Catalyx : Journal of Process Chemistry and Technology
Volume. 1 Issue 1 July 2024
Page No: 33-44

Determination of Antioxidant activities of locally produce rice in Northern and Western part of Nigeria, using Kebbi rice and Igbemo rice as case study

Marvellous K. Adealawode[1], Jeremiah P. Ugwo[2]
Ekiti State University, Nigeria[1]
Federal College of Education[2]
Correspondent : adealawode.m.178860113@eksu.edu.ng[1]

Received : May 24, 2024
Accepted : Juny 26, 2024
Published : July 15, 2024

Citation: Adealawode, M, K, & Ugwo, J, P. (2024). Determination of Antioxidant activities of locally produce rice in Northern and Western part of Nigeria, using Kebbi rice and Igbemo rice as case study. Catalyx : Journal of Process Chemistry and Technology, 1(1), 33-44

ABSTRACT: This research provides the antioxidant activities of locally produced rice in the Northern and Western regions of Nigeria, with a focus on Kebbi rice and Igbemo rice. The study utilizes the Ferric Reducing Antioxidant Power (FRAP) and 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assays to evaluate the antioxidant capacity of these rice varieties. In which the sample was extracted using solvent extraction method after which the antioxidant (AO) activity of the rice samples as ferric-reducing power, is determined using a modified FRAP (ferric reducing/antioxidant power) assay Sodium phosphate, buffer solution, pipettes, test tubes, centrifugal machine, TCA, KFC and reagent such as Fe(iii) solution were used to analyse the ferric reducing antioxidant power (FRAP) of the sample. Also, Methanolic solution, and spectrophotometer to measure absorbance at 516nm is used to determine the free radical scavenging ability of the extract against DPPH (1, 1-diphenyl-2-picryhydrazyl). Results reveal that Kebbi rice exhibits higher FRAP values compared to Igbemo rice, indicating superior antioxidant activity in the FRAP assay. Conversely, Igbemo rice demonstrates higher DPPH values than Kebbi rice, suggesting greater antioxidant potency in the DPPH assay. These findings underscore the variability in antioxidant properties among different rice varieties and highlight the importance of considering multiple assays for a comprehensive assessment of antioxidant activity. Understanding the antioxidant profiles of indigenous rice varieties like Kebbi and Igbemo rice is crucial for promoting their consumption and enhancing food security in Nigeria. Further research is warranted to elucidate the specific antioxidant compounds responsible for the observed differences and explore their potential health benefits.

Keywords: Antioxidant, Kebbi rice, Igbemo rice, DPPH, FRAP

INTRODUCTION

Rice (Oryza sativa) belongs to the family Poaceae, is a grain crop that remains the most frequent grains consumed widely in Africa, it has become prevalent food with a higher consumption rate, most especially in the western part of Africa, it can be eaten as cooked food or further processed in to rice flour, Rice Milk, Rice Noodles and others, based on the method it was processed. The larger rice food consumed is the cooked rice or boiled one. As over 75% of a household in western part of Africa consumes rice daily, it is considered as the major carbohydrates food consumed mostly, which can be taken as breakfast, lunch or dinner food in the region, due to this cause, rice remains one of the largest food imported to western part of Africa, as this import rates increases,

it leads to increase in the selling price of rice, due to the import prices some western part of Africa such as Nigeria in 2019, make a binding law to closes boarder for the importation of rice so as to develop and improve the local production of rice in the country, many find this challenging switching to the new development. Most especially considering the taste, chemical nutrients and health benefits of the local grown rice compared to the foreign rice import, at this detriment the consumption rate of rice did not reduce in Nigeria, as many state in the country facilitate there own rice production processes, even at which rice is is developed by small scale farmers at a lower levels, which will be enough just to take care of their families and somewhat left over available to be sold at nearby market or business sectors(Rickford, 2022).

