Project Report on

DEVELOPMENT OF ANTHOCYANIN-RICH NOODLES FROM COMPOSITE FLOUR OF WHEAT AND BLACK RICE

A Dissertation Submitted By

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In the partial fulfilment of the requirements for the Award of degree of

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Submitted To

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CERTIFICATE

This is to certify that the project entitled **"DEVELOPMENT OF ANTHOCYANIN RICH NOODLES FROM COMPOSITE WHEAT AND BLACK RICE"** submitted by **Ms. Abhirami E.M (Reg. No. VM23FPT001)** to the Department of Food Processing Technology, St. Teresa's College (Autonomous), Ernakulam, Mahatma Gandhi University, Kottayam, Kerala, in partial fulfilment for the award of the degree of **Master of Vocation (M. Voc) in Food Processing Technology** is a bonafide report of original research work done by her under the supervision and guidance of Ms. Crassina Kasar (Principal Scientist), Department of Flour Milling Baking and Confectionery Technology (FMBCT), CSIR - Central Food Technological Research Institute (CFTRI), Mysuru during December 2024 to April 2025.

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Place: Eranakulam

30/4/25

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DECLARATION

I, **ABHIRAMI E M**, hereby declare that the dissertation titled **DEVELOPMENT OF ANTHOCYANIN-RICH NOODLES FROM COMPOSITE FLOUR OF WHEAT AND BLACK RICE"** , submitted to St. Teresa's College (Autonomous) Ernakulam, in partial fulfilment of the requirements for the award of the degree of M.Voc Food Processing Technology, is a true and accurate record of the studies and research conducted by me under the supervision and guidance of **Smt. CRASSINA KASAR**, Senior Scientist, Department of Flour Milling, Baking, and Confectionery Technology, Central Food Technological Research Institute (CFTRI), Mysuru, Karnataka, during the period December 2023 to April 2025.

I further declare that the work presented in this dissertation has not been submitted to any other university or institution for the award of any degree. I am fully aware of the observations and results recorded in this report, and I confirm that they are accurate and true.

Place: CFTRI, Mysuru

Date: 23/04/2025

Abhirami

Signature of student

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Abhirami E M

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ABSTRACT

Black rice, a variety of the rice species *Oryza sativa L.*, is a functional food due to its numerous health benefits. It is primarily grown in the northeastern state of Manipur and the southern states of Kerala, Karnataka, and Tamil Nadu in India. Black rice is richer in proteins, vitamins, and minerals than regular white rice. It contains essential amino acids like lysine and tryptophan, vitamins such as B1, B2, and folic acid, and is a good source of minerals like iron, zinc, calcium, phosphorus, and selenium. Additionally, black rice is abundant in antioxidants, protein, and dietary fiber, as well as phenolics, flavonoids, and anthocyanins. Antioxidants play a crucial role as the body's first line of defense against free radical damage, helping to maintain overall health and well-being. These compounds offer significant health benefits, including reducing the risk of chronic diseases. Black rice promotes health and longevity, supports heart health, reduces atherosclerosis, helps control hypertension, improves digestion, has anti-inflammatory properties, alleviates allergies, detoxifies the body, enhances lipid profiles, lowers the risk of diabetes, aids in weight management, inhibits cancer growth, boosts cognitive function, and enhances overall quality of life. Given its numerous advantages over white rice, developing value-added products from black rice is highly beneficial. Hence, our objective was to study the processing conditions and quality properties of Black rice Noodles and their application in ready-to-use products.

Black aromatic rice (Oryza sativa) was ground into fine flour with a particle size of 150 µm using a hammer mill to produce black rice flour (BRF). Wheat flour (WF) was replaced with BRF at 0%, 10%,20%,30%, and 40% to produce rice noodles, viz., 0% BRF, 10% BRF, 20% BRF, 30% BRF, and 40% BRF, respectively. And also 30% improved with wheat gluten and corn starch for enhancing its quality. Semi-steamed noodles undergo partial steaming but skip the drying stage, resulting in a softer texture and quicker cooking time while retaining more moisture and certain nutrients.

The color characteristics were assessed as part of the physical properties. The cooking quality was evaluated in terms of optimal cooking time, water absorption, yield, and cooking loss. Additionally, the proximate composition, phytochemical characteristics, and antioxidant properties were analyzed.

Semi-steamed noodles retain a high moisture content because they undergo partial steaming without a drying phase. This process allows the noodles to absorb water during steaming, but since they are not subjected to dehydration, the moisture remains trapped within their structure. As a result, they have a softer texture, quicker cooking time, and improved freshness compared to fully dried noodles. Additionally, the absence of drying minimizes moisture loss, preserving their natural hydration levels.

Phytochemical analysis of noodles, including assessments of Total Phenolic Content, Total Flavonoid Content, and Total Anthocyanin Content, demonstrated that a higher proportion of BRF increased phytochemical content.

Additionally, the fat%, ash%, antioxidant activity, and phytochemical properties all increased with the rising amount of BRF. Considering the overall properties and nutritional profile, 30BRF was selected as the optimized product.

CHAPTER – 1
INTRODUCTION

INTRODUCTION

Rice (Oryza sativa L.) is a widely consumed grain worldwide. It is a major cereal crop in developing countries and serves as a staple food for more than half of the global population, with about 95% of its production occurring in Asia. Rice can be classified as non–glutinous and glutinous rice, also called non-waxy and waxy, respectively, based on the amylose content of the rice grains. (Reddy et al., 1994). Additionally, rice can be classified by its color, including white, purple, red, brown, and black. There are four primary classes of rice worldwide: indica, japonica, aromatic, and glutinous.

The incorporation of anthocyanin-rich ingredients into staple foods has gained significant attention due to their potential health benefits and functional properties. Black rice, a naturally pigmented variety of rice, is a rich source of anthocyanins—powerful antioxidants known for their role in reducing oxidative stress, supporting cardiovascular health, and exhibiting anti-inflammatory properties. The development of noodles using a composite flour of wheat and black rice presents an innovative approach to enhancing both nutritional value and sensory appeal while maintaining desirable cooking characteristics.

Wheat flour, traditionally used in noodle production, provides the necessary gluten structure for elasticity and firmness. However, the partial substitution of wheat flour with black rice flour introduces anthocyanins, improving the antioxidant profile of the noodles while contributing to their distinct dark purple hue. This formulation not only enhances the visual appeal but also aligns with the growing consumer demand for functional foods that offer health benefits beyond basic nutrition.

The sensory attributes of anthocyanin-rich noodles, including texture, flavor, and cooking quality, are crucial in determining their acceptability. The balance between wheat and black rice flour influences the firmness, chewiness, and overall mouthfeel of the noodles. Additionally, the presence of anthocyanins may impact the flavor profile, imparting a mild nutty taste characteristic of black rice. Understanding these interactions is essential for optimizing the formulation to ensure consumer preference and market viability.

This study aims to develop and evaluate anthocyanin-rich noodles using composite flour, focusing on their nutritional composition, sensory attributes, and cooking quality. By integrating black rice flour into wheat-based noodles, the research seeks to provide a healthier alternative to conventional noodles while maintaining desirable functional properties. The findings of this study will contribute to the growing body of research on functional food development and offer insights into the potential applications of anthocyanin-rich ingredients in staple food products.

CHAPTER – 2

AIM AND OBJECTIVES

AIM AND OBJECTIVE

- Optimization of levels of black rice for the preparation of 'purple' noodle
- Processing and technological properties of noodles
- Sensory and physical characteristics of noodles
- Phytochemical properties of noodles

CHAPTER – 3

LITERATURE REVIEW

REVIEW OF LITERATURE

3.1 Black Rice (Oryza sativa L.)

Black rice, constantly appertained to as forbidden rice, is considered a superfood of the 21st century. It's known for its capability to promote life, earning the surname" long-life rice." This unique variety of rice offers numerous health benefits, supported by nonfictional validation and modern molecular disquisition. For centuries, its benefits were kept secret by emperors. Consuming black rice in moderation can help cover against various serious conditions and affections. This is due to its high antioxidant content, which indeed surpasses that of blueberries. (Kushwaha, 2016). Black rice is a type of Oryza sativa, a species of rice, and is part of the Poaceae family. Compared to regular rice, black rice is packed with fresh vitamins and minerals.

Black rice is cultivated across an important corridor of Asia, including countries like India, Bangladesh, China, Korea, Japan, Thailand, Laos, Vietnam, and Indonesia. There are over 200 different kinds of black rice. (Rajarshi banarjee et al.,)

" Chakhao Amubi" is a variety of black rice grown in Manipur, India. The name translates to" Delicious Black Rice," with" Chakhao" meaning succulent and" Amubi" meaning black. Its distinctive purplish-black color comes from its high anthocyanin content.

Fig:3.1 Black rice

3.2 HISTORY

Black rice, originally cultivated in China before the Chinese dynastic period, was referred to as "luck rice" due to the belief that consuming it could lead to a longer life and help cure various diseases. This variety of rice results from a mutation in the Kala4 gene, which triggers the production of the black pigment anthocyanin. (Oikawa et al. 2401). Initially, people avoided consuming black rice because they associated its black color with being "dirty." However, it was later discovered that the grain's color is due to the accumulation of colored pigments. In black rice, the pigment responsible is anthocyanin, while in red rice, it is tannin. In black rice, the production of anthocyanin pigment occurs due to a mutation in the gene that regulates pro-anthocyanidin biosynthesis. Originally, black rice was reserved exclusively for the kings of China and Indonesia because of its high price and potent medicinal properties, which were believed to cure various ailments. However, today, it is accessible to local people as well.

In ancient times, black rice was highly valued and believed to prolong a king's life and enhance overall health. Today, it is cultivated and consumed globally. In Manipur, India, black rice is grown by small-scale traditional farmers. The largest producers of black rice are China (62%), followed by Sri Lanka (8.6%), Indonesia (7.2%), India (5.1%), Bangladesh (4.1%), and a few countries in Malaysia (Shivani Kumari, 2020).

3.3 VARIETIES OF BLACK RICE

There are different varieties of black rice primarily grown in Asia. Black Japonica Rice, Black Glutinous Rice, Italian Black Rice, and Thai Black Jasmine Rice. Black rice comes in a diverse range of seed colors. A recent study found that the activity of the Kala4 gene, which is essential for anthocyanin production, is responsible for the pigmentation in black rice. The same study suggests that mutations in the promoter of the Kala4 gene are responsible for the black rice phenotype. This mutation initially emerged in the tropical japonica and later spread to the indica subspecies.

1. Thai Black Jasmine Rice

This rice variety originated in Thailand and is a blend of Chinese black rice and jasmine rice. It features medium-sized grains. Thai jasmine black rice is known for its delightful fragrance, as jasmine rice, famous for its aromatic qualities, is grown in Thailand

2. Italian Black Rice

It's long-grain rice. This product contains both Chinese and Italian black rice. Italian rice with a rich buttery aroma. (Saha 51).

3. <u>Black Glutinous Rice</u>

Black sticky rice has small grains and a sticky texture that sets it apart from other rice varieties. The grains have an uneven color and are typically used to prepare sweet dishes in Asia

4. <u>Black Japonica Rice</u>

This variety was developed by blending two different types of rice grains. Short-grain and medium-grain rice are grown in the same field. The flavour of this cultivar is mildly spicy with a subtle sweetness. (Saha 51).

Thai Black Jasmine Rice

Italian Black Rice

Black Glutinous Rice

Black Japonica Rice

Figure 3.2 (a) Thai Black Jasmine Rice, (b) Italian Black Rice, (c) Black Glutinous Rice (d)Black Japonica Rice

3.4 PRODUCTION OF BLACK RICE

Black rice has been cultivated and consumed throughout Asia for centuries. In India, it's mostly grown in the northeastern state of Manipur.

The leading producing countries include,

Table 3.1 Black rice production around the world

China	148.87
India	112.91
Vietnam	28.47
Phillippines	12.24
Thailand	20.37
Burma	13.21

Source: United States Department of Agriculture (2017/2018)

3.5 NUTRITIONAL COMPOSITION

Sl.No	Components	Amount per 100g
1	Water	10.5g
2	Carbohydrate	
	Fiber, total dietary	4.2 g
	Starch	71.4 g
3	Protein	7.57 g
4	Total lipid (fat)	3.44 g
5	Nitrogen	1.21 g
6	Ash	1.34 g
7	Minerals:	
	Phosphorus, P	307 mg
	Potassium, K	256 mg

	Magnesium, Mg	113 mg
	Calcium, Ca	14 mg
	Manganese, Mn	3.91 mg
	Sodium, Na	<2.5 mg
	Zinc, Zn	1.72 mg
	Iron, Fe	1.12 mg
	Copper, Cu	0.21 mg
8	Vitamins and Other Components:	
	Niacin (Vitamin B3)	8.28 mg
	Thiamine (Vitamin B1)	0.319 mg
	Pyridoxine (Vitamin B6)	0.202 mg
	Biotin (Vitamin B7)	4.88 mg

Table 3.2 Proximate composition of unenriched, raw Black Rice

(source: USDA FoodData Central)

3.5.1 <u>Protein</u>

According to the OECD (2014), rice proteins are classified based on their solubility as follows: (i) Glutelins, which are soluble in alkaline solutions and account for 60% of the total proteins; (ii) Prolamins, which are soluble in alcohol and makeup about 25% of the total proteins; (iii) Globulins, which are soluble in salt water and represent around 10% of the total proteins; and (iv) Albumins, which are soluble in water and comprise about 5% of the total proteins. Proteins consist of amino acids, which can be categorized as essential, semi-essential, or non-essential. As a result, the nutritional value of a protein is determined by its content of essential amino acids, its capacity to meet the metabolic needs of humans, and the bioavailability of these amino acids (Nunes, Seferin, Maciel, Flôres, & Ayub, 2016).

Black rice (with an Amino Acid Score (AAS) of 68) offers a more complete and balanced amino acid profile than wheat (AAS of 43) and maize (AAS of 35), due to its higher levels of lysine and sulfur-containing amino acids (WHO, 2007). Additionally, it demonstrates superior biological value, protein efficiency, and digestibility compared to other cereals (Carvalho et al., 2013).

