Effect of roasting and cooking on physiochemical properties of black rice soluble extract

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Abstract

Rice (Oryza sativa L.) is a significant cereal consumed widely by over one-half of the world's population. There are numerous unique rice varieties present, some of them known as Traditional or Ancient grains. Black rice or 'Karupu Kauvni' is one such colored rice varieties known for their rich source of dietary fiber, resistant starch, minerals, carotenoids, flavonoids and polyphenols and intake of these pigmented varieties help in improving human health. This study shows the difference in the physicochemical properties of these glutinous rice samples. The physicochemical properties of three samples of Black rice soluble extract (control, roasted and cooked) were analyzed to determine pH, color, enzyme activity, viscosity and pasting properties. The tested samples and their results could serve as the baseline for further research and information on rice-based beverages and products' quality evaluation parameters. The soluble extract from such a plant-based source displays numerous benefits in comparison to other plant-based extracts. Despite its high carbohydrates, significantly lower amount of calcium and no cholestorol, it has been used significantly less in the food industry area.

Keywords: Black rice, physico-chemical properties, enzyme activity, starch

Introduction

Rice (Oryza sativa L.) is a vital and most common food staple in many Asian continents and is consumed by a significant sector of the world population. This cereal variety supplies significant nutrients such as carbohydrates, proteins, fatty acids and micronutrients like vitamins and trace minerals, thereby maintaining a daily calorie intake of 50 to 80% (Khush, 2005). Traditional rice varieties in India are reported to accumulate many genetic variations, including medicinal benefits and aroma (Ramanathan et al., 2014) [15]. These ancient varieties are more potent sources for several agronomic traits and sources of various bioactive non-nutrient components (Crozier et al., 2009) [2]. Rice is usually consumed after boiling or steaming as white rice with the husk, bran, and germ removed.

The widely popular eaten rice is the ‘White Rice,’ this rice, compared to other varieties of the same, has a lower number of essential micronutrients, which leads to micronutrient deficiency in individuals on regular intake. Consumption of a higher quantity of polished rice grains, i.e., high GI food, has also been reported contributing to higher insulin resistance and dyslipidemia (low-high density lipoprotein) among the Asian population. Therefore, further research on micro-nutrient and vitamin-rich rice with genetic engineering is a matter of great urgency and importance for the welfare of human health and nutrition (Crozier et al., 2009) [2].

There are numerous rice present varieties, and some contain colored pigments of red and black, most commonly known as Traditional or Ancient grains. Such traditional colored rice varieties are known for their rich source of dietary fiber, resistant starch, minerals, carotenoids, flavonoids and polyphenols, and intake of these pigmented varieties help in improving human health (Hanhineva et al., 2010; Hudson et al., 2000; Rao et al., 2010) [3, 4, 16]. The bioactive phytochemicals and micronutrient components of these traditional rice varieties serve as dietary supplements that play an essential role in diminishing the chances of non-communicable diseases like cardiovascular diseases, diabetes, cancer and stroke (Vichapong et al., 2010) [20]. One of the traditional dark brownish-black rice varieties called "Black Rice," also known as the 'Forbidden Rice' in China, is an ancient and rare rice variety.
Black rice has been a part of the Indian diet for many centuries, mainly cultivated in the North East region, called ‘Chak Hao’ and in the Southern parts, called Kavuni in Tamil. Black rice varieties contain shorter chains of starch molecules and low amylose content than white rice (Rice, 2016) [13]. Kavuni rice is glutinous waxy rice majorly known for its anti-diabetic and high anti-oxidant content, mainly anthocyanin (Oikawa et al., 2015) [12]. Morphologically, it has a long cultivation duration, low tillering and photosensitive traits, due to which it is not highly cultivated world-wide. Dehusked kavuni is dark brown to black, and the polished grains are light brown. Nutritionally, the recent unrelaveling of its biochemical properties has revealed that it contains significantly lowers levels of total soluble sugars, higher levels of amylose, dietary fiber, protein, β- carotene, lutein and polyphenols than other popularly consumed varieties of white rice. (Ramanathan et al., 2014) [15].