Regardless of Nigeria being the West Africa's biggest producer of rice, rice yield in Nigeria is low contrasted with different areas of the world, and this restricted creation is additionally diminished during post-farming activity. Notwithstanding unique small scale production and assortment of rice produced in Nigeria, there is an increase in the local rice produce in the country, as at 2019 - 2022 crop year, due to the government policy of closing the importation of foreign rice in the country, which leads to inflation and hike in price of rice. Many households which might not be able to afford the new price usually opt in for the local rice produce in the country, having a notable yield in rice production and increasing the number of farmers who produces rice. Different rice varieties possess varying levels of bioactive compounds that contribute to their antioxidant capacities. Antioxidants of rice are molecules that inhibit the oxidation of other molecules, thereby preventing the formation of free radicals that can damage cells and contribute to various diseases(Pulido & S.C, 2000).

The antioxidant activities and biological effects are critical in maintaining health and preventing disease. Pigmented rice varieties, such as red, black, and purple rice, generally have higher levels of phenolic compounds, flavonoids, and anthocyanins compared to white rice. For instance, the red rice variety DM29 has been found to have high levels of phenolic compounds and a strong antioxidant capacity(Chen et al., 2006; Oki et al., 2002). The antioxidant capacity of rice is influenced by a variety of factors including genetic variety, processing methods, and environmental conditions, The amount of antioxidants in rice is also significantly influenced by the environment, farming methods, and soil quality(Iqbal et al., 2005). Rice grains' ability to synthesize bioactive chemicals can be impacted by changes in soil nutrients and exposure to environmental stresses. Because the plants are healthier overall and more resilient to stress, research shows that rice grown in nutrient-rich soils typically has higher amounts of antioxidants. The chemical composition includes significantly contributing to its antioxidant qualities having certain phenolic substances like quercetin, ferulic acid, and p-coumaric acid(Raajeswari & P.A, 2021).

These substances, which are more prevalent in colorful rice cultivars, are essential to their capacity to scavenge free radicals. Numerous phenolic compounds found in rice have already been identified(Chung M et al., 2006; Manac et al., 2006). Higher molecular weight chemicals predominate in grains with red and black pericarp color, whereas light brown grains (around 85%) are primarily composed of low molecular weight phenolics, the primary phenolics in rice grains with light brown pericarp colors are phenolic acids, specifically ferulic and coumaric acids(Adom K & Liu R. H, 2002; Balasundram et al., 2006). Additional compounds found include vanillic acid,

syringic acid, caffeic acid, sinapic acid, protocatechuic acid chlorogenic acid, and hidroxybenzoic acid. The primary anthocyanins in rice grains with red and black pericarps are cyanidin-3-O-β-Dglucoside and peonidin-3-O-β-Dglucoside. The main characteristic that determined the type of phenolic compounds in the grain is the color of the pericarp, as no differences were observed among the anthocyanins when evaluating the grains with black pericarp from the subspecies indica and japonica. Other compounds identified include the phenolic acids, such as ferulic, caffeic, and protocatechuic acids, and the anthocyanidins, cyanidin, and malvidin. The color of the pericarp also indicates the amount of phenolics present in the grain; typically, red and black grains have higher phenolic concentrations. Antioxidants play a crucial role in protecting the body from oxidative stress and its associated damage, contributing to overall health and the prevention of chronic diseases(Benzie I F & Szeto Y, 1999; Collins A, 2005). Regular consumption of antioxidant-rich foods is recommended to maintain optimal health. Rice, particularly pigmented varieties like black, red, and purple rice, contains several antioxidants that contribute to its health benefits. the key antioxidant activities and biological effects associated with rice includes phenolic Compounds: including flavonoids and phenolic acids, which are potent antioxidants, these compounds scavenge free radicals and chelate metal ions, reducing oxidative stress(Dimitrios, 2006; Frank B, 2003).