3.5.2 Vitamins

Vitamins are essential chemical compounds needed in small amounts through our regular diet to support various biological functions and promote growth. Depending on how they are absorbed and stored in the body, they can be categorized as either water-soluble or fat-soluble. Fat-soluble vitamins, including Vitamins A, D, E, and K, are stored in adipose tissue. In contrast, the water-soluble vitamins, such as those in the B-group and Vitamin C, cannot be stored in the body and are excreted in the urine, requiring regular intake through diet.

Black rice is an excellent source of vital vitamins, particularly the B-complex group and Vitamin E. Vitamin E, a fat-soluble antioxidant, helps protect cell membranes from oxidative damage caused by free radicals and plays a key role in immune function, skin health, and cellular repair.

Among the B vitamins, Vitamin B1 (Thiamine) is crucial for energy metabolism, converting carbohydrates into glucose for daily activities and supporting nerve function, muscle contraction, and heart health. Vitamin B2 (Riboflavin) contributes to energy production, red blood cell formation, antioxidant defense, and promotes healthy vision, skin, and hair. Vitamin B3 (Niacin) helps convert food into energy, supports healthy cholesterol levels, cardiovascular health, and nervous system function, and is important for skin health. Together, these vitamins enhance the health benefits provided by black rice (Thanuja & Parimalavalli, 2018).

3.5.3 Minerals

Minerals play a crucial role in maintaining good health by helping to prevent diseases. (Ito & Lacerda, 2019). Black rice is notable for being rich in iron (which supports red blood cell production), manganese (which enhances reproductive health), potassium (which promotes muscle growth), and phosphorus (which helps maintain internal water balance). (Kushwaha, 2016). Therefore, consuming black rice, due to the presence of these nutrients, helps maintain better internal balance within the body (Duyi, Baran, and Chandra 2017). Ahmad et al. (2009) stated that the levels of Mn and Zn in black rice are higher than those found in non-pigmented ric e varieties.

3.5.4 Lipids

Rice generally contains a low lipid content. Chemically, its lipids are classified into two categories: (i) saponifiable lipids, which include triacylglycerols, diacylglycerols, monoacylglycerols, free fatty acids, and waxes; and (ii) unsaponifiable lipids, which consist of phytosterols, triterpene alcohols, γ-oryzanol, and vitamin E homologues, such as tocopherols and tocotrienols (Ito and Lacerda, 2019). Lipids are present in the germ, which makes up 2–3% of the total weight of paddy rice (OECD, 2014).

The lipid profile of black rice includes triglycerides, free fatty acids, sterols, and diglycerides, as well as lipid-conjugates such as acylsterol glycoside and sterol glycoside. It also contains glycolipids like cerebroside and phospholipids, including phosphatidylcholine and phosphatidylethanolamine (OECD, 2014).

Triglycerides are the primary type of fats found in black rice. A triglyceride molecule consists of glycerol and three fatty acids. In black rice, the main fatty acids are Oleic Acid (42.10%), Linoleic Acid (29.30%), and Palmitic Acid (20.30%) (Frei & Becker, 2005).

3.5.5 Carbohydrates

Starch is a primary component found in all rice varieties, including black rice, and is responsible for providing energy. The two main types of α-glucans present are (i) linear amylose and (ii) branched amylopectin, which affect the crystallinity of the grains based on how the starch chains are arranged (Ito and Lacerda, 2019). According to the OECD (2014), non-glutinous rice contains 10-30% amylose and 70-90% amylopectin.

Amylose content plays a crucial role in determining the quality of rice, especially regarding its cooking and pasting characteristics. Black rice with low amylose content becomes moist and sticky when cooked. In contrast, black rice with an intermediate amylose content cooks to a dry and fluffy texture and retains its softness after cooling. However, black rice with high amylose content also cooks to a dry, fluffy consistency but tends to harden once cooled due to the retrogradation of amylose molecules (Adu-Kwarteng, Ellis, Oduro, & Manful, 2003).

Black rice starch has unique properties, including a smooth flavor, no odor, white color, hypoallergenic, ease of digestion, and small granular form (Ziegler et al., 2017). Black rice is recognised as a superior fibre source. 75% of the total fibre is insoluble.

3.5.6 Iron

Iron is essential for transporting oxygen molecules to the haemoglobin in red blood cells, enabling the cells to supply oxygen throughout the body and produce energy. It also helps remove carbon dioxide. When iron levels are low in red blood cells, their ability to carry oxygen is impaired. This leads to a condition known as anemia, which results from iron deficiency. A shortage of iron can cause various issues, including fatigue, weakness, difficulty regulating body temperature, and pale skin.

3.6 BIOACTIVE COMPOUNDS IN BLACK RICE

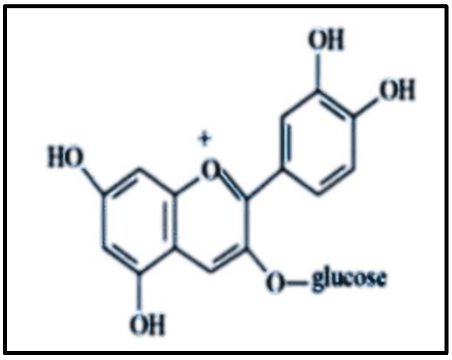
Bioactive compounds are found in various bran layers, including the pericarp, seed coat, and aleurone (Callcott et al., 2018). In black rice, these bioactive compounds can interact with starch during gelatinization, affecting its pasting, thermal, and digestibility characteristics (Zhu, 2015).

3.6.1 Anthocyanin

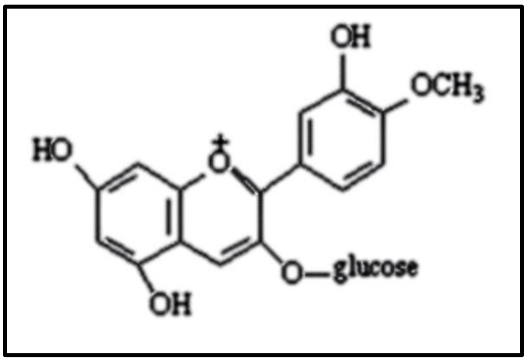
HPLC (High-Performance Liquid Chromatography) analysis showed that black rice contains three main types of anthocyanin pigments. The anthocyanins identified in two Japanese black rice genotypes, Asamurasaki and Okunomurasaki, were cyanidin-3-glucoside (C3G), peonidin-3-glucoside, and malvidin. Additionally, a fourth anthocyanin, petunidin-3-glucoside, has recently been discovered in the Chinakuromai variety. (Zhu et al. 2019). Dark pigments, like cyanidin, belong to this subcategory. These anthocyanin components are known for their high absorption rate, minimal degradation, and notable relevance in clinical applications compared to other anthocyanins. They have various effects on cells, with some demonstrating antidiabetic properties, while others are effective in managing "metabolic syndrome." (Zhu et al. 2019).

Anthocyanin is the primary bioactive compound found in black rice bran. (Devi, & Badwaik, 2022; Callcott et al., 2018). During the seed development phase, purple anthocyanin pigments begin to accumulate in the pericarp, giving black rice grains their dark purple color. The color intensity is so strong that the grains appear black, but once cooked, they transform into a rich purple hue. (Ito & Lacerda, 2019; Kushwaha, 2016). Anthocyanin is typically present as polyhydroxylated or methoxylated heterosides, which are derived from the flavylium ion or 2-phenylbenzopyrilium. Ito & Lacerda, 2019; Duyi et al., 2017).

Cyanidin-3-glucoside (C3G) is the predominant anthocyanin, accounting for 88% of the total anthocyanin content (Hou, Qin, Zhang, Cui, & Ren, 2013). According to Abdel-Aal, Young, and Rabalski (2006), black rice contains the highest total anthocyanin content, with 327.60 mg per 100 grams, surpassing all other colored grains studied. Other anthocyanins present in smaller quantities include peonidin-3-glucoside, cyanidin-3-rutinoside, and malvidin-3-glucoside (Chen, Nagao, Itani, & Irifune, 2012). Research has identified only six types of anthocyanins in raw black rice bran: cyanidin-3-O-glucoside, cyanidin-3-O-rutinoside, delphinidin, cyanidin, pelargonidin, and malvidin.



a) Cyanidin-3-glucoside



b) Peonidin-3-glucoside

Figure 3.3: Two primary anthocyanin pigments present in Black Rice

(Source: Hou et al., 2013)

Type of anthocyanin	**Quantity (mg/ kg)**	**Reference**
Cyanidin-3-glucoside	88.6-2013	Seo et al., (2011) Sompong et al., (2010) Abdel aal et al., (2006)
Petunidin-3-glucoside	4-10	Seo et al., (2011)
Peonidin-3-glucoside	135-1275	Seo et al., (2011) Sompong et al., (2010)
Cyanidin-3-rutinoside	19.90	Abdel aal et al., (2006) Huang and Lai, (2016)

Table 3.3: Types of Anthocyanin in Black Rice

(source: Arunima et al. (2021))

Total anthocyanin content	Reference
327.60 mg/ 100 grams	Abdel-Aal, Young, and Rabalski (2006)
109.50 - 256.60 mg/ 100 g	Sompong, Siebenhandl-Ehn, Linsberger-Martin, and Berghofer (2011)
32.40 - 50.30 mg/ 100 g	Frank, Reichardt, Shu, and Engel (2012)
4.35 - 7.16mg / g	Somsana et al, (2013)
145 - 441mg / g	Maisuthisakul and Changchub, (2014)
83.31 mg/g	Bhat and Riar, (2017)
340.10 mg/kg	Rajendran et al, (2018)
162.5 - 773.7mg / kg	Wongsa et al, (2018)
49.11 mg/g	Agustin et al, (2021)
1 - 806.17 mg/kg	Shozib et al, (2021)

Table 3.4: Total Anthocyanin content in Black Rice

(source: Pedro, Granato, and Rosso (2016) and Dewan et al. (2023))

3.6.2 Phenolic acids

In addition to being a source of anthocyanins, black rice also contains phenolic acids, which are classified into soluble conjugated phenolic acids and insoluble bound phenolic acids. (Duyi et al., 2017). Soluble phenolic compounds, such as cinnamic acids, protocatechuic acids, and gallic acids, are water-soluble. In contrast, bound phenolic acids like ferulic, coumaric, and caffeic acids are covalently attached to cell components like cellulose, hemicellulose, and lignin (Duyi et al., 2017; Ito & Lacerda, 2019).

Researchers, including Zhou et al. (2004) and Walter et al. (2011), have found that light brown and black pericarp rice varieties contain higher concentrations of phenolic compounds, ranging from 70–90% and 92–97%, respectively. The variation in phenolic content is influenced by factors such as the rice cultivar, the specific phenolic compounds in the rice kernels, the extent of milling, and the extraction methods used.

3.6.3 Tocopherols

Tocopherols, compounds with strong antioxidant properties, are found in rice bran and are commonly referred to as Vitamin E. (Goufo & Trindade, 2014)

These antioxidants play a crucial role in protecting cells from damage caused by free radicals, thereby supporting overall health and well-being. Vitamin E exists in eight distinct forms: four tocopherols and four tocotrienols. The four tocopherol types are α, β, γ, and δ. The main difference between tocopherols and tocotrienols lies in their tail structures: tocopherols have a saturated tail, whereas tocotrienols have an unsaturated one. Furthermore, the variations within each group are determined by the position of the methyl groups on the ring (Lumen Learning).

3.6.4 Tocotrienol

Oryzanols are compounds with strong antioxidant properties that help reduce blood plasma and serum cholesterol levels, lower hyperlipidemia, and prevent platelet aggregation. Additionally, they support uterine health by alleviating menopausal disorders.((Goufo & Trindade, 2014) .Oryzanols are a group of compounds found within γ-oryzanol, consisting of ferulic acid esters of sterols and triterpene alcohols. The amount of γ-oryzanol in black rice can vary depending on the rice variety and growing conditions. According to Huang and Lai (2016), black rice bran contains γ-oryzanol levels ranging from 3.95 to 7.72 mg per gram of dry matter. This is notably higher than the γ-oryzanol content in red rice bran, which ranges from 3.59 to 3.69 mg per gram, and white rice bran, which contains between 1.55 and 3.13 mg per gram of dry matter.

3.6.5 Carotenoids

Carotenoids are naturally occurring pigments found in various forms throughout the food chain and the human diet. High carotenoid levels in food can help prevent several types of cancer, heart disease, and lipoprotein oxidation. Additionally, dietary carotenoids provide significant benefits for eye health and overall ocular function (Eggersdorfer and Wyss, 2018). A study by Pereira-Caro et al. (2013) found that xanthophylls, specifically lutein and zeaxanthin, were the predominant carotenoids in Japanese black–purple rice, accounting for over 94% of the total carotenoid content, with minor components including carotenes, lycopene, and β-carotene.

3.7 AROMATIC COMPOUNDS IN BLACK RICE

Black rice has a unique flavor that differentiates it from other rice varieties. Taste is an important quality trait in rice, influencing consumer preference. Taste is a crucial quality trait in rice varieties, influencing consumer preference. This particular variety contains 35 volatile compounds. (Choi et al. 572, 2019). Ten aldehydes, two terpenoid compounds, three ketones, six alcohol compounds, four nitrogen-containing compounds, and ten aromatic compounds are present. Comparatively speaking, black rice has more volatile chemicals than white rice. (Zhang et al. 630). Compared to black rice, white rice has greater concentrations of alcohols, ketones, aldehydes, and terpenoids. Among the compounds analyzed, hexanal, 2-pentylfuran, and nonanal had higher concentrations than 2-acetyl-1-pyrroline. Certain compounds, such as 2-acetyl-1-pyrroline, indole, p-xylene, and guaiacol, serve as key indicators of the noticeable differences in the scents of cooked black and white rice. Two primary compounds, 2-acetyl-1-pyrroline, and guaiacol, are responsible for the distinctive aroma of black rice. Without these, the distinctive smell of black rice would not be present. (Panda, Jyotirmayee, and Mahalik ,2022).

3.8 QUALITY ASPECTS OF COOKED RICE

Rice quality is a complex characteristic made up of several components, including physical appearance, cooking and eating qualities, and nutritional benefits. Each of these components consists of various attributes, which are determined by their physicochemical properties as well as the historical and cultural practices of the people who consume the rice (Unneverh et al., 1992).

