACT

In Indonesia, rice (*Oryza sativa* L.) has different colors and shapes, visible from the plants and rice. There are several types of rice, one of which is black rice (*Oryza sativa* L. indica). Researchers are motivated to explore the benefits of black rice in Indonesia. This interest stems from the potential health benefits of black rice, such as its benefits in treating diabetes mellitus. The effectiveness of reducing blood sugar levels is crucial in the context of the increasing prevalence of diabetes in Indonesia, as projected by the International Diabetes Federation for 2045. The author made observations on the phytochemical and pharmacological activities of black rice, aiming to lay the foundation for further study and development. By searching online journals in the Scopus and PubMed databases using the keywords ("Black Rice") AND (antidiabetic) OR (diabetes) OR ("glucose lowering") for the last 10 years, the filtering process produced 3 articles on Scopus and 5 articles on PubMed, providing accurate data for review. Results show that black rice contains bioactive compounds such as flavonoids, phytic acid, polyphenolic compounds, and oryzanol, which provide significant health benefits. Anthocyanins, the main compounds responsible for the color of rice, contribute to antihyperglycemic properties and have various pharmacological activities, one of which is anti-diabetic benefits. In addition, the high content of anthocyanins, fiber, and other nutrients in black rice makes it effective in managing the glycemic index, and blood glucose levels, and improving overall health. In conclusion, black rice has the potential for health due to its anti-diabetic properties caused by anthocyanins, making it a promising functional food for overcoming the increasing prevalence of diabetes in Indonesia.

Keywords: Oryza sativa; Black rice; Antochyanine; Antihyperglycaemic

INTRODUCTION

In Indonesia, several colors of rice can be found, including red rice (*Oryza nivara*), black rice (*Oryza sativa* L. Indica), and white rice (*Oryza sativa* L.) as shown in Figure 1 (Kristamtini et al., 2016). Rice (*Oryza sativa* L.) has different shapes and colors, both in terms of the plant and the rice it produces. The production of black rice cultivation in Indonesia, especially in the Boyolali area, has experienced an increase significantly, starting at 16.7 tons in 2017 to a peak of 169 tons in 2020. However, black rice production is still trailing behind when compared to other varieties of rice. The white rice output in Boyolali in 2020 amounted to around 4999.20 tons (Devitha, Nandariyah, and Komariah, 2021).

The pigmented rice known as black rice (*Oryza sativa* L. indica) has a black covering on its endosperm (Kang, Jung, and Lee, 2014). Increased rice consumption of colored rice, such as black rice, can be attributed to people's shift toward healthy eating practices. Rice with water-soluble fiber is an effective food supplement for preventing diabetes complications in humans (Sivamaruthi, Kesika, and Chaiyasut, 2018). Black rice is categorized as a functional food that is superior to other rice varieties in terms of its ability to lower blood sugar levels. (Devitha, Nandariyah and Komariah, 2021). The International Diabetes Federation (IDF) projects that the number of people with diabetes in Indonesia could reach 28.57 million by 2045, which is a 47% increase compared to the number in 2021. The urgency of this article lies in efforts to increase the increasing prevalence of diabetes and encourage healthier dietary choices. The potential health benefits of black rice are an interesting topic in the context of public health and nutrition, especially considering the prospect of increasing diabetes cases in Indonesia.

METHOD

From the background above, the author will collect more information about the phytochemical and pharmacological activities of black rice. This review aims to provide accurate data to lay the foundation for further study and development. Data is retrieved from online journals, which are then screened. Keywords used "Black Rice" and antidiabetic, diabetical, or "glucose lowering" in Scopus and PubMed databases for the last 10 years. Search results on the Scopus and PubMed databases by looking at the titles of articles containing these keywords resulted in 3 articles and 5 articles, respectively.