Anthocyanins is also part of the antioxidant of rice, pigmented rice varieties are rich in anthocyanins, which are powerful antioxidants(ER. , T. A. R. Heim K & J, 2002; Ibitoye A, 2005). Anthocyanins help in neutralizing free radicals and protecting cells from oxidative damage. Vitamin E can also be present in rice, especially rice bran, contains tocopherols and tocotrienols (forms of vitamin E) that act as antioxidants by protecting cell membranes from lipid peroxidation(Hudson E et al., 2000; Hughes & Okafor, 2015). Other antioxidants coping's that can be found in rice is γ-Oryzanol, which is usually found inside the rice bran oil, γ-oryzanol is a mixture of ferulic acid esters of sterols and triterpenoid alcohols, known for its antioxidant properties. It helps in scavenging free radicals and protecting against oxidative damage(Hindustan Rubber Industries, 2020; Hu et al., 2003).

Because phenolic compounds in rice directly protect DNA from damage and have an impact on cell proliferation, studies using cell cultures have demonstrated that they may also be linked to antimutagenic, anti carcinogenic, and anti metastasis activities. Variety of factors, including the food matrix, the concentration of the polyphenol in the food, the background diet, and inter-individual variations that impact the concentration of active metabolites in the organism, the bioavailability of different polyphenols varies significantly(Gyamfi & Y.and, 1999; E. Heim K et al., 2002).

Still, only a small number of in vivo studies assessing the antioxidant potential of rice phenolics have been conducted, and the majority of them employed animal models rather than human subjects. Consuming the colored portion (pericarp) of rice grains has been demonstrated in animal studies to have positive effects on blood lipid regulation and related disorders, hence assisting in the prevention of cardiovascular issues(Goffman F. D & Bergman C. J, 2004). Understanding these factors can help in selecting and processing rice varieties to maximize their health benefits, particularly their antioxidant capacities, in relating this to the local rice produce in Nigeria, checking

through the antioxidants activities of the locally grown rice having high consumption rate since majority of the people switched to the consumption of the local rice due to the high cost of the imported rice. A portion of the locally produced rice in the nation includes the massive rice production from some Nigeria states rice produce, such as Kebbi rice farmer in kebbi state of nigeria harvest rice twice a year, this is due to the quality of inputs, training and extension services support being received by the farmers. Igbemo rice in Ekiti State is one of the most popular local rice brands consumed by Nigerians especially in the southwest region.

However the major health benefits of rice as it provides starch and other essential nutrients in the body, serves as essential boost for the local rice farmers to produce more of local rice as the problems of rice impurity and stones in the rice produce locally is reducing drastically, and there is rise in the consumption of local rice due to high cost of rice imported Even at which the production of the cereal crop requires some major preparation of the land used for the planting of rice, as it is a grain that is needed to be planted in a flooded area with some required specific amount of water, because better growth of different varieties of rice is enabled in a flooded soil, as a dry soil decreases some active mineral nutrients in rice, such as Mg, Cu, Zn, Ni and Cd. Which may later results to stunted growth and erected leaves.

The purpose of this research is to determine the antioxidant actives of local rice produce from the Northern and southern part of Nigeria using Kebbi rice in Kebbi state and Igbemo, rice in Ekiti state as case study. To ascertain the ferric reducing property and the free radical scavenging ability (FRAP) of the extract against DPPH (1,1-diphenyl-2-picryhydryzyl). Free radicals is an outcome of various metabolic activities and their excess production leads to many diseases. Therefore, it is necessary to neutralize excess free radicals. Oxygen free radicals are generated within the cells due to the various metabolic processes and mitochondrial energy production. These radicals are beneficial, as well as deleterious response. Their beneficial role includes response to the noxious stimuli that is antagonizing infectious agents, along with this they are part of cell-cell signaling processes.

Studies over time has indicated different DPPH free radical scavenging of rice extract, reveals that DPPH were greatly decreased with the further milling of rice grain, obviously in the present study, rice extract collected from the northern part of Nigeria (Kebbi) and western part of Nigeria (Igbemo Ekiti) were simultaneously measured with indices of ferric reducing property (FRAP) and ferric radical scavenging ability of the extract against DPPH in focus. This study is significant in which the entire work is designed to give the result on the antioxidant activity of rice generated. This result gotten would provide an adequate ideal on the removal of the potential damaging free radicals oxidizing agent associated with rice(Choi et al., 2007).