Grain quality is a key concern in rice production in India and many other rice-producing regions worldwide. The eating quality of rice, also referred to as rice palatability, is a crucial factor that determines its commercial value. For Asian markets, hardness and stickiness have been identified as the two most important factors influencing the palatability of cooked rice (Okabe, 1979). Data collected over the past few decades indicates that the eating quality of rice is directly linked to the physicochemical properties of the endosperm, such as amylose, protein content, moisture levels, and gelatinization characteristics (Juliano, 1985).

The quality of cooked rice is most accurately assessed through a combination of physical, chemical, and sensory properties (Koutroubas et al., 2004). Amylose content is considered the most important factor in evaluating the eating and cooking quality of rice (Shi et al., 2005). Previous studies have shown that rice with high eating quality typically has low amylose content (Juliano, 1985). In general, low-amylose rice is described as soft and sticky, while high-amylose rice tends to be firmer and fluffier (Rani and Bhattacharya, 1989). However, many rice cultivars with similar amylose content exhibit different pasting and texture properties, indicating that factors other than amylose contribute to rice's cooking characteristics and palatability (Champagne et al., 1999). According to Malik and Choudary (2001), amylose content is a key factor influencing stability, tenderness, volume expansion, and the appearance of cooked rice.

Rice with a high amylose content (25-30 percent) (non-waxy, non-glutinous rice) tends to cook firm and dry, while rice with an intermediate amylose content (20-25 percent) is generally softer and stickier. Rice with low amylose content (around 20 percent) is typically very soft and sticky (Yadav et al., 2007). Sutharut and Sudarat (2012) noted that colored rice varieties are not as popular for consumption due to the firm texture of the cooked rice, despite the well-known health benefits of the pigments in these rice types. Black rice, in particular, is believed to be rich in gluten, requires longer cooking times, and is stickier compared to white rice.

The concentration of total soluble phenolic compounds (TSPC) and antioxidant activity (AOA) in rice grains with different processing methods (brown, polished, parboiled brown, and parboiled polished) was measured, along with the TSPC levels in both raw and cooked grains. Significant differences in TSPC and AOA concentrations were found among genotypes, with higher values observed in red and black pericarp-colored grains, and a strong positive correlation between these parameters. Surh and Koh (2014) reported no significant loss of anthocyanins during cooking in black rice. Roasting caused the greatest reduction (94%), followed by steaming (88%), pan-frying (86%), and boiling (77%). After cooking, the concentration of phenolic compounds dropped significantly, with the black rice cultivar having higher amylose content showing much lower preservation of these compounds.

3.9 HEALTH BENEFITS OF BLACK RICE

Black rice is often referred to as "long-life rice" because of its numerous health benefits. The rice contains anthocyanins, which are essential for neuroprotection by mitigating oxidative stress (Sridevi J, Kowsalya S, Bhooma Mani N 2018). Research has demonstrated that the anthocyanins in black rice help reduce reactive oxygen species (ROS), which can lead to cell damage in animals, plants, and humans. As a result, nutritionists and dietitians consider black rice to be a highly nutritious food (Sah SK, Kushwaha UKS 2016). Consuming black rice is highly beneficial for the body, promoting overall health and boosting the immune system.

Anti-inflammatory properties

Inflammation is the body's natural response to protect us from bacterial and viral infections. Chronic inflammation seems to be at the root of many serious illnesses and diseases. Research conducted on the anti-inflammatory effects of pigmented rice has shown that it helps reduce inflammation.

Black rice is an effective remedy for chronic conditions associated with inflammation. The anthocyanin of black rice is found to inhibit skin inflammation. As cyanidin-3-O-glucoside is rich in black rice bran, it helps manage chronic gut inflammation (Prasad et al., 2019).

Cardiovascular Disease Prevention

Cardiovascular disease is a major public health concern and is the leading cause of death in developed countries. As a result, it is crucial to explore alternative sources, such as functional foods, to help prevent and manage the risks associated with this disease. Increasing the consumption of black rice can be beneficial in preventing heart disease. The antioxidant in black rice, anthocyanin, helps lower LDL cholesterol levels, reducing the risk of atherosclerosis and heart attacks. It also helps lower blood pressure and supports overall heart health by inhibiting cholesterol absorption (Jerzy Zawistowski et al., 2009) (Ujjawak Kumae Singh Kushwaha, 2016).

Anthocyanin extract from black rice has been shown to inhibit the growth of liver cancer cells, and lower blood plasma levels of cholesterol, triglycerides, and LDL (low-density lipoprotein), while increasing HDL (high-density lipoprotein). It is also considered a potent agent for cardiovascular disease therapies.

Anti-cancer property

According to the American Cancer Society, cancer is a group of diseases characterized by the uncontrolled growth and spread of abnormal cells. If the spread of these cells is not controlled, it can lead to death (American Cancer Society, 2013, p. 216). Evidence suggests that a healthy lifestyle, including a diet rich in natural products such as fruits, vegetables, herbs, and cereals, can help reduce the risk of cancer. Many of the phytochemicals in these natural products are secondary metabolites, including flavonoids, phenols, terpenoids, and alkaloids.

Flavonoids and phenols, in particular, are the primary compounds found in rice bran (especially colored rice) and have been suggested to possess anti-cancer properties for various types of cancer cells (Pratiwi et al., 2017). Cyanidin 3-glucoside and peonidin 3-glucoside, anthocyanins from black rice, can be combined with doxorubicin to inhibit cancer cell growth. These anthocyanins have been reported as potential agents for cancer chemoprevention. The research also indicates that these active anthocyanin compounds could prevent cancer invasion into other tissues (Chen et al., 2006). Black rice ("Cempo Ireng") bran extract fractions, which contain cyanidin 3-glucoside and peonidin 3-glucoside, exhibit cytotoxic activity and induce apoptosis in cervical cancer cells (Pratiwi et al., 2005).

Anthocyanins, like other antioxidants, help protect the body from free radical damage, which can contribute to cancer development. One study found that anthocyanins extracted from black rice significantly inhibit the spread of certain cancers by limiting DNA damage. A more recent study also suggested that black rice anthocyanins have the potential to prevent tumor metastasis in breast cancer cells.

Antioxidant Effect

Anthocyanin, one of the key compounds found in black rice, acts as an antioxidant by neutralizing harmful molecules, protecting arteries, and preventing DNA damage. These flavonoid pigments, known as anthocyanins, serve as a rich source of antioxidants and help reduce or prevent the production of reactive free radicals that can damage cells. According to the research by Adyati Putriekasari Handayani, Roselina Karim, and Kharidah Muhammad (Handayani et al., 2017), the cooking water of pigmented rice, which contains these antioxidants in an aqueous extract form, has the potential to be developed into an antioxidant drink. Black rice extract is particularly effective at neutralizing superoxide anions compared to hydroxyl radicals. In addition to anthocyanins, black rice is also rich in tocopherols, a potent antioxidant better known as vitamin E. Recent studies suggest that consuming foods containing multiple types of antioxidants may provide greater health benefits than the combined effects of each antioxidant alone (Imana Pal, 2018).

Antidiabetic properties

Black rice is low in sugar and high in fiber, both of which are beneficial for protecting the body against diabetes mellitus. Unlike white rice, black rice does not cause the blood glucose fluctuations often associated with it. Additionally, black rice contains essential minerals that help regulate blood pressure. This makes black rice a beneficial addition to the diet for diabetics.

The most prevalent anthocyanin in black rice bran extract is cyanidin 3-glucoside, which helps lower lipid levels by regulating hepatic lipogenic enzyme activities. Research has shown that black rice extract, rich in anthocyanins, can prevent hyperlipidemia and diabetic conditions in rats fed a fructose-rich diet (Pratiwi et al., 2005).

Obesity

A report suggests that regularly consuming black rice can help with weight management due to its unpolished nature and high fiber content. Black rice supports detoxification and reduces fatty acid production, which helps decrease the accumulation of intracellular lipids between tissues (Dias et al., 2017).

Black rice for GI (Gastrointestinal) health

Pigmented rice is an excellent source of fiber, and black rice, in particular, is rich in fiber. A 50g serving of cooked black rice contains 2g of fiber, making it beneficial for patients suffering from chronic constipation by aiding in improved bowel movements.

Black rice for skin and hair health

Black rice water offers antioxidant protection for the scalp and hair, helping to achieve smooth and glossy hair. It provides biotin and B vitamins, which are beneficial for hair and skin health. The anthocyanins in black rice, which act as antioxidants, protect the body from free radical damage. These antioxidants help prevent premature skin aging and promote the overall health of both hair and skin. Additionally, black rice water helps maintain skin firmness, restore elasticity, and support hair growth (Ujjawak Kumar Singh Kushwaha, 2016).

3.10 EFFECT OF PROCESISNG METHOD OF BLACK RICE

Black rice, widely recognized as a superfood, is praised for its impressive nutritional advantages. However, the methods used to process black rice can greatly influence its nutritional content, texture, and overall quality. Gaining insight into how various processing techniques affect black rice is essential for maximizing its health benefits and culinary potential.

3.10.1 Milling and Grinding

During rice processing, particularly grinding, the aleurone layer is negatively affected (Ma et al., 2022). When done moderately, grinding can improve both the flavor and appearance of rice. However, as the milling degree increases, there is a significant reduction in the color of black rice, which is linked to a continuous decrease in anthocyanin content (Sapna et al., 2019). At a milling degree of 2%, the loss of anthocyanin content is minimal. Anthocyanin levels remain high between milling degrees of 2% and 4%, preserving good taste quality. However, when the milling degree reaches between 4% and 7%, the loss of total anthocyanins increases sharply, ranging from 57% to 90% (Ma et al., 2020). At a milling degree of 9%, anthocyanin content can be almost entirely lost (Paiva et al., 2014). As a result, the milling process causes varying levels of nutrient loss (Bagchi et al., 2021; Mohidem et al., 2022), particularly in colored rice varieties (Hu et al., 2022).

Even after just 10 seconds of milling, the phenolic content drops significantly to 127.82 mg GAE/100 g ($p<0.05$). Continued milling further depletes phenolic content, reducing it to 61.01 mg GAE/100 g after 100 seconds. Additionally, a moderate number of phenolic compounds (58.38 mg GAE/100 g, or 31%) is lost after 10 seconds of milling (DOM * 6%). When all bran is removed (calculated as the difference in contents between black rice and rice milled for 30 seconds or DOM * 12%), about 102.17 mg GAE/100 g, or 55%, of phenolic compounds are eliminated (Sirisoontaralak et al., 2020).

3.10.2 Extrusion

Extrusion cooking involves plasticizing wet, expandable feed materials within a tube under pressure, heat, and mechanical shear. The process uses a holding bin, mixing cylinder, and an extruder barrel to feed the material. The barrel contains a series of locks, dies, and orifices that progressively narrow from the intake to the outlet. In just 30 seconds, the material's temperature can rise to 135 to 160°C under pressures of 15 to 40 atmospheres due to the combined effects of pressure, friction, and attrition as it moves through the extruder barrel. This sudden drop in pressure causes rapid expansion as steam escapes from the product during extrusion. Depending on the initial moisture content, this steam loss can reduce the moisture content of the extruded material by up to 50%. Nutritionally, extrusion serves several purposes: it shears and gelatinizes starch, denatures and shears protein, destroys bacteria and some toxins, restructures texture, and dehydrates the food (Smith, 1975).

The primary goal of extruding cereal flour is to achieve starch gelatinization and degradation, protein denaturation, and the partial or complete disruption of the flour's crystalline structure. These functional changes brought about by extrusion can alter the acceptability of the cereal flour. Key parameters that may be affected include water absorption, specific volume, water holding capacity, and dough viscosity. These modifications can influence the texture, structure, and overall quality of the final food product (Martínez et al., 2013).

3.10.3 Drying

Lang et al. (2019) investigated the impact of drying temperature, storage time, and storage conditions on the phenolic compounds in black rice. They tested drying at temperatures of 20, 40, 60, 80, and 100°C, with a storage period of 12 months, under normal, nitrogen, and vacuum atmospheres. Their findings revealed that higher drying temperatures led to a reduction in total phenolic compounds. Free flavonoid levels also decreased when the temperature exceeded 60°C. However, protocatechuic acid and quercetin were the only phenolic compounds that did not decrease with increasing drying temperatures. In contrast, ferulic acid, p-coumaric acid, gallic acid, and caffeic acid levels were reduced. Notably, the amount of protocatechuic acid increased with higher drying temperatures, potentially due to the breakdown of anthocyanin cyanidin-3-O-glycoside. This indicates that drying temperature plays a significant role in affecting the phenolic content in black rice, with some compounds being more stable than others.

3.10.4 Cooking

Cooking involves the application of heat to food, such as boiling, frying, or baking, which changes its texture and flavor. It also leads to a reduction in free phenolic compounds, with some anthocyanins decreasing and others increasing (Cañizares et al., 2025). A study by Aalim, Wang, and Luo (2021) on black rice (Oryza sativa L.) processing observed a decrease in the levels of cyanidin-3-glucoside (from 156.76 to 116.18, 135.15, 36.72, and 21.64 $mg\cdot100\ g^{-1}$) and rutin (from 4.32 to 3.97, 0.75, 4.05, and 2.09 $mg\cdot100\ g^{-1}$). In contrast, the levels of kaempferol (from 1.23 to 2.87, 2.57, 1.73, and 2.28 $mg\cdot100\ g^{-1}$) and isorhamnetin (from 2.51 to 3.56, 3.01, 5.58, and 4.52 $mg\cdot100\ g^{-1}$) increased across different preparation methods, including raw, cooked, roasted, and oil-fried rice.

3.11 NEED FOR VALUE ADDITION OF PIGMENTED RICE

Rice has been a staple food for over half of the global population, with numerous varieties, including black rice. Despite its well-recognized health benefits, challenges remain in making these benefits accessible and increasing its appeal in fast-paced urban settings. This highlights the importance of value addition, where rice can be transformed into convenient, nutritious products like ready-to-eat mixes, noodles, and more. By adding value, not only can the losses from traditional postharvest processing be minimized, but its commercial value can also be significantly enhanced.

3.12 APPLICATION IN THE FOOD INDUSTRY

Extruded Products

Extruded snacks are commercially successful due to their diverse product range, easy availability, convenience, and long shelf life. Examples of extruded products include pasta, noodles, breakfast cereals, and modified starches. These snacks are made from cereal flour with a high starch content, as starch can gelatinize during the extrusion process, turning into a plasticized mass that can be shaped into various forms using dies. Additionally, extruded products can also be made from raw materials rich in protein.