RESULTS AND DISCUSSION

Black Rice

Black rice (*Oryza sativa* L. indica), known as "beras hitam" in Indonesia, has significant cultural and culinary importance in the country. It is commonly used in traditional desserts and sweet snacks, and it has been a part of various ceremonial dishes and rituals. The deep purple hue and nutty flavor of black rice make it a distinctive and revered ingredient in Indonesian cuisine. Furthermore, black rice has gained attention for its potential health benefits and nutritional value, leading to its exploration as a functional food in Indonesia. While its traditional use in Indonesia is primarily culinary, its potential medicinal properties have sparked interest in its therapeutic uses because it contains ingredients that are good for health (Kang, Jung, and Lee, 2014; Jun et al., 2015). In Indonesia, there is not only black rice, various types of rice have different contents, including carbohydrates, protein, fat, fiber, iron, zinc minerals, tocopherols, thiamine, and riboflavin (Kumar and Murali, 2020). As shown in **Table I** regarding the comparison of content between black, white, and red rice. When extracting black rice, the components extracted will adapt to the solvent used, as shown in **Table II**.

Table I. The Comparison of Content between Black, White, and Red Rice

Content	Total content			References
	Black rice	White rice	Red rice	
Carbohydrate (mg/g)	34.0±0.5	28.0±0.3	23.0±0.4	(Riyatun et al., 2018; Rathna Priya et al., 2019; Kumar and Murali, 2020)
Protein (mg/g)	8.5±0.5	2.7±0.04	7.0±0.05	
Fat (mg/g)	2.0±0.06	0.3±0.01	0.8±0.01	
Fiber (mg/g)	4.9±0.3	0.6±0.1	2.0±0.6	
Iron (µg/g)	3.5 ± 0.15	1.2 ± 0.19	5.5 ± 0.14	
Tocopherol (µg/g)	12.54 ± 0.34	0.1 ± 0.14	10.77 ± 0.24	
Thiamine (µg/g)	0.46 ± 0.032	0.7 ± 0.06	0.33 ± 0.15	
Riboflavin (µg/g)	0.403 ± 0.04	0.03 ± 0.33	0.105 ± 0.03	
Zinc (µg/g)	3.16 ± 0.05	1.41 ± 0.039	1.91 ± 0.036	
Peonidin 3-glucoside (µg/g)	11.1 ± 0.16	-	11.07 ± 0.97	(Fathurrizqiah and Panunggal, 2015; Mbanjo
Cyanidin 3-glucoside (µg/g)	140.83 ± 2.0	-	-	

Cyanidin 3,5-diglucoside (μg/g)	20.0 ± 2.0	-	-	et al., 2020; Agustin, Safitri and Fatchiyah, 2021)
Pelargonidin 3- O - glucoside (μg/g)	8.0 ± 1.0	-	-	
Peonidin 3- O -glucoside (μg/g)	500.0 ± 11.0	-	-	
Cyanidin 3-O-arabinoside (μg/g)	9.0 ± 1.0	-	-	
Diosmedin 8-C-hexoside (μg/g)	87.0 ± 16.0	-	8.0 ± 2.0	
Quercetin 3-O-rutinoside (μg/g)	107.0 ± 19.0	-	-	
Isorhamnetin 3-O-glucoside(μg/g)	8.2 ± 0.2	-	-	
Lutein (μg/g)	4.3 ± 3.4	0.006 ± 0.001	0.4 ± 0.1	
Zeaxanthin (μg/g)	1.9 ± 0.2	0.002 ± 0.001	0.1 ± 0.1	
Lycopene (μg/g)	0.16 ± 0.04	-	-	
β-caroten (μg/g)	0.20 ± 0.01	-	-	
Ferulic acid (μg/g)	362.0 ± 0.2	158.3 ± 0.04	-	