The soluble extract from such a plant-based source displays numerous benefits in comparison to other plant-based extracts. However, it contains more carbohydrates, a significantly lower amount of calcium and no cholesterol. Kavuni, glutinous type rice, is usually processed and consumed as simple foods like steamed black glutinous rice or boiled black glutinous rice. As glutinous rice is almost entirely dominated by amylopectin and hence has a very sticky feature. Glutinous rice has a high starch content and contains 1-2% amyllose and 98-99% amylopectin. Higher amylopectin level contributes to the stickiness of rice. Starch digestibility means the easiness level with which starch can be hydrolyzed to become a simpler substance. Starch digestibility could be increased with the help of an enzyme. With the hydrolysis process's help, the enzyme can easily break down starch into simple sugars. However, the major drawback of high starch digestibility is that the starch into glucose leads to an increased level of blood glucose on consumption. This causes blood glucose levels to elevate, thereby causing an increase in the need for insulin by the body to convert glucose into energy (M. Kang et al., 2011)

While being processed to be converted to various types of processed foods, glutinous waxy undergoes a reduction in its nutritional value, starch digestibility, and energy value. The different processes that glutinous rice undergo are roasting, steaming, puffing, and boiling. Roasting is a technique of cooking without oil. Steaming is a method of moist cooking, where the rice is indirectly cooked with the help of boiling liquid or steam. The puffing method uses temperature and pressure to change the structure of the food material, resulting in an expansion in the rice grain volume. Boiling is a technique that uses boiling water as a medium of heat transfer (Rini et al., 2019) [18]. This study on the physicochemical properties of black rice extract was conducted to study and further understand its nature. Despite its excellent nutritional properties, due to the lack of product availability world-wide, black rice is rarely used in processing industries.

Materials and Methods

Preliminary preparation of rice

Black ‘kavuni’ paddy was procured from the local farmer market. The rice was then dehusked and polished. 150 g of the dehusked and partially polished rice was then divided into three parts of 500 g each. The first part of 500g of black rice was washed thoroughly to remove all the dirt and unwanted material to prevent the chance of any contamination and soaked for 1 hour with a 1:2 ratio of lukewarm water. The seconds part of 500g rice was roasted at 100-120°C for 2-4 mins until the slight brownish color was obtained. The roasted rice was then washed thoroughly and then soaked for 1 hour with 1:2 of rice is to water ratio. The third part of the rice was washed and cleaned to remove dirt. The rice was then soaked for 1 hour with a 1:2 rice is to water ratio. After the soaking process, the water is drained out from the rice using a filter net/cloth, as this water usually contains harmful toxins released from the rice (Padma et al., 2018) [13]. Furthermore, the third part of rice was then cooked with 1:2 rice is to water ratio for 20-25 mins at 140-180°C, until rice turns mushy.

Extract preparation

All three parts of rice, i.e., control, roasted, cooked was then homogenized using a grinder with 1:2 rice to water ratio for 5-7 mins until slurry of medium thick consistency was obtained in case of control and roasted black rice sample and a gelatinized thick sample was obtained in case of cooked rice. The mixture was then filtered using a muslin cloth.

The three samples were then placed heated in a hot water bath until the desired temperature of 65-68°C was obtained for 15 mins. To this mix, the enzyme is added and stirred correctly and allowed to carry the enzymatic reaction for further 15-20 mins. The total time taken by the enzymatic reaction to ensure the liquefaction and the saccharification step in all three samples provides a milky texture and functionality to the sample. It prevents the occurrence of any undesirable flavors from yielding a non-allergic rice liquid product. (Mitchell et al., 2010) [11]. After the enzyme treatment, the three samples were then heated at 85°C for 15 mins and stored in glasses bottles in a refrigerated condition.

Physico-chemical analysis of soluble rice extract prepared from black’ Kavuni’ rice

Estimation of Total soluble solids (TSS) before and after enzyme treatment

TSS is the sugar content present in the solution. The TSS of the three sample before and after enzyme addition were determined using a handheld ATAGO refractometer. Before measurement of the TSS of the samples, the refractometer was calibrated using distilled water. A drop of rice soluble extract of each sample was placed in the refractometer sample slot, and the readings were recorded and expressed in °Bx.