Noodles and pasta

Black rice bran powder was used to replace wheat flour in noodles at concentrations of 0%, 2%, 5%, 10%, and 15%. The analysis showed that the protein, fat, and ash contents in the noodles increased with the addition of black rice bran powder. The texture of the noodles became firmer as the concentration of black rice bran powder increased, while cohesiveness decreased. When testing the cooking characteristics, it was found that the optimal cooking time for black rice bran noodles was 7 minutes. These noodles also demonstrated antioxidant activity (Kong et al., 2012). In a study by Laishran and Das (2017), black rice was incorporated into pasta as a source of bioactive compounds, and its quality attributes were evaluated. They reported that the antioxidant activity and phenolic content of black rice pasta decreased due to the degradation of anthocyanins during the high-temperature extrusion cooking process. Sethi et al. (2020) examined the quality of pasta enriched with black rice bran and concluded that a 15% addition was optimal. The resulting pasta had high protein (9.99 g/100 g), fiber (2.79 g/100 g), and anthocyanin (165.27 mg/100 g) content.

Black rice in cookies/biscuits

Vitali (2009) noted that biscuits can be easily fortified to create healthier products. Kim et al. (2006) conducted a study in which 20% of wheat flour was replaced with black rice powder to make cookies using a standard procedure. The properties of the dough were assessed, revealing that the pH of the cookie dough increased with the addition of black rice powder. The cookies were then baked and tested for color, spreadability, and textural properties. The dough became darker due to the presence of black rice powder, and the color deepened further during baking. In another study by Klunklin and Savage (2018), purple rice flour was used in biscuits at 25%, 50%, and 100% replacement levels. The study found that the protein digestibility increased, while the starch digestion rate decreased as the level of purple rice flour increased. The biscuits made with 100% purple rice flour had a very low glycemic index. The 25% and 50% replacement levels were well-accepted in sensory analysis. The findings suggest that the addition of purple rice flour to cookies or biscuits could serve as a functional food for diabetic patients, as it slows starch digestion and helps regulate blood glucose levels.

Black rice in bread

In a study by Sui et al. (2016), small amounts of black rice flour were used as a substitute for regular flour in bread making due to its beneficial nutraceutical properties. When black rice flour was substituted at a 2% level, no significant difference was observed compared to the control bread (which contained 0% black rice flour). However, at a 4% substitution level, the resulting bread exhibited a denser crumb structure and reduced elasticity.

Black rice in cakes and muffins

Mau et al. (2017) found that adding black rice to cakes resulted in increased crumb hardness and chewiness. The cakes also exhibited a denser crumb structure, replacing the usual airy, porous texture. Additionally, the moisture content, cake volume, springiness, and resilience were reduced in the baked cakes. However, the cakes containing black rice demonstrated higher antioxidant activity.

Black rice and Sausage

Sai Krok Isan, also known as Sai Krok Prew, is one of the most popular types of fermented pork sausage in Thailand. It is made from pork meat, cooked rice, salt, and various spices. To achieve an intense pink color that appeals to consumers, food additives like nitrates and nitrites are used. This vibrant color is created through the formation of nitrosomyoglobin. Nitrates also help protect the sausage from microbial growth and spoilage. However, it has been proven that nitrates, when consumed with sausages, can have negative health effects and are linked to cancer. As a result, the European Commission has banned the use of nitrates and nitrites in meat products. In response, research has focused on developing a natural pigment that can replicate the functions of nitrates, such as color development, lipid oxidation prevention, and spoilage inhibition. The colorant powder, extracted from black rice bran using an ohmic heating-assisted solvent extraction method, has the potential to be used as a natural coloring agent and antioxidant in fermented pork sausages.

Anthocyanins as a natural colorant in yogurt

Yogurt is a fermented dairy product made through the bacterial fermentation of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* cultures. Flavored yogurts, which have gained global popularity, are typically made using artificial flavors and colors. However, long-term consumption of these artificial additives may have negative health effects. To address this, research has been conducted to replace artificial colors with natural alternatives. One such effort involved using anthocyanin, a natural pigment from king rice (black rice), to color yogurt. Anthocyanin gives a bright purple hue and possesses antioxidant properties. An experiment was carried out to explore the use of black rice bran as a colorant in yogurt, as well as its potential as a functional ingredient. The black rice bran colorant powder was obtained through enzymatic extraction.

Anthocyanin in fermented Thai pork sausage

Fermented pork sausage is a popular variety of sausage in Thailand, typically made from pork meat, cooked rice, salt, and various spices. Food additives like nitrates and nitrites are commonly used to give the sausage a vibrant pink color, which is achieved through the formation of nitroso-myoglobin (10m et al., 1991). Nitrates also help prevent microbial growth and spoilage in sausages. However, consuming nitrates with sausages has been linked to negative health effects and is known to be cancer-causing. As a result, the European Commission has banned the use of nitrates and nitrites in meat products. In response, research has focused on introducing a natural pigment that can perform similar functions, such as color development, lipid oxidation prevention, and spoilage inhibition. The colorant powder was extracted from black rice bran using an ohmic heating-assisted solvent extraction method. This natural colorant and antioxidant have the potential to be used in fermented meat sausages as a safe and effective alternative to nitrates.

Other applications like, In Asia, black sticky rice is commonly used in desserts and sweet snacks. Black rice extracts are an excellent source of natural food coloring pigments. The pigments in black rice extracts, which can range from black to pink, make black rice bran powder an ideal and healthier alternative to artificial food colorants. In China, black rice is used to make black vinegar and various types of wine. Alcoholic beverages made from cooked black rice have been found to have higher antioxidant activity compared to non-alcoholic drinks made from the same rice (B. Krishna Veni, 2019).

3.13 WHEAT

Wheat (Triticum aestivum L.) is the most widely cultivated cereal crop globally, with an annual planting area of approximately 237 million hectares, producing a total of 420 million tonnes. (Isitor et al., 1990; Langer and Hill,1991Olabanji et al., 2004). Wheat, as a crucial industrial crop, serves as the primary raw material in feed mills and is also a key ingredient in various products such as bread, cake, biscuits, pasta, spaghetti, semovita, and macaroni, all of which contain significant amounts of wheat.Wheat is a highly adaptable crop, cultivated in a variety of soil and climatic conditions.Wheat is a good source of carbohydrates, protein, and essential vitamins and minerals, including vitamins B and E, calcium, iron, and fiber.

The grain's composition, which includes the bran, germ, and endosperm, plays a key role in its nutritional and functional properties. The bran is a valuable source of dietary fiber and micronutrients, while the germ contains vital vitamins, minerals, and healthy fats. The endosperm, mainly made up of starch and proteins such as gluten, is essential for determining wheat's effectiveness in baking and food processing (Liu, 2019). These features highlight wheat's significance in both health and industry, driving ongoing advancements in wheat breeding and processing technologies.

Figure 3.4: Wheat

The industrial development of whole wheat flours is a relatively recent advancement, spurred by the renewed recognition of the health benefits provided by the bran, germ proteins, and dietary fiber. Currently, China, India, and the US are among the leading wheat producers globally.

<u>3.14 NUTRITIONAL COMPOSITION OF WHEAT</u>

No.	Components	Amount Per 100g
1	Water	11.1 g
	Carbohydrates:	
2	Fiber, total dietary	3 g
3	Protein	12 g
4	Nitrogen	1.92 g
5	Total lipid (fat)	1.7 g
	Energy:	
6	At water General Factors	362 kcal
	At water Specific Factors	370 kcal
7	Ash	0.56 g
8	Minerals:	
	Phosphorus, P	134 mg
	Potassium, K	150 mg
	Magnesium, Mg	36.1 mg

	Calcium, Ca	22 mg
	Manganese, Mn	0.819 mg
	Sodium, Na	2 mg
	Zinc, Zn	1.15 mg
	Iron, Fe	1.18 mg
	Copper, Cu	0.212 mg
9	Vitamins and Other Components:	
	Niacin (Vitamin B3)	1.59 mg
	Thiamine (Vitamin B1)	0.298 mg
	Pyridoxine (Vitamin B6)	0.085 mg

Table 3.5 Proximate composition of all-purpose, unenriched, wheat flour (source: USDA FoodData Central, 2020)

3.14.1 Carbohydrates

Wheat carbohydrates, primarily starch, play a crucial role in human nutrition. Starch makes up about 60-70% of the wheat kernel and is the main source of energy derived from wheat. It is stored as granules within the endosperm and exists in two forms: amylose and amylopectin. Amylose is a straight-chain polymer, whereas amylopectin is a branched polymer.

Both types significantly affect the functional properties of wheat-based products like bread and pasta. The digestibility of wheat starch and its glycemic index are important factors that influence its nutritional value and potential health effects (Khalid, Hameed, and Tahir, 2023).

Non-starch polysaccharides (NSPs), including arabinoxylans and β-glucans, are another essential carbohydrate component found in wheat, primarily in the bran and aleurone layers. These dietary fibers are widely recognized for their health benefits, such as improving gut health, reducing cholesterol, and helping to regulate blood glucose levels. However, incorporating wheat bran into food products can pose challenges, particularly in terms of texture and sensory qualities. To overcome these issues, various modification techniques have been developed and effectively applied (Sztupecki et al., 2023).

3.14.2 Protein

Protein, derived from the Greek word "proteios," meaning "primary," is essential for both humans and animals. In wheat grains, protein typically makes up 10%-18% of the total dry matter. Wheat proteins are classified based on their extractability and solubility in different solvents, a system introduced by T.D. Osborne. His method involves sequentially extracting ground wheat grain to separate various protein fractions: albumins (soluble in water), globulins (insoluble in pure water but soluble in dilute NaCl solutions, and insoluble in high NaCl concentrations), gliadins (soluble in 70% ethyl alcohol), and glutenins (soluble in dilute acid or sodium hydroxide solutions).

Wheat gluten, a protein complex primarily composed of gliadin and glutenin, makes up about 75-80% of the total protein in wheat. Gluten proteins are crucial for defining the processing qualities of wheat flour, contributing to the cohesiveness and viscoelasticity needed to shape dough into bread, noodles, and other food products. From a nutritional standpoint, wheat gluten is an excellent protein source, providing essential amino acids, though it is notably deficient in lysine (Wieser, Koehler, & Scherf, 2023). The health effects of gluten vary among individuals. In those who are susceptible, gluten proteins are the main triggers of celiac disease and other gluten-related intolerances (Caio et al., 2019). Furthermore, non-celiac gluten sensitivity and wheat allergies are conditions where gluten can cause adverse effects, including digestive discomfort or allergic reactions (Scibilia et al., 2006).

3.14.3 Fat

Although lipids represent a small portion of cereals, they play a vital role in determining the quality and texture of food. Due to their amphipathic nature, lipids can interact with proteins and starch, forming inclusion complexes that affect the structure and properties of food. The germ contains the highest concentration of lipids, around 11%, but notable amounts are also present in the bran, as well as in the starch and proteins of the endosperm. Wheat lipids are rich in essential fatty acids such as linoleic acid, which are important for maintaining human health. These lipids also contain sterols and tocopherols, which are known for their antioxidant properties and their benefits for cardiovascular health. However, the refining process significantly reduces the lipid content in wheat flour, as both the germ and bran are removed during milling. This reduction can lower the overall nutritional value of the final product (Šramková et al., 2009).

3.14.4 Vitamins

Vitamins are essential organic compounds obtained from plants and microorganisms, as the human body cannot synthesize them. These micronutrients are critical for various physiological functions, including coenzyme activity, serving as precursors, specialized roles (e.g., Vitamin A is crucial for vision, while ascorbate supports specific hydroxylation reactions), antioxidative defense (Vitamins C and E, along with certain carotenoids, protect against oxidative damage), and genetic regulation and stability.

Tocols, which include tocopherols (T) and tocotrienols (T3), are vitamin E compounds known for their antioxidant properties, essential for protecting biological membranes. These compounds are made up of a chromanol ring and a phytyl side chain, with tocotrienols differing due to their unsaturated side chain that contains three double bonds. The distribution of tocopherols and tocotrienols in wheat varies across its seed components, as noted by Hidalgoa and Brandolini (2008). The germ contains the highest levels of α-tocopherol, β-tocopherol, and total tocols, while α-tocotrienol and β-tocotrienol are mostly found in the bran, with significant amounts also present in the flour.

Carotenoids, which are precursors to vitamin A (retinol), are found in wheat mainly as β-carotene and related compounds. While wheat is not a major source of vitamin A, its carotenoid content contributes to its nutritional value. In the human body, β-carotene and other carotenoids from wheat are converted into retinol, the active form of vitamin A, through oxidation in the intestinal mucosal brush border or the liver. Wheat-derived carotenoids have an advantage over direct retinol sources because they can be converted to vitamin A based on the body's needs, reducing the risk of vitamin A toxicity associated with excessive retinol intake. This makes carotenoids from wheat a safe and valuable addition to human nutrition, particularly in regions where vitamin A deficiencies are common.

3.14.5 Minerals

The presence of various minerals in wheat, particularly in the bran, plays a significant role in addressing hidden hunger (micronutrient deficiency) globally. Wheat is rich in essential minerals such as potassium (K), phosphorus (P), magnesium (Mg), and calcium (Ca), as well as micronutrients like iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu). These important minerals are mainly concentrated in the bran and germ layers of the wheat kernel. Therefore, whole wheat products provide greater nutritional value compared to refined wheat flour, which loses much of these mineral-rich layers during processing (Yildiz, 2022). Processing methods like milling and baking can impact the distribution of minerals, often resulting in a reduction of their content in the final product. Additionally, factors such as genetic makeup, environmental conditions, and agronomic practices influence the mineral profile of wheat grains (Wysocka, Cacak-Pietrzak, & Sosulski, 2025).

3.15 NOODLES

Noodles, a staple food in numerous Asian countries, boast a history spanning more than 4,000 years. Their global consumption has risen due to convenience, nutritional value, and great taste (Li et al., 2012).

People could only find dried or instant fried noodles in supermarkets due to their ease of preservation. However, the deep drying can diminish the flavor, texture, and even the nutritional value of these noodle products. As a result, fresh noodles, the traditional form of Chinese noodles, are gaining popularity for their unique taste and flavor. Nevertheless, because fresh noodles contain over 30% water and have a higher initial microbial load, they are highly susceptible to spoilage and must be stored in refrigeration (Li, Zhu, Guo, Peng, & Zhou, 2011).