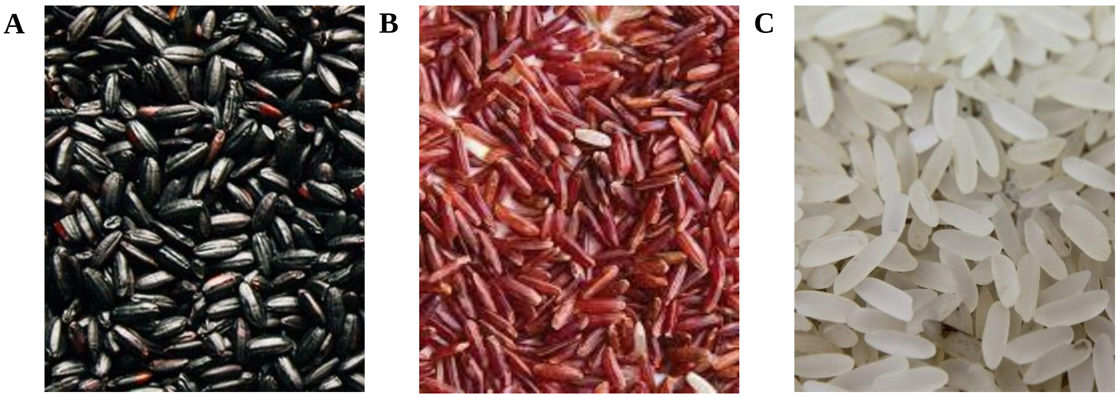


Figure 1. (A) Black Rice (*Oryza sativa* L. Indica), (B) Red Rice (*Oryza nivara*), and (C) White Rice (*Oryza sativa* L.)

Table II. Compound Content of Black Rice and Black Rice Extracted in Ethanol and Methanol Extractors and Acidified Extracts

Sample and solvent	Target compound	Content (mg/g extract)	Reference
Black rice extracted using Methanol	*cyanidin-3-glucoside* *Peonidin*-3-glucoside	1.24 ± 0.27 0.76 ± 0.12	(Suwannakul et al., 2015)
Black rice extracted using Ethanol: HCl 1N (50.78%;0.6mL)	*cyanidin-3-glucoside*	0.638 ± 20.77	(Bae et al., 2017)
Black rice extracted using 0.1 N HCl in Methanol	*Cyanidin 3-glucoside* *peonidin 3-glucoside*	5.69 ± 0.28 11.46 ± 0.57	(Pengkumsri et al., 2015)

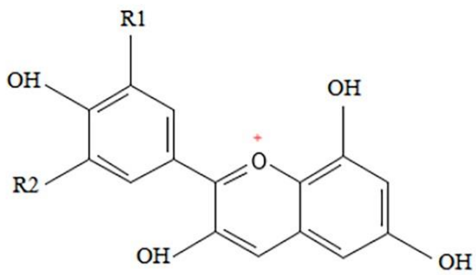
Phytochemical constituents

Black rice includes bioactive ingredients such as flavonoids, phytic acid, polyphenolic compounds, and oryzanol, which have significant health advantages and function as antioxidants and anti-inflammatory agents. It has the potential to be medicinal (Pang et al., 2018). Another advantage of black rice is the mineral content of phytochemicals such as unsaturated fatty acids, GABA, ɣ-oryzanol, protein, phenols, anthocyanins, and vitamins, whose composition depends on the variety and place of cultivation (Pengkumsri et al., 2015; Kushwaha, 2016). For a more complete look at the compounds in black rice, see **Table I**.

Anthocyanin is the main compound in antihyperglycemic

The term "anthocyanins" originates from the Greek language, with "anthos" meaning "flower" and "kyanos" meaning "blue". Anthocyanin is a non-photosynthetic pigment that is synthesized in the cytoplasm and stored in the vacuolar lumen of epidermal cells (Pervaiz et al., 2017). Anthocyanins are the polyphenols of the flavonoid class that are the largest contributors to coloring flowers, fruits, seeds, leaves, and organic tubers and can dissolve in polar solvents (Du et al., 2015; Ifadah, Wiratara, and Afgani, 2021).

Anthocyanins are composed of anthocyanidins, which have a phenyl-2-benzopyrilium salt structure. This structure consists of a carbon skeleton ($C_6C_3C_6$) with three carbon atoms connected by an oxygen atom, linking two benzene aromatic rings (C_6H_6). Chemically, anthocyanins are derivatives of a single aromatic structure, cyanidin. The type of anthocyanin has differences based on the bond between the R3' and R5' groups with the aromatic anthocyanin ring (Pervaiz et al., 2017). Pelargonidin (Pg), cyanidin (Cy), peonidin (Pn), delphinidin (Dp), petunidin (Pt), and malvidin (Mv) are the most prevalent anthocyanidins in nature (Nassour, Ayash and Al-tameemi, 2020). The stability of anthocyanin is influenced by factors such as pH, temperature, and light exposure. The chemical structure of anthocyanins is shown in **Figure 2**.