Diagram Of The Rice Sample Used

1. NORTHERN (Kebbi Rice)

Pict 1 : Kebbi rice before grinding

Pict 2. Kebbi rice after grinding

2. WESTERN (Igbemo Ekiti Rice)

Pict 3. Igbemo rice before grinding

Pict 4. Igbemo rice after grinding

The aim of the research work is to determine the antioxidant activity of rice produce from the Northern (Kebbi) and Western (Igbemo Ekiti) part of Nigeria. The specific objective are to:

a. Determine the Ferric Reducing Property (FRAP) of rice extract in the western (Igbemo Ekiti) and northern (Kebbi) part of Nigeria.
b. Determine the Free Radical of the extract using DPPH (1,1-diphenyl-2-picryhydryzyl) method.

METHOD

Samples

Freshly milled rice samples were collected directly from North western Nigeria (Kebbi, in Kebbi State for Kebbi rice) and also from South western Nigeria (Igbemo Ekiti, in Ekiti State) from the milling system to the polyethylene bags. These bags were made air tight and stored at 4°C. Refined, bleached and deodorized (RBD.

Sample Preparation

The rice sample were collected and examined to ensure there is no physical damage or insect infestation of rice and then cleaned thoroughly. This was then air dried for about 2 to 3 days, to prepare it for grinding. The rice were grounded properly with electric grinder, to the preferred powdered surface with the help of the grinder, and were stored in a air tight container for further analysis.

Extraction Of Rice Extract

The rice sample was extracted using solvent extraction method. This was done by addition of 200ml of n-hexane to 5g of rice sample to 500ml beaker. The mixture was left for 72 hours (3

days) with continuous shaking using a orbital shaker. There after the mixture was filtered using filter paper and the filtrate was kept in the refrigerator for further analysis.

Antioxidant Activity Determination

1. Determination Of Ferric Reducing Antioxidant Property (Frap)

The reducing property of the extract was determined using the method of Pulido et al., (2000), 0.25ml of the extract was mixed with 0.25ml of 200mm of Sodium phosphate buffer pH 6.6 and 0.25ml of 1% KFC. The mixture was incubated at 50◦C for 20min, thereafter 0.25ml of 10% TCA was also added and centrifuge at 2000rpm for 10min, 1ml of the supernatant was mixed with 1ml of distilled water and 0.1% of FeCl3 and the absorbance was measure at 700nm.

2. Determination Of Free Radical Scavenging Ability

The free radical scavenging ability of the extract against DPPH (1, 1- diphenyl-2-picryhydrazyl) was determined using Gyamfi et. al. (1999) method. 1ml of the extract was mixed with 1ml of the 0.4mM methanolic solution of the DPPH, the mixture was left in the dark for 30min before measuring the absorbance at 516nm.

RESULT AND DISCUSSION

Table 1 antioxidant activity of the rice samples using (DPPH) method.

	Kebbi	**Igbemo**
%DPPH radical Scavenging ability	20.6434	22.334

Source: From the analysis

From the result presented above, The research findings indicate that Igbemo rice exhibits a higher 2,2- Diphenyl-1-picrylhydrazyl (DPPH) assay value of 22.334 mg/g compared to Kebbi rice, which has a DPPH assay value of 20.6434 mg/g. This discrepancy suggests that Igbemo rice possesses a greater capacity to scavenge free radicals and hence has higher antioxidant activity than Kebbi rice. The differences in DPPH assay values between Kebbi rice and Igbemo rice highlight the variability in antioxidant activity among different rice varieties. These variations can be attributed to factors such as genetic diversity, environmental conditions, and agricultural practices. Environmental factors, including soil composition, climate, and growing conditions, can significantly impact the accumulation of antioxidant compounds in rice grains.