Rice noodles are widely enjoyed as a traditional dish with distinct flavor, taste, and texture in numerous East and Southeast Asian countries (Fu et al., 2020; Kasunmala et al., 2020; Yi et al., 2020).

Rice noodles can be categorized into fresh wet, semi-dried, and dried types based on their moisture content (Li et al., 2015). Fresh rice noodles offer excellent flavor and texture but have a short shelf life due to their high moisture content. The dehydration process can negatively impact the flavor and texture, often necessitating methods to prolong the noodles' shelf life. With increasing consumer demand for convenient and health-conscious food options (Diez et al., 2009). reducing the moisture content of rice noodles to a safe level, as seen in semi-dried rice noodles, is an ideal solution. This approach preserves the fresh noodles' flavor and texture while providing the extended shelf life of dried noodles (Tong et al., 2015).

3.16. Ingredients used for semi-steamed Noodles

The chemical and physical properties of the final rice noodle product are influenced by the choice of primary ingredients. The essential mixture of flour and water is required for rice noodle production, although additional additives may be used from time to time (Valencia & Purwanto, 2020; Ridwansyah et al., 2020; Putri & Sumardiono, 2020).

Starch Source

It is a key ingredient in the production of noodles . Starchy materials such as corn, potato, sorghum, cassava, and broken rice particles can also be utilized (Nateghi et al., 2021). Rice grains are preferred due to their ability to achieve the desired amylose-amylopectin ratio

(Zhiyuan & Yanyan, 2011; Valencia & Purwanto, 2020). In extrusion processes, starches with high amylopectin content tend to melt rather than gelatinize, while starches rich in amylose gelatinize effectively at high temperatures as water molecules are trapped between the polymer chains (Zhiyuan & Yanyan, 2011). Currently, sorghum flour, soybean flour, modified cassava flour, and corn flour are used to prepare noodles.

3.17 Benefits

Convenience: Instant noodles are easy to prepare, typically needing only boiling water or a few minutes in the microwave, making them a convenient meal choice for those with busy schedules.

Cost-Effective: Instant noodles are usually low-cost, offering an affordable food option, particularly for students or individuals on a limited budget.

Variety: Instant noodles are available in a wide range of flavors and styles to suit different preferences. Some options even include added vegetables, proteins, or spices.

Portability: Instant noodles are lightweight and easy to carry, making them a convenient option for camping, travel, or quick meals while on the move.

3.18 Role of semi-steamed noodles

Semi-steamed noodles play an essential role in the instant noodle market by providing a balance of convenience, texture, and nutrition. The partial steaming process enables the noodles to cook quickly, requiring only a brief time in boiling water or the microwave, making them a great choice for busy individuals. This technique helps preserve the noodles' texture, preventing them from becoming too soft or mushy, thus enhancing the overall eating experience. Moreover, semi-steamed noodles have a longer shelf life than other varieties, as the steaming process keeps them fresh without refrigeration. They also retain more nutrients compared to deep-fried noodles, offering a healthier alternative. Additionally, the versatility of semi-steamed noodles makes them suitable for a wide range of flavors and toppings, appealing to a variety of tastes.

3.19 Future Aspects

To enhance sustainability and conserve the indigenous black rice species of Manipur, further research on black rice is essential. Addressing malnutrition could be partly achieved by promoting special rice varieties such as black rice and red rice as staple crops, along with raising public awareness. This would encourage the widespread adoption of these varieties for cultivation across various regions of India, thereby fostering the development of varieties with enhanced agronomic traits and increased market appeal. Both genotype and phenotype improvements are crucial for producing superior rice varieties.

The Indian black rice variety "Chakhao" is known for its resistance to insect pests and its drought tolerance, making it a valuable resource for developing rice varieties with enhanced grain quality, antioxidant properties, and increased yield potential. However, boosting the productivity of black rice is necessary to compensate for its longer harvest period. As a result, it is vital to create varieties that offer both higher and earlier yields (Shivani Kumari)

CHAPTER – 4

MATERIALS AND METHODS

MATERIALS AND METHODS

4.1 MATERIALS

Black rice flour

It was obtained from local farmers in Manipur and ground into a fine powder using a laboratory mill.

Wheat flour:

The wheat flour used in the studies was sourced from the local market. The flour's characteristics, including moisture content, ash content, falling number, and Zeleny's sedimentation value, were determined using AACC methods (2000).

The equipment used in the experiments included: an Aluminium 36 R Cylindrical Probe, Balance, Boiling Flask, Buchner Flask, Centrifuge, Cuvette, Desiccator, Digital Vernier Caliper, Dough Mixer, Dryer, Extruder, Falling Number Apparatus, Filtered Glass Crucible, Graduated Measuring Cylinders, Grinder, Hot Air Oven (set to 105°C and 130°C), HunterLab Color Measuring System, Kjeldahl Apparatus, Kjeldahl Flask, Laboratory Mill, Mettler Balance, Muffle Furnace, Petri Plate, Rice-shaped Die, Sedimentation Shaker, Soxhlet Apparatus, Steamer, Analyzer (TAHDi), UV-Vis Spectrophotometer, Vacuum Pump, Viscometer Stirrer, Vortex Mixer, Water Bath, Weighing Machine, Whatman Filters (1 and 40), and others.

The chemicals utilized in the experiments were: Acetone, Aluminium Chloride, Amyl Glucosidase, Boric Acid, Bromophenol Blue, H2SO4, Copper Sulphate, Ethanol, Folin-Ciocalteu's Reagent (10%), HCl, Isopropyl Alcohol (99-100%), KCl Buffer, Lactic Acid Reagent, MES-TRIS Buffer, Methanol, Mixed Indicator, NaOH, Petroleum Benzene, Potassium Sulphate, Protease, Quercetin, Sodium Acetate Buffer, Sodium Carbonate (7.5%), Sodium Hydroxide, Sodium Nitrite, α-Amylase, Methanol, DPPH (1.1-diphenyl-2-picrylhydrazyl), Potassium dihydrogen phosphate, Potassium hydrogen phosphate, Potassium ferric cyanide, Trichloroacetic Acid (TCA), Ferric Chloride, Ascorbic Acid, Ethanol, and Phosphomolybdate Reagent (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate).

INGREDIENTS



Black rice flour **Wheat flour** **Water**

Figure 4.1 Ingredients for black rice noodles

4.2 METHODS OF PREPARATION

4.2.1 PREPARATION OF BLACK RICE NOODLES

To find the optimal proportion of wheat flour for producing extruded black rice noodles, preliminary experiments were performed by varying the amounts of BRF from 0 to 40%. Apart from wheat flour (100% WF), three flour blends were prepared by replacing wheat flour with black rice flour (BRF) at 10%, 20%, 30%, and 40% levels. The flour blend (200 g, with all other ingredients based on flour), salt (1%), and water (30-32%) were mixed in a planetary mixer (Spar mixer SP-800, Taiwan) for 10 minutes at 132 rpm. The resulting dough was covered with a moist cloth and rested for 30 minutes for proper hydration. A laboratory-scale extruder (La Monferrina model Dolly S/N, Italy) equipped with a noodle die of 1.5 mm diameter was employed to obtain noodle strands of about 20 cm. The fresh noodles were then steamed for 2 min in a steam combi-oven (XT Snack, Inoxtrend, Italy) at 95% RH and 100°C.

Flow chart of the production of semi-steamed black rice noodles

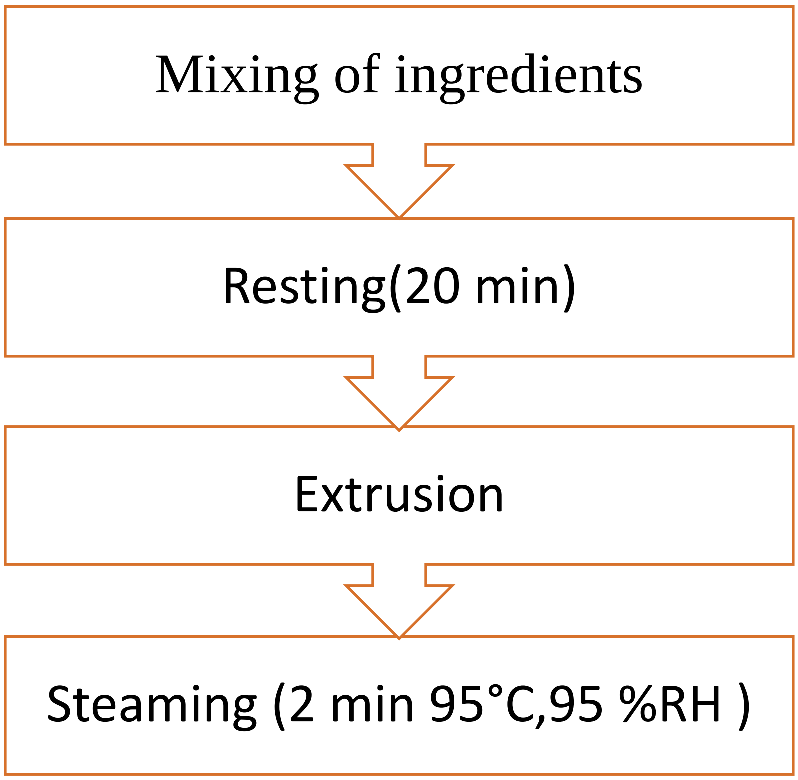
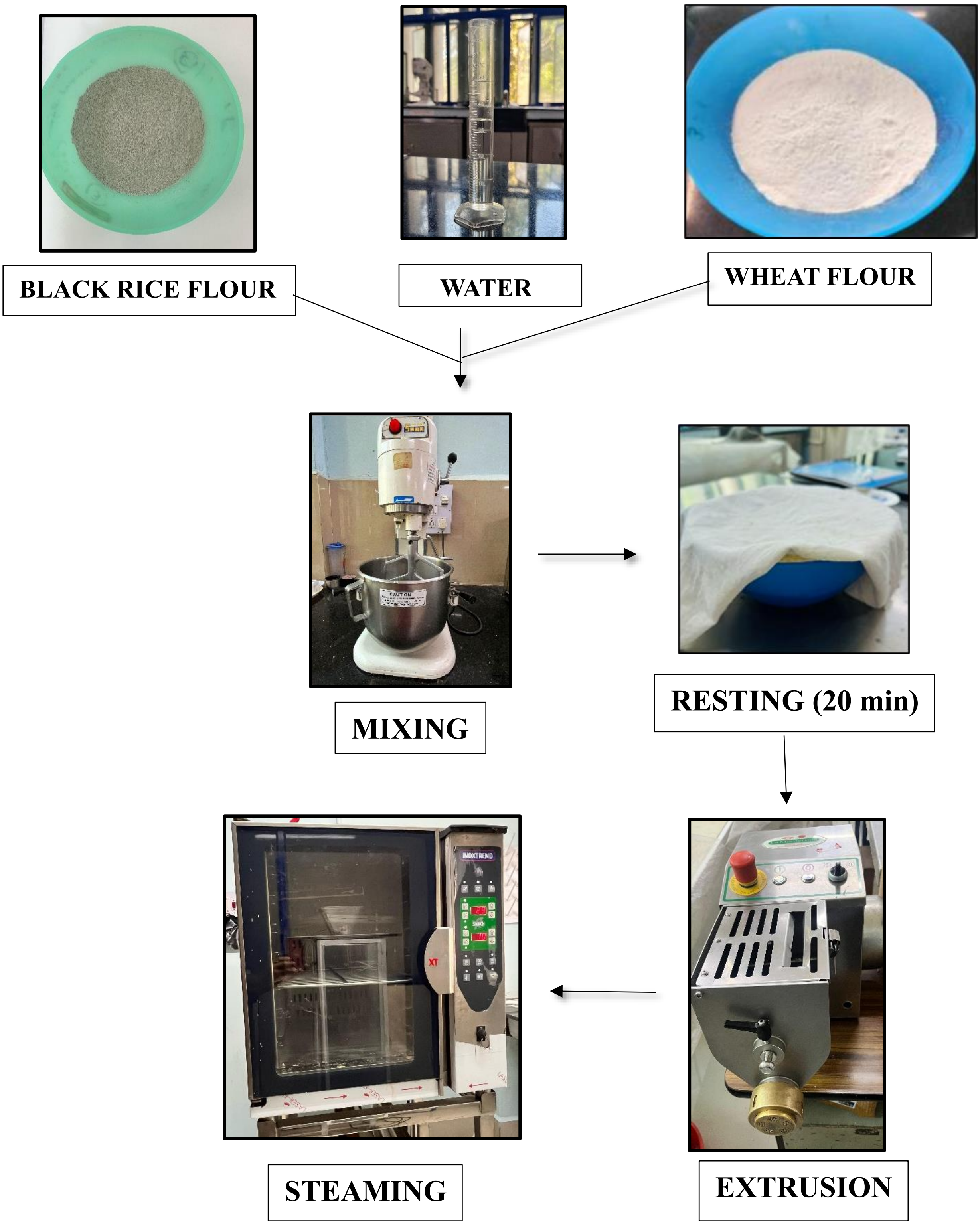


Figure 4.2 : General flow chart for product preparation

4.3 DIAGRAMATIC REPRESENTATION FOR THE PRODUCTION OF NOODLES FROM BLACK RICE AND WHEAT FLOUR



CONTROL

10% BRF

20%BRF

30%BRF

40%BRF

Fig. 4 .4 Extruded rice noodles with varying levels of black rice (BRF)

4.2.2 Product Formulation and Sample Preparation

SAMPLE	WF (%)	BRF (%)	WATER (%)	SALT (%)
CONTROL	**100**	**0**	**30**	**1**
10%	**90**	**10**	**30**	**1**
20%	**80**	**20**	**32**	**1**
30%	**70**	**30**	**32**	**1**
40%	**60**	**40**	**32**	**1**

Table 4.1 Product formulation

Black rice noodles formulation (100% wheat flour) consisted of wheat flour and water. Wheat flour was then replaced with black rice flour at varying proportions:10%, 20%, 30%, and 40%The water content remained constant at 32% across all formulations. The ingredient proportions for the different formulations are shown in the Table 4.1

Each ingredient was weighed according to the specified formulations, then mixed. The mixture was allowed to rest for 20 minutes before being extruded. After extrusion, the mixture was immediately steamed and then kept in the refrigerator for further storage.