Anthocyanin stability	
pH	5.0 – 6.0
Temperature	50^0C

Figure 2. Anthocyanin (Hidayah, Winarni Pratjojo and NuniWidiarti, 2014; Liu et al., 2018)

Anthocyanins are easily soluble in water and some polar organic solvents such as ethanol, methanol, acetone, and chloroform. The addition of organic acids such as acetic acid, citric acid, or hydrochloric acid can enhance the stability of anthocyanins in water and polar solvents that are neutral or alkaline. By combining polar solvents with appropriate organic acids, it is possible to achieve very acidic pH conditions (pH 1-2) that enhance the stability of anthocyanins in the form of red flavium cations. Conversely, when the solvent is coupled with weak acids, the color of anthocyanins fades to a lighter shade of red. The substance exhibits a pH of 3, and appears purplish red at pH 4, purple at pH 5-6, and blue-purple at pH 7. Ethanol and organic acid solvents are comparatively less hazardous than methanol and HCl (Pedro, Granato, and Rosso, 2016).

Anthocyanins offer numerous advantages in the prevention of different degenerative ailments, including cardiovascular disease, as well as the inhibition and reduction of cholesterol levels. The inhibition process involves disrupting the sequence of free radical propagation by utilizing the hydroxyl groups (OH) in ring B as electron donors, thereby preventing the generation of free radicals (Forbes-Hernández et al., 2017). Several studies have proven the pharmacological activity of anthocyanins as antidiabetics (Jia et al., 2020); anti-cancer; anti-inflammatory (Luna-Vital, Weiss and Gonzalez de Mejia, 2017);

cardiovascular (Makhmudova et al., 2021); anti-aging; preventing liver function disorders (Jiang et al., 2015); and Obesity is caused by an ongoing process of oxidation in the body, which leads to cell damage or uncontrolled growth of cells into lipid peroxide or malondialdehyde (MDA), finally resulting in cell death (Sadighara et al., 2015; Al-okbi et al., 2020; Idayu, Suhaili and Manshoor, 2022).

On oral and intravenous (IV) administration, the half-life of C3G is between 0.7-1.8 hours and 0.3-0.7 hours. The main metabolites of C3G are methylation and glucuronidation products. The enzymes involved in anthocyanin metabolism are cytochrome P450 enzymes, especially CYP3A4, CYP2C9, and CYP2C19 isozymes (De Ferrars et al., 2014).

Pharmacological activity

The C3G content possessed by black rice is very high and can inhibit alpha-glucosidase (Bae et al., 2017), increase the effectiveness of glucose uptake in several tissues (Jia et al., 2020), reduce adipose inflammation and hepatic steatosis in rats on a high-fat diet, and reduce hyperglycemia in diabetic rats. Meanwhile, its fiber content can slow down the rate of absorption of food in the digestive tract. Ferulic acid acts as an antioxidant, and phenolic compounds also act as antioxidants and as inhibitors of liver cytochrome P450. As shown in Table III regarding the Pharmacological activity of black rice (Fathurrizqiah and Panunggal, 2015; Darajat, Sakinah, and Hairrudin, 2019).

Table III. Pharmacological Activity of Black Rice

Benefits	Dosage	Reference
Antioxidants	1000 mg/kgBW	(Tananuwong and Tewaruth, 2010)
Antidiabetic Repair damaged liver cells Prevent kidney function disorders Prevent pancreatic dysfunction	50 mg/kgBW	(Wahyuni, Munawaroh and Da'i, 2016; Wahyuni et al., 2020)
Antiinflammatory Chemoprevention	500 mg/kgBW	(Suwannakul et al., 2015)
Preventing anemia Relieving digestive problems Antihypertensive Antihypercholesterolemia	-	(Devitha, Nandariyah and Komariah, 2021)

Rice contains a greater quantity of phenolics and flavonoids compared to wheat flour. Black rice exhibits higher phenolic and anthocyanin levels, resulting in heightened antioxidant efficacy as compared to white rice. Equally vital components are protein, diverse amino acids, vitamins, and numerous minerals such as iron, calcium, zinc, magnesium, and manganese. Black rice has a higher fiber content compared to white rice and brown rice.
Amylose and amylopectin are present in black rice, constituting a glucose polymer that forms starch and influences the rice's fluffy texture. Based on its amylose concentration, rice is categorized into four types. The presence of amylose and amylopectin in black rice, which constitute its starch content, has a significant impact on lowering blood glucose levels. A food ingredient with a high amylose content exhibits a lower glycemic index value compared to a food component with a low amylose concentration. Therefore, the consumption of foods that have high quantities of amylose can effectively decrease glycemic index values in individuals with diabetes and help regulate blood glucose levels in non-diabetic individuals (Afandi, 2023).