Variations in these factors between the regions where Kebbi and Igbemo rice are cultivated may contribute to the observed differences in antioxidant activity. Genetic variations among rice varieties play a crucial role in determining their antioxidant profiles. Different rice cultivars may

contain varying concentrations of antioxidant compounds, leading to differences in their ability to scavenge free radicals and protect against oxidative stress. Also, the research analysis indicates that Igbemo rice exhibits higher antioxidant potency as measured by the DPPH assay compared to Kebbi rice, this suggests that Igbemo rice may provide superior protection against oxidative damage and associated health risks, it may offer greater health benefits associated with antioxidant properties compared to Kebbi rice. Antioxidants are known to combat oxidative stress and reduce the risk of chronic diseases such as cardiovascular diseases, cancer, and neurodegenerative disorders.

Furthermore, understanding the antioxidant activities of locally produced rice varieties such as Kebbi and Igbemo rice is crucial for promoting their consumption and preserving cultural heritage. Incorporating antioxidant-rich rice varieties into the diet can contribute to improved nutrition and overall health outcomes in communities where these varieties are traditionally consumed.

Table 2. The antioxidant activity of rice samples using ferric reducing antioxidant power

	Kebbi	**Igbemo**
FRAP (mg/g)	**8.0749**	**7.8964**

Source: From the analysis

From the result presented above, The research findings reveal that Kebbi rice exhibits a higher Ferric Reducing Antioxidant Power (FRAP) value of 8.0749 mg/g compared to Igbemo rice, which has a FRAP value of 7.8964 mg/g. This disparity suggests that Kebbi rice possesses a greater capacity to reduce ferric ions and hence has higher antioxidant activity than Igbemo rice. There is more nutritional value in Kebbi rice because of its higher FRAP value, which implies a richer content of antioxidant compounds compared to Igbemo rice. Antioxidants play a crucial role in neutralizing harmful free radicals in the body, thereby reducing the risk of oxidative stress-related diseases.

The differences in antioxidant activity between Kebbi rice and Igbemo rice could be attributed to various factors, including soil composition, climate, cultivation practices, and genetic variations. Geographical factors specific to the regions where these rice varieties are grown may influence the accumulation of antioxidants in the grains. The higher antioxidant activity of Kebbi rice suggests potential health benefits associated with its consumption, including reduced risk of chronic diseases such as cardiovascular diseases, cancer, and diabetes. Incorporating Kebbi rice into the diet may contribute to overall health and well-being, as Kebbi rice possesses a superior antioxidant potential compared to Igbemo rice, as evidenced by its higher FRAP value(J.-M. Zhou & Ibrahim, 2004). This suggests that Kebbi rice may offer greater protection against oxidative damage and associated health risks. Also, understanding the antioxidant properties of locally produced rice varieties such as Kebbi and Igbemo rice is significant not only from a nutritional perspective but also from a cultural and economic standpoint(Zhao & Moghadasian, 2008; T. Zhou et al., 2004). Promoting the consumption of indigenous rice varieties rich in antioxidants can contribute to food

security, support local agriculture, and preserve traditional culinary practices(A et al., 2007; Reader & Nwankoro, 2017).

CONCLUSION

The research investigated the antioxidant properties of Kebbi rice and Igbemo rice, two locally produced rice varieties in Nigeria. The research employed two methods to assess antioxidant activity:

- Ferric Reducing Antioxidant Power (FRAP) assay
- 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay

Key findings:

1. Kebbi rice exhibited higher FRAP values, indicating greater capacity to reduce ferric ions and potentially possessing higher overall antioxidant activity based on this assay.
2. Igbemo rice displayed higher DPPH values, suggesting a stronger ability to scavenge free radicals according to this assay.

These contrasting results highlight the importance of using multiple assays for a comprehensive evaluation of antioxidant activity in rice varieties.