4.2.3 CHARACTERIZATION OF WHEAT FLOUR

4.2.3.1 DETERMINATION OF ZELENY SEDIMENTATION

PRINCIPLE:

The sedimentation value is the volume of sediment formed when flour is suspended in water and treated with lactic acid. This sediment consists of swollen gluten and occluded starch.

APPARATUS:

Grinder, sedimentation shaker.

REAGENTS:

Isopropyl alcohol (99-100%), bromophenol blue, and lactic acid agents.

PROCEDURE

3 to 2 grams of flour is added to a 100 ml stoppered measuring cylinder that contains 50 ml of water with bromophenol blue. The mixture is thoroughly combined by shaking the cylinder horizontally 12 times. The cylinder is then placed on a shaker and shaken for 5 minutes. Afterward, 25 mL of isopropyl alcohol is added, and the cylinder is shaken again for 5 minutes. Following this, the cylinder is positioned upright, and after exactly 5 minutes, the volume of the sediment (in ml) is recorded. This volume represents the sedimentation value in ml, which is then adjusted to a 14% moisture basis.

Figure 4.5 Sedimentation Shaker

CALCULATION

$$\text{Sedimentation value} = \text{Sedimentation uncorrected} \times \frac{100-14}{100-\text{Moisture in flour}}$$

4.2.3.2 FALLING NUMBER

PRINCIPLE:

The time in seconds required to stir and allow a viscometer stirrer to fall a fixed distance through a hot aqueous flour suspension being liquefied by the enzyme in a standardized apparatus.

APPARATUS:

Grinder, balance, and falling number apparatus (water bath, test tube, stopper, and stirrer)

PROCEDURE

Grind 100g of wheat using a lab grinder. Place the ground wheat into the heater of the falling number apparatus and allow the water to reach a boiling point. Weigh 7 grams of the sample and transfer it into the falling number tube. Insert the rubber stopper and shake the tube upright 10 times to ensure the flour is fully suspended in the water. Use the viscometer stirrer to scrape down the upper part of the tube. Place the falling number tube in the water bath and start the timer. The stirrer will automatically mix the flour suspension for 60 seconds, resulting in a liquefied gel. The falling number is then calculated based on a 14% moisture basis.

Figure:4.6 Falling Number System

CALCULATION

$$\text{Falling number} = \text{Falling number uncorrected} \times \frac{100 - 14}{100 - \text{Moisture content}}$$

4.2.3.3 ESTIMATION OF GLUTEN

PRINCIPLE:

The gluten content in a flour sample can be estimated by washing the dough to remove starchy sugars, water-soluble proteins, and other minor components. The resulting wet, cohesive mass is known as wet gluten, while the dried product derived from this mass is referred to as dry gluten.

PROCEDURE

Exactly 25g of flour is kneaded with approximately 15 ml of water to form a dough ball. The dough is then left submerged in water for one hour to ensure complete hydration. After this, the starch is removed by gently kneading the dough in a stream of water over a fine sieve or silk cloth until the wash water runs clear. The cohesive gluten is then pressed as dry as possible and weighed to determine the wet gluten content. The wet gluten is then dried at 105°C for 24 hours and weighed again to determine the dry gluten content.

Figure 4.7 Gluten

CALCULATION

$$\text{Wet Gluten (\%)} = \frac{A \times 100}{C}$$

$$\text{Dry Gluten (\%)} = \frac{B \times 100}{C}$$

Where,

(A) Wt. of wet gluten

(B) Wt. of dry gluten

(C) Wt. of flour

4.2.4 COOKING PROPERTIES OF NOODLES

4.2.4.1 Optimal Cooking Time (OCT in min)

Noodles (5 g) were immersed in boiling water (60 ml), one piece of noodles (5cm) was taken out every 25 s, and squeezed to visually observe the time of disappearance of the white core (ungelatinized starch). The OCT was achieved when the noodle was fully hydrated.

4.2.4.2 Cooking Weight

The extruded samples were cooked and drained. Then, the drained extruded sample weight should be taken using a weighing balance.

4.2.4.3 Cooking Loss (CL)

10 g noodle strips were simmered (2-5 min) in a beaker with 100 ml of boiled water. The cooked noodles were collected in a strainer and allowed to cool for 5 min, whereas the cooking water was collected in a glass beaker and evaporated in a hot air oven at 105°C until constant weight. For the cooking loss, the final weight (W3) was recorded as the weight of the beaker after drying. The following equations calculate the water absorption (WA) and CL in triplicate.

CALCULATIONS

The water absorption (WA), cooking loss (CL), and cooking yield (CY) were calculated in duplicate using the following equations.

$$\textbf{Water Absorption (g/g)} = \frac{W2 - W1}{W1}$$

Where,

W1 = Weight of raw rice noodles

W2 = Weight of cooked noodles

$$\textbf{Cooking loss (\%)} = \frac{W_f - W_i}{W_1}$$

Where,

Wf = Weight of Petri plate after drying

Wi = Weight of Petri plate

W1 = Weight of raw rice noodles

$$\textbf{Cooking yield (g)} = W2/W1$$

$$\textbf{Cooking yield (\%)} = \frac{W2 \times 100}{W1}$$

4.2.5 PROXIMATE ANALYSIS

4.2.5.1 MOISTURE CONTENT

PRINCIPLE:

The moisture content is expressed as the percentage of weight loss after drying the sample for 1 hour at 130°C.

APPARATUS:

Hot air oven, lab grinder, aluminium dishes, Mettler balance, and desiccator.

PROCEDURE

The moisture content was determined using a hot air oven. A sample of approximately 5-10g was weighed, ground, and placed into a clean, pre-weighed glass Petri dish. The combined weight of the sample and the Petri dish was recorded, and then it was heated in the hot air oven at 105°C for 3 hours. After cooling in a desiccator, the dish was weighed again. This process was repeated until a constant weight was achieved.

Figure 4.8 Hot air oven

CALCULATION:

$$\textbf{Moisture content (\%)} = \frac{\underline{(W1 - W2) \times 100}}{(W1-W2)}$$

W1 = Weight of dish + flour before drying (gm)

W2 = Weight of dish + flour after drying (gm)

W = Weight of empty aluminium dish (gm)

4.2.5.2 DETERMINATION OF ASH

PRINCIPLE:

Total ash is the inorganic residue left after incineration in the open air under atmospheric pressure.

APPARATUS:

Muffle furnace, crucible, tongs, Mettler balance, and desiccator.

PROCEDURE

Take a fresh sample for the determination, rather than the leftover material from the moisture determination. Ignite the dried sample in the dish, which was used after the moisture determination, with a burner flame until it is charred. Then, transfer the sample to a muffle furnace set at 550-600°C and continue heating until grey ash is obtained. Allow the dish to cool in a desiccator and weigh it. Repeat the process of heating, cooling, and weighing at half-hour intervals until the weight difference between two consecutive weighings is less than 1 mg. Record the lowest weight. If the ash still contains black particles, add 2-3 drops of pre-heated water (60°C), break the ash, and evaporate it to dryness at 100-110°C. Re-ash the sample at 550°C until the ash is white or slightly grey.

CALCULATION

$$\textbf{Ash content} = \frac{(W2-W1) \times 100}{(W1-W2)}$$

Figure 4.9 Muffle furnace

4.2.5.3 DETERMINATION OF PROTEIN

PRINCIPLE:

The protein content is determined based on the organic nitrogen content using the Kjeldahl method. In this process, various nitrogenous compounds are converted into ammonium sulfate by boiling with concentrated sulfuric acid. The formed ammonium sulfate is then decomposed with an alkali (NaOH), releasing ammonia, which is absorbed in excess standard acid solution and subsequently back titrated with a standard alkali.

REAGENTS:

Digestion mixture: Powdered potassium sulphate and copper sulphate were mixed thoroughly in the ratio 10:1.

Concentrated sulphuric acid 10ml for digestion

Sodium hydroxide solution 20 %: 200 gm of sodium hydroxide pellet was dissolved in 1000 ml of distilled water for digestion.

Sodium hydroxide solution 40 %: 40 gm of sodium hydroxide pellet was dissolved in 100 ml of distilled water for distillation

Boric Acid 4%: 4 gm of boric acid was dissolved in 100 ml of boiling distilled water. After cooling, transfer the solution into a glass stoppered bottle.

Mixed indicator: Dissolve 0.1% bromocresol green with 2 ml of methyl red solution in a bottle provided with a dropper which will deliver about 0.05 ml / 4 drops.

0.1N HCL: approximately 1.43 ml of anhydrous HCL was dissolved in 1L of distilled water.

APPARATUS

Micro kjeldahl apparatus

PROCEDURE

Weigh about 0.5 gm of the sample and transfer it to a 500 or 800 mL Kjeldahl flask, taking care to see that no portion of the sample clings to the neck of the flask. Add 3gm of digestion mixture and 10 mL of concentrated sulphuric acid. Place the flask on the stand in the digestion chamber and digest. Heat the flask gently at low flame until the initial frothing ceases and the mixture boils steadily at a moderate rate. Continue heating for about 150 minutes until the color changes to pale blue. Distillate that contained ammonia was collected in the conical flask containing 25ml of 4% boric acid with three drops of mixed indicator. The ammonia was converted to ammonium meta borate and titrated with standardized 0.1N HCL. A reagent blank should be run to subtract reagent nitrogen from the sample nitrogen.

CALCULATION

Moles of HCl = moles of NH3 = moles N in the sample

$$N\% = \frac{14.01 \times 0.1N \times (TV - BV) \times 100}{W \times 1000}$$

$$P\% = N\% \times 6.25$$

TV = Titre value of sample

BV = Blank value

W = Weight of sample

Protein on dry wt. Basis = [Protein content / (100 – Moisture content)] * 100

Ideally the protein content of food stuff is calculated by multiplying its total nitrogen content by a factor 6.25. This factor is used whenever the nature of the protein is unknown or when the product to be analysed is a mixture of different proteins with different factors. However, use of different Nitrogen conversion factors for different matrices may lead to better accuracy of results.

(a) Digestion Unit

b) Distillation unit

Figure 4.10 : Kjeldahl Apparatus

(a) Distillate for titration

(b) Titrated distillate

Figure 4.11: Protein content determination (endpoint)

4.2.5.4 DETERMINATION OF FAT

PRINCIPLE

For semi-continuous solvent extraction, the solvent builds up in the extraction chamber for 5-10 minutes and surrounds the sample, and then siphons back to the boiling flask. Fat content is measured by the weight loss of the sample or by the weight of fat removed.

PROCEDURE

Accurately weigh 5g of the substance in a suitable thimble, then let it dry for two hours at 100°C. The thimble should be placed in the Soxhlet extraction device and extracted with Petroleum Ether at 40–60 °C for eight hours. Dry the extract in the Soxhlet flask, whose empty mass was earlier measured by taring at 95 to 100 °C for an hour. Desiccate and weigh after cooling. Continue drying, cooling, and weighing at intervals of 30 minutes until there is a mass change of no more than 2 milligrams between two subsequent weighing. Record the lowest mass obtained.

The percentage fat was calculated as follows,

$$\textbf{Fat \%} = \frac{(W2-W1) \times 100}{W}$$

Were,

W = Weight of sample, g

W1 = Weight of empty flask, g

W2 = Weight of flask with fat, g

Figure 4.12 Soxhlet Apparatus

4.2.5.5 ANALYSIS OF DIETARY FIBRE

PRINCIPLE

The petroleum benzene ether-defatted samples are treated with enzymes that are similar to the digestive process in the human digestive system. The digestible carbohydrates are broken down into simpler sugars and then removed from the sample by precipitation and filtration. The non-digestible precipitates contain dietary fiber as well as protein and inorganic material.

METHOD

The sample was defatted with hexane before the fiber analysis. In a conical flask, 0.5 g of the defatted sample is suspended in 40 mL of MES-TRIS buffer treated with 50µL of α-amylase and then kept in a boiling water bath for 15 minutes at 95°C with continuous agitation and then cooled down to 60°C. 10 mL of distilled water is added to the conical flask. After that, 100µL of Protease was added and incubated for 30 minutes at 60°C in the water bath with agitation. After this, the flask was removed from the water bath, and 5 mL of 0.561M HCL solution was dispensed, and the pH was adjusted to 4.0-4.7 with 1M NaOH or 1 M HCl. About 300 µL Amyl Glucosidase was added, and the samples were incubated for another 30 minutes at 60°C. Then, the solution is filtered through a washed and dried, weighed, and marked glass crucible with a 0.5g Celite bed in a Buchner flask.

Residue (Insoluble Fiber)

The prepared digested solution is filtered, and the crucible residue is the insoluble fibre. It is then washed with 15ml of 78% ethanol, 15ml of 95% ethanol, and 15ml of acetone, then dried in a hot air oven at 105°C for 4 hrs. After cooling to room temperature in a desiccator, the crucible is weighed and placed in the muffle furnace for incineration at 550°C for 5 hours, cooled down in a desiccator, and weighed again.

Filtrate (Soluble Fiber)

The filtrate collected from the insoluble fibre was transferred to a beaker, and four times the quantity of preheated 60°C ethanol was added and kept overnight for precipitation. It was then filtered in a dried and weighed crucible with a celite bed. It is washed with 15ml of 78% ethanol, 95% ethanol, and 15 mL of acetone and then dried in the hot air oven for 4 hrs at 105°C, weighed at room temperature, and then kept for incineration in the muffle furnace at 550°C for 5 hours and cooled in a desiccator and weighed.

The dietary fibre can be calculated as follows,

$$\textbf{\% of dietary fiber} = \frac{(W1 - W2) - (W3 - W2) \times 100}{W}$$

Where, W = weight of sample,

W1 = weight after oven drying,

W2 = weight of empty crucible,

W3 = weight after muffle furnace drying

(a) Vacuum Pump

(b) Filtered glass crucible

Figure 4.13: Instruments used in dietary fibre analysis

4.2.6 PHYSICAL CHARACTERISTICS

4.2.6.1 Instrumental Colour Analysis

The surface color of the black rice-based noodles was measured using the HunterLab color measurement system (Labscan XE system, USA). The L*, a*, b*, and dE color scales were employed for this analysis. The L* value represents the level of lightness or darkness, with lower values indicating darker colors and higher values indicating lighter colors. The a* value reflects the degree of redness or greenness, where a positive value indicates red and a negative value indicates green. The b* value indicates the degree of yellowness or blueness, with positive values signifying yellow and negative values signifying blue. The dE value represents the color difference. These values are necessary for a complete description of the sample's color. A standard whiteboard made from barium sulfate (with 100% reflectance) was used as the reference to calibrate the instrument with the illuminant. The product was placed in a sample container, and reflectance was automatically recorded across wavelengths ranging from 360 to 800 nm.