Estimation of pH

The three samples’ pH was measured using a digital pH meter (Innco microprocessor pH-mV- Temp meter). The samples’ pH was taken in triplicates, one of the fresh samples (day 1) and one of the samples after 7 days in refrigeration. The pH meter probe was inserted into the samples, and the stable reading attained was considered the final pH value for the respective sample.

Estimation of color

The color parameter of the soluble starch extract was determined using the Hunter's lab ColorFlex EZ colorimeter. The mean of the triplicate values of the three samples was taken as the results. The chroma value (C*) and Redness Index (RI) was calculated using equation i and ii, respectively.

\[ C^* = \sqrt{(a^*)^2 + (b^*)^2} \]  \hspace{1cm} (i)

\[ RI = \frac{a^*}{b^*} \]  \hspace{1cm} (ii)
Measurement of Pasting Properties and Viscosity
The Rapid Visco Amylograph (RVA) MCR-52 was the preferred instrument for determining the pasting properties and viscosity for the three black (treated and untreated) rice soluble extract samples.

The pasting properties were measured by taking 25 ml of each sample and placing it into the RVA. The measurements were performed under a constant shear velocity of 110 rpm. The temperature profile used was: the sample was held at 50 °C for 2 min; followed by an increase in temperature from 50 °C to 95°C at a rate of 5°C/min; then held at 95 °C for 5 min; later cooled back to 50°C at a rate of 5 °C/min; and finally held at 50°C for 4 min (Yue et al., 2009) [23].

For determining the viscosity, the flow properties of the three samples were measured using the RVA. The resulting curves were fitted into the Herschel Bulkley Model using the following equation, the n value and the R² values were obtained for the respective samples tested.

\[ y = a + b \times x \]  

... (iii)

Herschel-Bulkley model

Results and Discussion

Three types of the soluble extract of black rice, i.e., control (no heat provided to sample), roasted (120°C for 2 mins) and cooked (160 °C for 20 mins) samples were used to study the variation in different physicochemical properties such as TSS, pH, color, pasting properties and viscosity.

TSS value of the rice extract

TSS obtained for initial and enzyme treated samples (control, roasted and cooked) of black rice soluble extract by using a hand-held refractometer are as shown in Figure no.1.

Earlier conducted studies have shown starch digestibility is affected by the amylose content present in the rice starch, and comparatively, black rice has a Meager amount of amylose content to other white rice (Wickramasinghe & Noda, 2008) [22]. Therefore, the starch in such rice is more easily digested by enzyme activity.

Variation of pH on Black rice soluble extract

The three treated samples’ pH values were measured in two conditions, i.e., day 1 (freshly prepared) and after day 7 in refrigeration as shown in Figure 2. The pH values of the three (treated with enzyme) black rice soluble extracts estimated on Day 1 showed very slight variation in pH from the day prepared to Day 7 later in refrigeration. The treated control sample’s pH value moderately decreased from 5.97 to 5.52, the pH of the treated roasted sample showed the highest decrease of all three samples from 5.74 to 5.45, and the pH of the treated cooked sample showed the slightest decrease from 6.23 to 6.22. The pH of the black rice soluble extract under all experimental conditions was found to be in the range of 5.45-6.23, with a significant difference (p > 0.05)

![Fig 1: TSS of sample for untreated and treated samples of Black rice extract](image1)

![Fig 2: The pH of treated samples on Day 1 and after Day 7 in refrigeration](image2)

Colour estimation of Black rice extract

Three samples of black rice extract (control, roasted and cooked) were taken. The roasted and the control sample was tested against the control sample. The samples were pinkish-red in color due to the high levels of anthocyanin content tested against the control sample. The samples were pinkish-red in color due to the high levels of anthocyanin content present in the sample. The resultant L*, a*, b* values obtained are shown in Table 1. The RI value obtained from the three samples is as shown in Figure 3.

![Table 1: Colorimeter values (L*, a*, b*, Chroma C*)](table1)
Viscosity and Pasting Properties of Black rice soluble extract

The viscosity of the three samples (treated and untreated with enzyme) was measured using the RVA. The viscosity parameters were determined using the Herschel-Bulkley method using equation iii.