The fiber content in black rice also has pharmacological activity as a controller for GD, hypertension, and hypercholesterolemia. The mechanism by which fiber reduces blood sugar and cholesterol is through its ability to slow down the rate of gastric emptying, so the absorption of these substances will be delayed. In addition, food can act as a physical barrier, thereby blocking contact with the gastrointestinal mucosal surface (Yuda et al., 2020).

CONCLUSION

Black rice (*Oryza sativa* L. indica) in Indonesia, known as "beras hitam", shows a lot of potentials, one of which is health. One of the potential health benefits is due to the antidiabetic properties caused by anthocyanins, making it a promising functional food for overcoming the increasing prevalence of diabetes in Indonesia.

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REFERENCES

Afandi, F.A. (2023) 'The Correlation Between Amylopectin Chain-Length and Glycemic Index Value of Carbohydrate Foods: A Review', *Food Scientia Journal of Food Science and Technology*, 3(December), pp. 165–180. Available at: https://doi.org/10.33830/fsj.v3i2.6503.2023.

Agustin, A.T., Safitri, A. and Fatchiyah, F. (2021) 'Java red rice (*Oryza sativa* l.) nutritional value and anthocyanin profiles and its potential role as an antioxidant and anti-diabetic', *Indonesian Journal of Chemistry*, 21(4), pp. 968–978. Available at: https://doi.org/10.22146/ijc.64509.

Al-okbi, S.Y. *et al.* (2020) 'Rice bran as source of nutraceuticals for management of cardiovascular diseases, cardio-renal syndrome, and hepatic cancer', *Journal of Herbmed Pharmacology*, 9(1), pp. 68–74. Available at: https://doi.org/10.15171/jhp.2020.10.

Bae, I.Y. *et al.* (2017) 'Optimized preparation of anthocyanin-rich extract from black rice and its effects on in vitro digestibility', *Food Sci Biotechnol*, 26(5), pp. 1415–1422. Available at: https://doi.org/10.1007/s10068-017-0188-x.

Darajat, A., Sakinah, E E. and Hairrudin, H. (2019) 'Effect of rice fiber analog content on GLUT4 expression in skeletal muscle of diabetic rats', *Jurnal Gizi Klinik Indonesia*, 16(1), p. 14. Available at: https://doi.org/10.22146/ijcn.31806.

Devitha, M., Nandariyah, and Komariah (2021) 'Black Rice Production Dynamics Members Of The Boyolali Organic Rice Farmers Alliance (APOLI) Amid Climate Anomalies', *Sinkesjar*, 1(1), pp. 438–447.

Du, H. *et al.* (2015) 'Methylation mediated by an anthocyanin, O-methyltransferase, is involved in purple flower coloration in Paeonia', *Journal of Experimental Botany*, 66(21), pp. 6563–6577. Available at: https://doi.org/10.1093/jxb/erv365.

Fathurrizqiah, R. and Panunggal, B. (2015) 'Resistant Starch, Amylose, and Amylopectin Sorghum Snack Bars as Alternative Snacks for Patients with Type 2 Diabetes Mellitus', *Journal of Nutrition College*, 4(2), pp. 562–569.

De Ferrars, R.M. *et al.* (2014) 'The pharmacokinetics of anthocyanins and their metabolites in humans', *British Journal of Pharmacology*, 171(13), pp. 3268–3282. Available at: https://doi.org/10.1111/bph.12676.

Forbes-Hernández, T.Y. *et al.* (2017) 'Strawberry (cv. Romina) methanolic extract and anthocyanin-enriched fraction improve lipid profile and antioxidant status in HepG2 cells', *International Journal of Molecular Sciences*, 18(6), p. 1149. Available at: https://doi.org/10.3390/ijms18061149.