Figure:4.14 Hunter L* a* b* Colour Analyzer

4.2.7 SENSORY EVALUATION

Sensory evaluation of black rice noodles encompasses an analysis of their unique visual, textural, and organoleptic qualities. Their striking purple-black color, derived from anthocyanin pigments, enhances their visual appeal. The texture is firm yet slightly chewy, reflecting the unique properties of black rice. A mild, nutty flavor complements the natural profile of the noodles, while a subtle earthy aroma adds depth to the sensory experience. The attributes evaluated in the test were appearance, color, aroma and flavour, discreteness, chewiness, taste, and mouthfeel.

Black rice noodles are cooked by boiling them in potable water until they achieve a tender yet firm texture. The cooking process involves bringing water to a boil, adding the noodles, and simmering them for 5-7 minutes, based on optimal cooking time and depending on the desired consistency. After cooking, the noodles are drained and rinsed with cold water to prevent stickiness and preserve their unique texture.

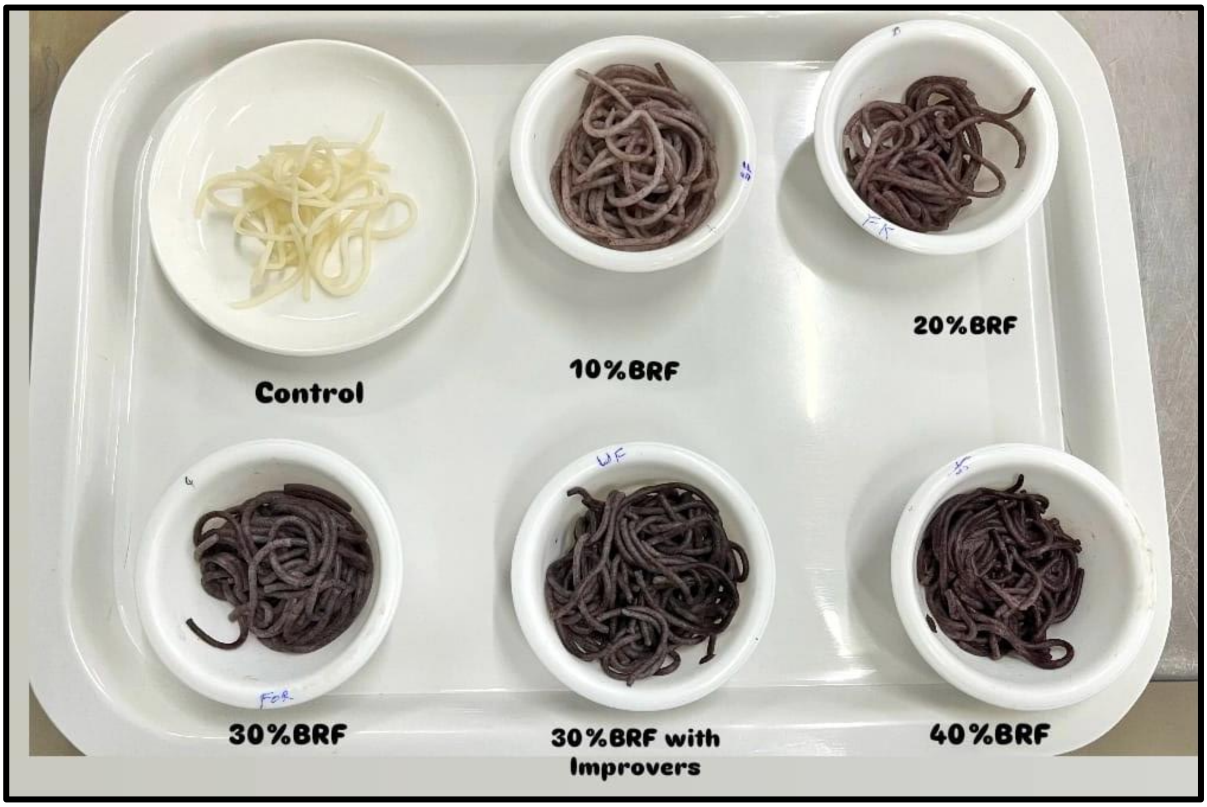


Figure 4.15: Black Rice Noodles, control, 10% BRF, 20% BRF, 30% BRF,30% BRF with Improvers, and 40% BRF [from left to right, top to bottom]

.4.2.8 PHYTOCHEMICAL ANALYSIS

Preparation of extract

To extract the free compounds, 25 mL of methanol was added to 10 g of each sample, and the mixture was stirred at 40°C overnight. The liquid was then filtered through a Whatman filter-40. The filtrate was centrifuged for 10 minutes at 5000 rpm and 25°C. The supernatant was collected and stored at -20°C in the dark until the total phenolic content (TPC) and total flavonoid content (TFC) were measured. The extraction was performed in triplicate.

Water bath

Centrifuge

Vortex mixer

Spectrophotometer

Cuvette

Ph meter

Figure:4.16 Instruments used for phytochemical analysis

4.2.8.1 TOTAL PHENOLIC CONTENT

Preparation of reagents

Folin-Ciocalteu's reagent (10%) - 10 ml of Folin-Ciocalteu's reagent in 100 ml of distilled water.

Sodium carbonate (7.5%) - dissolve 7.5 g of sodium carbonate in 100 ml of distilled water.

Quercetin was used as the standard in the TFC assay.
The total free polyphenol content of extracts was determined using the Folin-Ciocalteu method (Singleton & Rossi, 1965). For each sample, 80 µl was mixed with 1.0 ml of 10% Folin-Ciocalteu reagent and 0.8 ml of 7.5% sodium carbonate, and the volume was adjusted to 5.5 ml with distilled water. The mixture was incubated in the dark at 25 °C for 45 minutes. Absorbance was measured at 765 nm using a Shimadzu UV-VIS-1800 spectrophotometer (Japan). Total polyphenol content (TPC) was calculated using a standard gallic acid curve and expressed as mg of Gallic Acid Equivalents (GAE) per 100g dry weight. Each analysis was performed in duplicate.

(A) After Addition of Folin-Ciocalteu's Reagent (10%)

(B) Followed by Sodium Carbonate (7.5%) addition

Figure 4.17 Changes in the sample colour during various stages of total phenol content test

4.2.8.2 TOTAL FLAVONOID CONTENT

Aluminium chloride colorimetric assay (Woisky and Salatino, 1998)

Principle

The colorimetric assay for detecting flavonoids using aluminum chloride, as described by Woisky and Salatino (1998), involves the formation of a stable color complex when aluminum chloride reacts with flavonoids. This reaction occurs primarily with the C-4 keto group and the C-3 or C-5 hydroxyl groups, resulting in a stable complex in an acidic environment. Additionally, ortho-dihydroxyl groups in the A and B rings of flavonoids can form acid-labile complexes. The flavanol complexes exhibit maximum absorption at 510 nm, and the intensity of the color is directly proportional to the concentration of the complex.

Reagents and apparatus:

Aluminium chloride, sodium nitrite, quercetin, reagent bottle, conical glass test tubes, centrifuge, UV-Vis spectrophotometer, sample extracts

Preparation of reagents:

Aluminium chloride (1:10) - dissolve 10 g of aluminium chloride in 100 ml of distilled water.

Sodium nitrite (1:20) - dissolve 5 g of sodium nitrite in 100 ml of distilled water.

Sodium hydroxide (IM) – Dissolve 4 g of sodium hydroxide in 100 ml of distilled water.

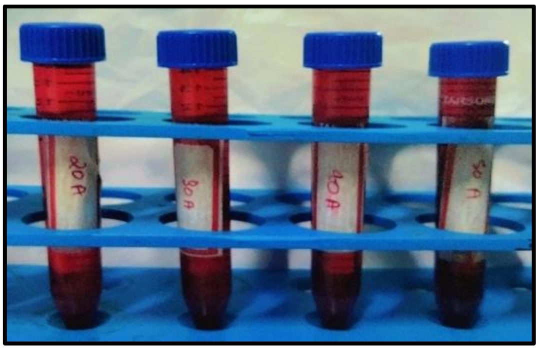
Quercetin was used as the standard in the TFC assay.

Preparation of extract

To extract the free compounds, 24 mL of acidified methanol (methanol: 1N HCl in an 85:15 v/v ratio) was added to 3g of each sample. The mixture was then agitated at 35°C for 40 minutes at 100 rpm, followed by filtration through a Whatman filter-40. The filtrate was centrifuged at 5000 rpm for 10 minutes at 35°C, and the supernatant was collected and stored at -20°C in the dark. The extraction procedure was performed in triplicate.

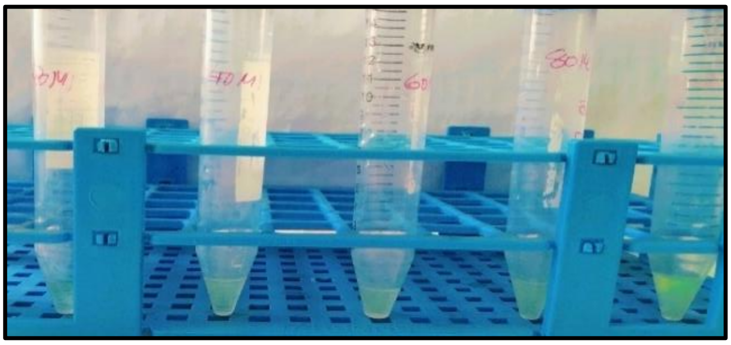
Procedure:

To create a standard curve, 3 mg of quercetin was dissolved in deionized water, and the volume was adjusted to 6 mL. A 250 µl aliquot of the extract was mixed with 1.25 ml of distilled water. To this mixture, 75 µl of 5% sodium nitrite was added, and the solution was incubated at room temperature (RT) for 6 minutes. Next, 150 µl of 10% aluminum chloride was added, and the mixture was incubated at RT for an additional 5 minutes. Following this, 0.5 ml of 4% sodium hydroxide was introduced, and the volume was adjusted to 3 ml with distilled water. The solution was thoroughly mixed and then centrifuged at 3000 rpm for 5 minutes to obtain a clear solution. The total flavonoid content (TFC) was determined by measuring the absorbance at 510 nm using a UV spectrophotometer.

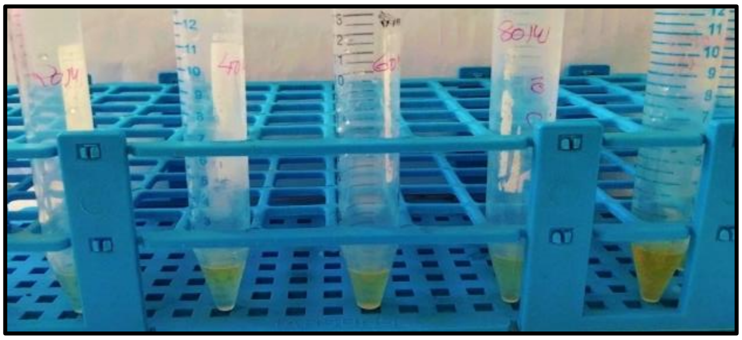


(a) After filtration (b) After centrifugation

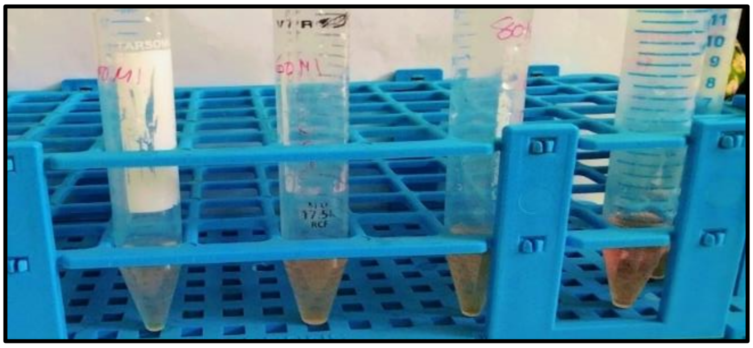
Figure 4.18: Acidified methanolic sample extracts



(a) Addition of sodium nitrite (5%)



(b) Addition of aluminium chloride (10%)



(c) Addition of sodium hydroxide (4%)

Figure 4.19: Changes in the sample colour during various stages of the total flavonoid content test

4.2.8.3 TOTAL ANTHOCYANIN CONTENT

Reagents and apparatus:

KCl buffer (pH 1.0) and sodium acetate buffer (pH 4.5), Test tubes, centrifuge, and UV-Vis spectrophotometer.

Principle:

A color change in the pH of monomeric anthocyanin pigments occurs at pH 1.0, where the colorful oxonium form is present, and at pH 4.5, where the colorless hemiketal form is observed. The difference in pigment absorption is directly proportional to the pigment concentration at 520 nm, with values expressed as cyanidin-3-glucoside equivalents. Degraded anthocyanins do not exhibit a color change regardless of pH and are excluded from the analysis, as they absorb at both pH levels.

Preparation of buffer:

KCL buffer – To prepare 0.03M KCl, weigh 0.2236 g of KCl into a beaker and add distilled water 100ml. Measure the pH and adjust it to 1.0 with HCl. Transfer to a 100, volumetric flask, and dilute to volume with distilled water

Sodium acetate buffer - Weigh 3.28 g sodium acetate in a beaker, and a distilled water 100 ml. Measure the pH and adjust it to 4.5 with HCl. Transfer to a 100 mL volumetric flask and dilute to volume with distilled water.