IMPLICATIONS

1. Variability in antioxidant properties: Different rice varieties possess varying levels of antioxidant compounds, influenced by factors like genetics and growing conditions.
2. Promoting local rice consumption: Understanding the antioxidant profiles of local varieties like Kebbi and Igbemo rice can encourage their consumption and support food security in Nigeria(*Total Global Rice Consumption*, 2024).
3. Potential health benefits: The observed antioxidant activity suggests potential health benefits associated with consuming these rice varieties, including reduced risk of chronic diseases.
4. Further research: Elucidating the specific antioxidant compounds responsible for the observed differences and exploring their potential health benefits is recommended.

This research provides valuable insights into the antioxidant properties of Nigerian rice varieties and paves the way for further exploration of their health benefits.

Promotion of Indigenous Rice Varieties:

Given their antioxidant properties, there is a need to promote the cultivation, consumption, and commercialization of indigenous rice varieties like Kebbi rice and Igbemo rice. Government agencies, agricultural extension services, and non- governmental organizations can play a role in raising awareness and supporting farmers engaged in the production of these rice varieties.

Integration of Antioxidant-Rich Foods.

Encouraging the consumption of antioxidant-rich foods, including indigenous rice varieties, as part of a balanced diet can contribute to improved health outcomes and disease prevention. Nutrition education programs should emphasize the importance of dietary diversity and the inclusion of antioxidant-rich foods in daily meals(Birt D. F et al., 2001; Bravo, 1998).

Sustainable Agriculture Practices

Sustainable agricultural practices that prioritize soil health, biodiversity conservation, and environmental sustainability can enhance the antioxidant content of rice and other crops. Investing in agroecological approaches and organic farming methods can support the production of nutrient-dense foods while minimizing environmental impact.

REFERENCE

A, P. Y., B, S. T., & Morita, N. (2007). *Identification of phenolic compounds isolated from pigmented rices and their aldose reductase inhibitory activities : science direct : journal of Food Chemistry* (Vol. 101, Issue ue 4, pp. 1616–1625).

Adom K, & Liu R. H. (2002). Antioxidant activity of grains. *J Agric Food Chem*, *50*, 6182– 6187.

Balasundram, N., Sundram, K., & Samman, S. (2006). Phenolic compounds in plant and agri-industrial byproducts: antioxidant activity, occurrence, and potential uses. *Food Chem*, *99*, 191–203.

Benzie I F, & Szeto Y. (1999). Total antioxidant capacity of teas by the ferric reducing/antioxidant power assay. *J Agric Food Chem*, *47*, 633–636.

Birt D. F, Hendrich, S., & Wang, W. (2001). Dietary agents in cancer prevention: flavonoids and isoflavonoids. *Pharmacol Therapeut*, *90*, 157–177.

Bravo, L. (1998). Polyphenols: chemistry, dietary sources, metabolism, and nutritional significance. *Nutr Rev*, *56*, 317–333.

Chen, P., Kuo, W., Chiang, C., Chiou, H., Y., H., & Chu, S. (2006). *Black rice anthocyanins inhibit cancer cells invasion via repressions of MMPs and uPA expression*. Chem-Biol Interact.

Choi, Y., S., J. H., & Lee, J. (2007). Antioxidant activity of methanolic extracts from some grains consumed in Korea. *Food Chem*, *103*, 130–138.

Chung M, Walker P, & Hogstrand. (2006). Dietary phenolic antioxidants, caffeic acid and Trolox, protect rainbow trout gill cells from nitric oxide-induced apoptosis. *Aquat Toxicol*, *80*, 321–328.

Collins A, R. (2005). Assays for oxidative stress and antioxidant status: applications to research into the biological effectiveness of polyphenols. *Am J Clin Nutr*, *81*, 261 –267.

Dimitrios, B. (2006). Sources of natural phenolic antioxidants. *Trends Food Sci Tech*, *17*, 505–512.

Frank B, H. (2003). Plant-based foods and prevention of cardiovascular disease: an overview. *The American Journal of Clinical Nutrition*, *78*(3), 544 –551.

Goffman F. D, & Bergman C. J. (2004). Rice kernel phenolic content and its relationship with antiradical efficiency. *J Sci Food Agr*.