Hidayah, T., Winarni Pratjojo and NuniWidiarti (2014) 'Pigment and Antioxidant Stability Test of Natural Dragon Fruit Peel Extract', *Indonesian Journal of Chemical Science*, 3(2), pp. 135–140.

Idayu, N., Suhaili, M. and Manshoor, N. (2022) 'Ethnomedicine, phytochemistry, and bioactivities of Hibiscus sabdariffa L. (Malvaceae)', *Journal of Herbmed*

Pharmacology, 11(4), pp. 451–460. Available at: https://doi.org/10.34172/jhp.2022.52.

Ifadah, raida amelia, Wiratara, pinasthika rizkia warapsari and Afgani, chairul anam (2021) 'Review: Anthocyanin and its Health Benefits', *Jurnal Teknologi Pengolahan Pertanian*, 3(2), pp. 11–21.

Jia, Y. *et al.* (2020) 'A dietary anthocyanin cyanidin-3-O-glucoside binds to PPARs to regulate glucose metabolism and insulin sensitivity in mice', *Commun Biol*, 3(1), pp. 2–11. Available at: https://doi.org/10.1038/s42003-020-01231-6.

Jiang, X. *et al.* (2015) 'Cyanidin-3- O -β-glucoside Purified from Black Rice Protects Mice against Hepatic Fibrosis Induced by Carbon Tetrachloride via Inhibiting Hepatic Stellate Cell Activation', *Journal of Agricultural and Food Chemistry*, 63(27), pp. 6221–6230. Available at: https://doi.org/10.1021/acs.jafc.5b02181.

Jun, H. Il *et al.* (2015) 'Isolation and Identification of Phenolic Antioxidants in Black Rice Bran', *Journal of Food Science*, 80(2), pp. C262–C268. Available at: https://doi.org/10.1111/1750-3841.12754.

Kang, Y.J., Jung, S.W. and Lee, S.J. (2014) 'An optimal extraction solvent and purification adsorbent to produce anthocyanins from black rice (*Oryza sativa* cv. Heugjinjubyeo)', *Food Science and Biotechnology*, 23(1), pp. 97–106. Available at: https://doi.org/10.1007/s10068-014-0013-8.

Kristamtini *et al.* (2016) 'Genetic Advance and Heritability of Agronomic Characters of Black Rice in F2 Population', *Penelitian Pertanian Tanaman Pangan*, 35(2), pp. 119–124.

Kumar, N. and Murali, R.D. (2020) 'Black Rice : A Novel Ingredient in Food Processing', *J Nutr Food Sci*, 10(771), pp. 1–7. Available at: https://doi.org/10.35248/2155-9600.20.10.771.Copyright.

Kushwaha, U.K.S. (2016) *Nutrition Profiles of Black Rice, Black Rice*. Nepal: Nepal Agricultural Research Council. Available at: https://doi.org/10.1007/978-3-319-30153-2_4.

Liu, Ya *et al.* (2018) 'Effect of temperature and pH on stability of anthocyanin obtained from blueberry', *Journal of Food Measurement and Characterization*, 12(3), pp. 1744–1753. Available at: https://doi.org/10.1007/s11694-018-9789-1.

Luna-Vital, D., Weiss, M. and Gonzalez de Mejia, E. (2017) 'Anthocyanins from Purple Corn Ameliorated Tumor Necrosis Factor-α-Induced Inflammation and Insulin Resistance in 3T3-L1 Adipocytes via Activation of Insulin Signaling and Enhanced GLUT4 Translocation', *Molecular Nutrition and Food Research*, 61(12), p. 1700362. Available at: https://doi.org/10.1002/mnfr.201700362.

Makhmudova, U. *et al.* (2021) 'Phytosterols and Cardiovascular Disease', *Current Atherosclerosis Reports*. Springer US, p. 68. Available at: https://doi.org/10.1007/s11883-021-00964-x.

Mbanjo, E.G.N., *et al.* (2020) 'The Genetic Basis and Nutritional Benefits of Pigmented Rice Grain', *Frontiers in Genetics*, 11(March), pp. 1–18. Available at: https://doi.org/10.3389/fgene.2020.00229.