The results are as shown in Table 2. The untreated cooked sample showed a flow index \( n = 1.1657 \) (shear-thickening properties), where the remaining sample displayed the flow index \( n = 0.01 \) (shear-thinning properties).

Table 2: RVA readings - Flow index \( (n) \), correlation ratio \( (R^2) \) and type of liquid of black rice soluble extract samples

| Types of Samples | Correlation Ratio \( (R^2) \) | Flow Index \( (n) \) | Type               |
|------------------|-----------------------------|------------------|--------------------|
| Untreated control | 0.89957                     | 0.01             | shear-thinning     |
| Treated control  | 0.90874                     | 0.01             | shear-thinning     |
| Untreated roasted| 0.84985                     | 0.01             | shear-thinning     |
| Treated roasted  | 0.84965                     | 0.01             | shear-thinning     |
| Untreated cooked | 0.87852, 1.1654             | shear-thickening |
| Treated cooked   | 0.80475                     | 0.01             | shear-thinning     |

Previous studies showed that depending on the type, amylose content and gelatinization temperature of the rice deeply affects its rheological and cooking properties. Also, the amylose to amylopectin ratio in raw rice has an impact on the functional properties of the starch, which in turn affects the quality of the end product, such as changes in the rheological properties of different rice-based beverages and products (Joshi et al., 2015; Lee et al., 2019) \(^5, 10\). The amount of amylose present in rice impacts the pasting and viscosity properties of the rice starch. Studies have shown that rice starches obtained from waxy or low amylose content rice display lower pasting properties than non-waxy type rice starches (H. J. Kang et al., 2006) \(^6\). The starch swells up during heating of the rice starch in water, causing the amylose to leach out. These swollen starch granules increase the viscosity, causing the resultant breakdown of the starch's viscosities from the breakdown of the gelatinized starch granules (Shih et al., 2007) \(^19\). The pasting properties of the three samples, i.e., control, roasted and cooked (with and without enzyme treatment), were tested using the RVA and the results are as shown in Figure 4.
The peak viscosity and final viscosity of the three samples, i.e., control, roasted and cooked (with and without enzyme treatment), both had no significant difference (with \( p > 0.05 \)). The high peak and breakdown viscosities of starch granules in control and roasted samples show the ease with which the starch granules can be broken upon heating after the maximum swelling at the peak viscosity. Generally, rice with low amylase content possesses this property, which results in the stickiness of the paste. (Sompong et al., 2011) [20]. Samples without the addition of enzyme contain more starch content and hence more viscosity causing the samples to become chewy, sticky, highly adhesive and low in hardness (Chen et al., 2019) [1].

**Conclusion**

Black rice is a nutrient-rich, low-fat source of high carbohydrates. It is tasty and versatile applications in food processing. The present conducted studies illustrated the physicochemical properties of three different samples of black rice soluble extracts. The analysis of the rice extract's physicochemical properties of three different samples of black rice was illustrated the carbohydrates. It is tasty and versatile applications in food processing. The present conducted studies illustrated the physicochemical properties of three different samples of black rice soluble extracts. The analysis of the rice extract's physicochemical properties and ultrastructure of rice varieties.