Gyamfi, M. A., & Y.and, M. (1999). Yoko A.(1999). Free-radical scavenging action of medicinal herbs from Ghana: Thonningia sanguinea on experimentally-induced liver injuries. *General Pharmacology: The Vascular System*, *32*(6), 199, 661–667.

Heim K, E., R., T. A., & J, B. D. (2002). Flavonoid antioxidants: chemistry, metabolism and structure-activity relationships. *J Nutr Biochem*, *13*, 527–584.

Heim K, ER. , T. A. R., & J, B. D. (2002). Flavonoid antioxidants: chemistry, metabolism and structure activity relationships. *J Nutr Biochem*, *13*, 527–584.

Hindustan Rubber Industries. (2020). *India's Leading rice rubber rolls manufacturer provides quality products for rice mills*. https://www.hindustangroup.net/modern-rice-milling-process

Hu, C., Zawistowski, J., Ling, W., & D, K. D. (2003). Black rice (Oryza sativa L. indica) pigmented fraction suppresses both reactive oxygen species and nitric oxide in chemical and biological model systems. *J Agric Food Chem*, *51*, 5271–5277.

Hudson E, A., A, D. P., T, K., J, S. M. S., & A, G. (2000). Characterization of potentially chemopreventive phenols in extracts of brown rice that inhibit the growth of human breast and colon cancer cells. *Cancer Epidem Biomar*, *9*, 1163–1170.

Hughes, & Okafor. (2015). *Review-21-Introduction to agriculture rice. Course hero-homework help, literacture review chapter (2):13-20 from*. https://www.coursehero.com/file/p3dsoq4f.

Ibitoye A, A. (2005). Laboratory manual in basic methods in plant and food analysis. *A.A.A.C. Official Methods of Analysis*.

Iqbal, S., I, B. M., & Anwar, F. (2005). Antioxidant properties and components of some commercially available varieties of rice bran in Pakistan. *Food Chem*, *93*, 265–272.

Manac, C., Williamson, G., Morand, C., Scalbert, A., & Rémésy, C. (2006). *Bioavailability and bioefficacy of polyphenols in humans. I. Review of 97 bioavailability studies: national library of medicine*.

Oki, T., Masuda, M., Furuta, S., Nishiba, Y., Terahara, N., & Suda, I. (2002). Involvement of anthocyanins and other phenolic compounds in radical-scavenging activity of purple-fleshed sweet potato cultivars. *Journal of Food Science*, *67*(5), 1752–1756.

Pulido, R., & S.C, L. B. A. F. (2000). Antioxidant Activity of Dietary Polyphenols As determined by a Modified Ferric Reducing/Antioxidant Power Assay. *Journal of Agricultural and Food Chemistry*, *JO(48,8*, 3396–3402.

Raajeswari, & P.A. (2021). *Food and nutrition: F01FS12 Composition of Rice grain*. https://doi.org/.http://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/S000444FN/P000546/M011648/ET/1533209357Q-I.pdf.

Reader, & Nwankoro. (2017). *Review-21-Introduction to agriculture rice. Course hero-homework help, literature review chapter (2):13-20 from*. https://www.coursehero.com/file/p3dsoq4f

Rickford, S. (2022). *The process of rice production*. https://knowingrice.com/processes-of-rice-production.

Total global rice consumption. (2024). https://www.statista.com/statistics/255977/total-

Zhao, Z., & Moghadasian, M. H. (2008). *Chemistry, natural sources, dietary intake and pharmacokinetic properties of ferulic acid: A review: national library of medicine*.

Zhou, J.-M., & Ibrahim, R. K. (2004). Tricin—a potential multifunctional nutraceutical. *Phytochemistry Reviews*, *9*, 413–424.

Zhou, T., Wang, Y., Chen, J.-Q., Araki, H., Jing, Z., Jiang, K., Shen, J., & Tian, D. (2004). Genome-wide identification of NBS genes in japonica rice reveals significant expansion of divergent non-TIR NBS-LRR genes. *Molecular Genetics and Genomics*, *271*, 402–415.