Nassour, R., Ayash, A. and Al-tameemi, K. (2020) 'Anthocyanin pigments : Structure and biological importance Anthocyanin pigments : Structure and biological importance', *Journal of Chemical and Pharmaceutical Sciences*, 13(4), pp. 45–57.

Pang, Y. *et al.* (2018) 'Bound phenolic compounds and antioxidant properties of whole grain and bran of white, red and black rice', *Food Chemistry*, 240(2018), pp. 212–221. Available at: https://doi.org/10.1016/j.foodchem.2017.07.095.

Pedro, A.C., Granato, D. and Rosso, N.D. (2016) 'Extraction of anthocyanins and polyphenols from black rice (*Oryza sativa* L.) by modeling and assessing their reversibility and stability', *Food Chemistry*, 191, pp. 12–20. Available at: https://doi.org/10.1016/j.foodchem.2015.02.045.

Pengkumsri, N. *et al.* (2015) 'Physicochemical and antioxidative properties of black, brown and red rice varieties of northern Thailand', *Food Science and Technology*, 35(2), pp.

331–338. Available at: https://doi.org/10.1590/1678-457X.6573.

Pervaiz, T. *et al.* (2017) 'Naturally Occurring Anthocyanin, Structure, Functions and Biosynthetic Pathway in Fruit Plants', *Journal of Plant Biochemistry & Physiology*, 05(02). Available at: https://doi.org/10.4172/2329-9029.1000187.

Rathna Priya, T.S. *et al.* (2019) 'Nutritional and functional properties of coloured rice varieties of South India: A review', *Journal of Ethnic Foods*. Journal of Ethnic Foods, pp. 1–11. Available at: https://doi.org/10.1186/s42779-019-0017-3.

Riyatun *et al.* (2018) 'Proximate Nutritional Evaluation of Gamma Irradiated Black Rice (*Oryza sativa* L. cv. Cempo ireng)', *IOP Conference Series: Materials Science and Engineering*, 333(1), pp. 2–6. Available at: https://doi.org/10.1088/1757-899X/333/1/012073.

Sadighara, P. *et al.* (2015) 'The injection of rice bran oil to avian egg : focus on carotenoids content of liver and brain in embryonic period', *Journal of Herbmed Pharmacology*, 4(2), pp. 53–55.

Sivamaruthi, B.S., Kesika, P. and Chaiyasut, C. (2018) 'A Comprehensive Review on Functional Properties of Fermented Rice Bran', *Wolters Kluwer - Medknow*, 1(2), pp. 218–224. Available at: https://doi.org/10.4103/phrev.phrev.

Suwannakul, N. *et al.* (2015) 'Purple rice bran extract attenuates the aflatoxin B1-induced initiation stage of hepatocarcinogenesis by alteration of xenobiotic metabolizing enzymes', *Asian Pacific Journal of Cancer Prevention*, 16(8), pp. 3371–3376. Available at: https://doi.org/10.7314/APJCP.2015.16.8.3371.

Tananuwong, K. and Tewaruth, W. (2010) 'Extraction and application of antioxidants from black glutinous rice', *LWT - Food Science and Technology*, 43(3), pp. 476–481. Available at: https://doi.org/10.1016/j.lwt.2009.09.014.

Wahyuni, A.S. *et al.* (2020) 'The synergistic effect of black rice bran extract and glibenclamide on protecting renal, hepatic, and pancreatic cells in alloxan induced rats', *Int J Pharm Res*, 12(1), pp. 509–517. Available at: https://doi.org/10.31838/ijpr/2020.12.01.113.

Wahyuni, A.S., Munawaroh, R. and Da'i, M. (2016) 'Antidiabetic mechanism of ethanol extract of black rice bran on diabetic rats', *Natl J Physiol Pharm Pharmacol*, 6(2), pp. 106–110. Available at: https://doi.org/10.5455/njppp.2015.5.1111201590.

Yuda, I.P. *et al.* (2020) 'Antidiabetic Activity of Black Rice (*Oryza sativa* L. indica) Infusion Using Glucose Tolerance and α-Glucosidase Inhibitory Assays', *Majalah Kesehatan Pharmamedika*, 11(2), pp. 123–132. Available at: https://doi.org/10.33476/mkp.v11i2.1326.