### Reference

1. Chen X, Zhang X, Wang B, Chen P, Xu Y, Du X, et al. Investigation of water migration and its impacts on eating quality of black rice during cooking process. Journal of Cereal Science 2019;89(130):102810. https://doi.org/10.1016/j.jcs.2019.102810
2. Crozier A, Jaganth IB, Clifford MN. Dietary phenolics: Chemistry, bioavailability and effects on health. Natural Product Reports 2009;26(8):1001-1043. https://doi.org/10.1039/b802662a
3. Hanhineva K, Törrönen R, Bondia-Pons I, Pekkinnen J, Kolehmainen M, Mykkänen H, et al. Impact of dietary polyphenols on carbohydrate metabolism. International Journal of Molecular Sciences 2010;11(4):1365-1402. https://doi.org/10.3390/ijms11041365
4. Hudson EA, Dinh PA, Kokubun T, Simmonds MSJ, Gescher A. Characterization of potentially chemopreventive phenols in extracts of brown rice that inhibit the growth of human breast and colon cancer cells. Cancer Epidemiology Biomarkers and Prevention 2000;9(11):1163-1170.
5. Joshi R, Mo C, Lee WH, Lee SH, Cho BK,. Review of Rice Quality under Various Growth and Storage Conditions and its Evaluation using Spectroscopic Technology. Journal of Biosystems Engineering 2015;40(2):124-136. https://doi.org/10.5307/jbe.2015.40.2.124
6. Kang HJ, Hwang IK, Kim KS, Choi HC. Comparison of the physicochemical properties and ultrastructure of japonica and indica rice grains. Journal of Agricultural and Food Chemistry 2006;54(13):4833-4838. https://doi.org/10.1021/jf060221+
7. Kang M, Kim J, Rico CW, Nam S. A comparative study on the physicochemical characteristics of black rice varieties. November 2009, 1241-1254. https://doi.org/10.1080/10942911003637350
8. Khash GS. What it will take to Feed 5. 0 Billion Rice consumers in 2030 2005, 1-6. https://doi.org/10.1007/s11103-005-2159-5
9. Kowalska E, Ziarno M. Characterization of Buckwheat Beverages Fermented with Lactic Acid Bacterial Cultures and Bifidobacteria 2020, 1-11.
10. Lee Y, Dias-morse PN, Meullent J. Effect of rice variety and milling fraction on the starch gelatinization and rheological properties of rice milk 2061, 1-5.
11. Mitchell JB, Examiner P, Pratt HF. United States Patent 2010;2(12).
12. Okawa T, Maeda H, Oguchi T, Yamaguchi T, Tanabe N, Ebana K, et al. The birth of a black rice gene and its local spread by introgression. Plant Cell 2015;27(9):2401-2414. https://doi.org/10.1105/tpc.15.00310
13. Padma M, Jagannadaraa PVK, Edukondalu L, Ravibabu G, Aparna K. Physico-Chemical Analysis of Milk Prepared from Broken Rice 2018;7(10):426-428.
14. Pertin H. Application of the falling number method for evaluating alpha-amylase activity. Cereal Chemistry 1964;41(3):127-140.
15. Ramanathan V, Muthurajan R, Natesan S. Unraveling the nutritional and therapeutic properties of ‘Kavuni’ a traditional rice variety of Tamil Nadu 2014. October. https://doi.org/10.1007/s13562-014-0274-6
16. Rao ASVC, Reddy SG, Babu PP, Reddy AR. The antioxidant and antiproliferative activities of methanolic extracts from Njavara rice bran. BMC Complementary and Alternative Medicine 2010, 10. https://doi.org/10.1186/1472-6882-10-4
17. Rice B. Black Rice 2.1 2016, 21-47. https://doi.org/10.1007/978-3-319-30153-2
18. Rini Yenrina R, Angraini T, Chania NE. The effects of various way of processing black glutinous rice (oryza sativa l. Processing var glutinosa) on digestibility and energy value of the products. IOP Conference Series: Earth and Environmental Science 2019;327(1). https://doi.org/10.1088/1755-1315/327/1/012013
19. Shih F, King J, Daire K, An H, Ali R. Physicochemical properties of rice starch modified by hydrothermal treatments 2007;84(5):527-531.
20. Sompong R, Siebenhandl-ehn S, Linsberger-martin G, Berghofer E. Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka. Food Chemistry 2011;124(1):132-140. https://doi.org/10.1016/j.foodchem.2010.05.115
21. Vichapong J, Sookserm M, Srijesdaruk V, Swatsitang P, Srijaramai S. High performance liquid chromatographic analysis of phenolic compounds and their antioxidant activities in rice varieties. LWT - Food Science and Technology 2010;43(9):1325-1330. https://doi.org/10.1016/j.lwt.2010.05.007
22. Wickramasinghe HAM, Noda T. Physicochemical properties of starches from Sri Lankan rice varieties. Food Science and Technology Research 2008;14(1):49-54. https://doi.org/10.3136/fstr.14.49
23. Yue J, Knoerzer K, Mawson R, Kentish S, Ashokkumar M. Ultrasonics Sonochrome The pasting properties of sonicated waxy rice starch suspension. Ultrasonics-Sonochemistry 2009;16(4):462-468. https://doi.org/10.1016/j.ultsonch.2009.01.002