Estimation of total anthocyanin content:

The anthocyanin content was determined using a pH differential method. Two dilutions of the extracts were prepared: one with a 0.03 M potassium chloride buffer (pH 1.0) and the other with a 0.4 M sodium acetate buffer (pH 4.5), each diluted according to the previously determined dilution factor (extract: buffer ratio of 1:4 v/v). The mixtures were centrifuged at 4°C for 10 minutes at 1600 rpm to obtain clear solutions. The absorbance of the diluted extracts was measured at 520 nm. The total anthocyanin content was calculated using the following formula:

Absorbance = pH 1 - pH 4.5

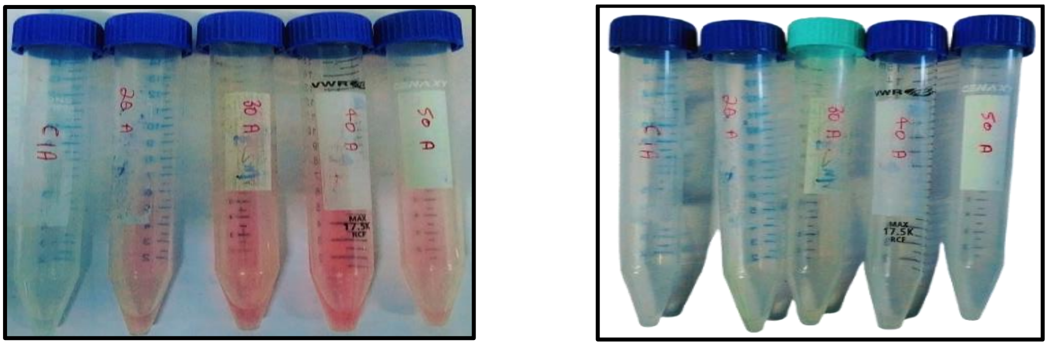
$$\text{Concentration (mg/g)} = \frac{\text{Absorbance} * \text{DF} * \text{MW} * 1000}{\varepsilon * 1}$$

where, MW = molecular weight,

DF = dilution factor

ε = molar absorptivity

The anthocyanin concentration was calculated and expressed as cyanidin-3-glycoside equivalents (mg/g). The molecular weight (MW) of cyanidin-3-glucoside is 449.2 g/mol, and the molar extinction coefficient (ε) for cyanidin-3-glucoside (cyd-3-glu) is 26,900 L/mol·cm. The path length (l) is 1 cm, and 1000 is the conversion factor from grams to milligrams. The total anthocyanin content was then converted to milligrams of anthocyanin per gram of sample.



(a) At pH 1 **(b) At pH 4.5**

Figure 4.20 : Changes in the sample colour during various stages of total anthocyanin content test

CHAPTER -5

RESULT AND DISCUSSION

5. RESULT AND DISCUSSION

5.1 FORMULATION AND STANDARDIZATION OF NOODLES

The water content in each formulation was modified according to the texture requirements and the water absorption characteristics of the raw materials. Consequently, the general formulation was adapted to meet these specific needs, as illustrated in Table 5.1

Table 5.1 Formulation and standardization of noodles

Sample	WF(g)	BRF(g)	Salt (%)	Water (%)	Improvers (%)	
					Gluten	Corn starch
Control	200g	0	1%	30%	0	0
10%	180g	20g	1%	30%	0	0
20%	160	40	1%	32%	0	0
30%	140	60	1%	32%	0	0
30%	130	60	1%	35%	5%	3%
40%	120	80	1%	32%	0	0

Standardization was conducted twice with meticulous care to ensure thorough mixing of the ingredients and adequate resting of the mixture for proper hydration. The water content was adjusted as part of the standardization process. Steaming was carried out for 3 minutes for the control sample and formulations containing 10% BRF. However, for formulations with higher percentages of BRF (20%, 30%, and 40%), the steaming time was reduced to 2 minutes. This adjustment was made to prevent excessive gelatinization of the starches and maintain the desired texture for semi-steamed noodles. Since the noodles were semi-steamed, no drying process was applied. Preliminary sensory and cooking quality assessments were then performed, and the 30% BRF formulation was selected based on its appearance, overall cooking quality, and sensory evaluation. To further enhance the quality characteristics of the 30% BRF formulation, improvers such as gluten and corn starch were added to the final product, and the water content was increased to 35% to ensure better hydration and improved functionality of the added improvers, facilitating optimal mixing, elasticity, and overall texture in the final product.

CONTROL

10%BRF

20%BRF

30% BRF

30% BRF with improvers

40%BRF

Figure5.1Standardizednoodles(a)Control, (b)10%BRF, (c)20%BRF, (c)30%BRF, (d)30%BRF improvers, (e) 40%BRF

5.2 CHARACTERIZATION OF WHEAT FLOUR

The characterization of wheat flour utilized for the preparation of noodles is provided in Table 5.1

PARAMETER	SPECIFICATION
Falling Number (sec)	515 + 5
Sedimentation Value (ml)	29.703 + 0.471
Dry Gluten (%)	9.021 + 0.002

Table 5.2 Characteristics of wheat flour

FALLING NUMBER

The activity of the enzyme α-amylase in flour is assessed using the falling number (FN) test, which is a crucial indicator of flour quality. α-Amylase is a cereal enzyme found in wheat after harvest, and its activity is influenced by the moisture content of the wheat kernels. Higher moisture levels in the kernels generally result in increased α-amylase activity, a common occurrence in grains exposed to wet conditions or improper storage. A higher falling number indicates that the plunger takes longer to pass through the slurry, suggesting that the grain has minimal enzymatic activity and has not begun to germinate. The falling number for the wheat flour was 515 ± 5 seconds.

ZELENY'S SEDIMENTATION

The quantity and strength of gluten in the flour sample influence the sedimentation value, which is measured by the volume (in milliliters) of settled gluten. Due to their lower density, gluten particles become less compact when they absorb more water in the presence of lactic acid, causing them to sediment or sink more slowly. The Zeleny sedimentation value for the wheat flour was 29.703 ± 0.471 mL, suggesting that the wheat flour used in this study had a medium-strong quality.

GLUTEN

Wheat contains a protein called gluten, which imparts the unique baking properties to wheat flour. The percentage of wet gluten and dry gluten in the wheat flour was determined to be 26.159 ± 0.057% and 9.021 ± 0.002%.

5.3 PROXIMATE COMPOSITION

PARAMETER	WHEAT FLOUR	BLACK RICE FLOUR
Moisture (%)	8.79 ± 0.13	8.21 ± 0.019
Ash (%)	0.83 ± 0.00	1.08 ± 0.00
Protein (%)	10.1 ± 0.24	8.12 ± 0.03
Fat (%)	1.60 ± 0.03	3.36 ± 0.22
Total Dietary fibre (%)	4.55 ± 0.28	4.88 ± 0.78

Table 5.3 Proximate composition of raw materials

The proximate compositions of wheat flour and black rice flour is listed out in Table 5.2

Moisture

Moisture content is closely associated with the shelf-life stability of food products, as higher moisture levels can enhance the risk of microbial spoilage. In this study, the moisture content of black rice flour was found to be similar to that of wheat flour. However, wheat flour had a slightly higher moisture content of 8.797 ± 0.132%, compared to 8.215 ± 0.0195% in black rice flour. This indicates that wheat flour is more likely to be susceptible to spoilage than black rice flour.

Ash

Ash content is an indicator of the mineral content in food. Black rice exhibited a higher ash content of 1.085 ± 0.001%, compared to wheat flour, which had an ash content of 0.830 ± 0.000%. This suggests that black rice has a superior nutritional profile, particularly in terms of its rich mineral content. Similar findings were reported by Anitha Kumari and Kassegn, who noted that colored flours typically have higher ash content and are a better source of minerals than white wheat flour.

Protein

The protein content of black rice flour is nearly comparable to that of wheat flour, although wheat flour contains a higher protein level (10.1 ± 0.24%) compared to black rice flour (8.12 ± 0.03%). This difference can be attributed to the higher gluten content in wheat flour. The elevated protein content in wheat is beneficial, as it supports the recommended daily protein intake and adds significant economic value. Furthermore, protein content is key in determining the quality and characteristics of the final products. In contrast, black rice is naturally gluten-free, which accounts for its slightly lower protein content relative to wheat flour. This makes black rice an excellent option for individuals with gluten intolerance or those following a gluten-free diet, while wheat flour remains the preferred choice for those requiring higher protein intake.

Fat

The fat content in flours contributes to the flavor and overall attractiveness of the final product. A notable difference in fat content was found between wheat flour and black rice flour. Black rice flour had a higher fat content of 3.36 ± 0.22%, compared to wheat flour, which contained 1.60 ± 0.03%.

Dietary fibers

Dietary fibers are carbohydrate polymers that cannot be broken down by the body's enzymes and are important for their various health benefits, including easing constipation, supporting weight management, and reducing the risk of diabetes and heart disease (Anitha Kumari et al.). Black rice is a valuable source of dietary fiber. Dietary fiber (DF) can be categorized into soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) based on its solubility in hot water (He et al., 2022). Black rice is an excellent source of dietary fiber. The content of insoluble, soluble, and total dietary fiber in black rice flour (3.25 ± 0.13%, 1.30 ± 0.15%, and 4.55 ± 0.28%, respectively) was significantly higher than that found in common wheat flour (3.28 ± 0.17%, 0.54 ± 0.18%, and 3.83 ± 0.28%, respectively).

Therefore, black rice can serve as a valuable aid for digestive health.

The table presents the proximate composition of the control sample alongside the 30BRF (optimized product). The graph illustrates the moisture content across various formulations. Since moisture content is closely linked to shelf life, water content was adjusted for different formulations. Moisture content was analyzed for all samples, including the control, as well as formulations with 10%, 20%, 30%, and 40% BRF, along with the 30% BRF formulation enhanced with improvers. Notably, the moisture content remains high in all formulations due to the extrusion process, followed by steaming for only 2 to 3 minutes, without any additional drying steps.

The moisture content observed was as follows: control (25.07 ± 0.27%), 10% BRF (21.47 ± 0.27%), 20% BRF (23.75 ± 0.39%), 30% BRF (27.29 ± 0.58%), 40% BRF (22.90 ± 0.41%), and 30% BRF with improver (27.83 ± 0.15%). The moisture-retaining properties of Black Rice Flour, attributed to its high starch and dietary fiber content, contribute significantly to the elevated moisture levels in all samples.

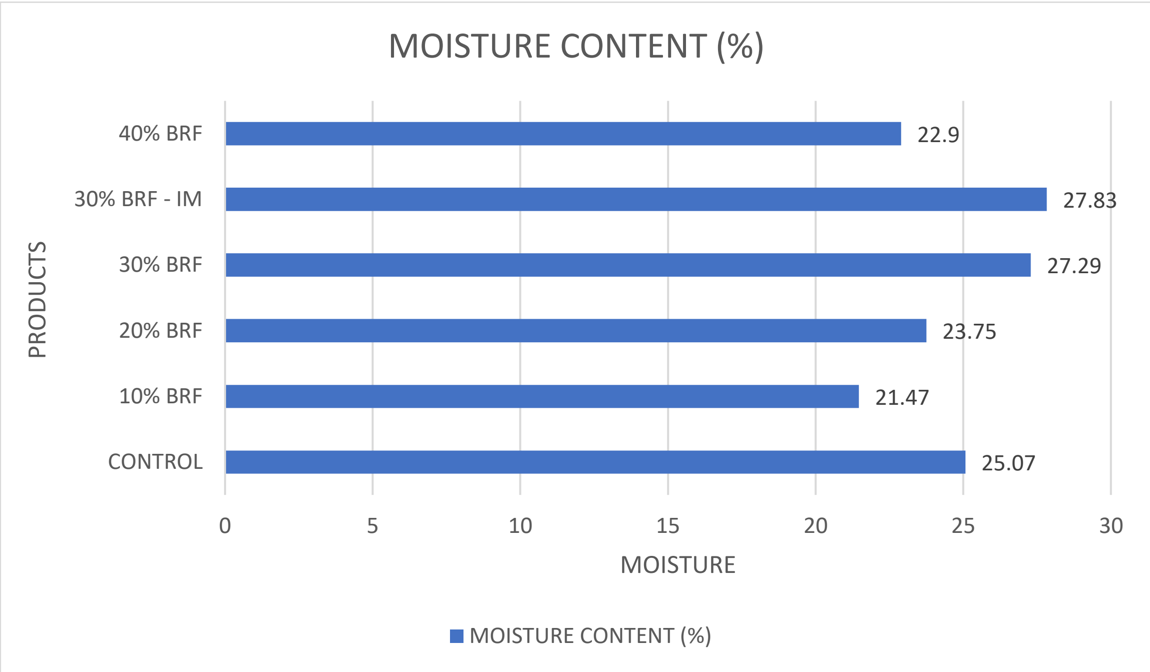


Figure 5.2 Moisture content of Noodles

5.4 PROXIMATE COMPOSITION OF SEMI-STEAMED BLACK RICE NOODLES

PARAMETER	CONTROL	30%
Moisture	25.07±0.27	27.29±0.58
Ash	1.04 ± 0.06	0.70±0.02
Protein	4.26 ± 0.02	3.95 ± 0.04
Fat	0.55±0.17	0.46±0.17
Total Dietary Fibre (%)	3.83 ± 0.28	4.06 ± 0.40

Table 5.4 Proximate composition of semi-steamed black rice noodles

The ash content of the control was found to be 1.04% ± 0.06%, and 30 BRF was found to be 0.70% ± 0.02%. The ash content of the flour samples slightly decreased upon extrusion.

Protein content plays a vital role in determining the quality and characteristics of the final product. Unlike wheat flour, black rice is naturally gluten-free, which partly accounts for its slightly lower protein content. The protein content in the control and 30% BRF samples was recorded at 4.62 ± 0.02% and 3.95 ± 0.04%, respectively. During the extrusion process, both starch and protein components may undergo slight alterations. The observed reduction in protein content can be attributed to protein denaturation caused by the high temperatures, pressure, and shear forces involved in extrusion.

The fat content in flour contributes to improving the flavor and overall quality of the finished product. The fat content of the control and 30% BRF samples was found to be 0.55 ± 0.17% and 0.46 ± 0.17%, respectively. The higher fat content in the flour compared to the extruded samples suggests that some fat is lost during the extrusion process, likely due to exposure to high temperature, pressure, and shear. This fat loss is also influenced by the characteristics of the fat, such as its melting point and solubility. Moreover, since higher fat content can increase the risk of rancidity over time, the reduced fat in extruded products contributes to their improved stability against rancidity.

Black Rice is a rich source of dietary fibre. Total dietary fibre content in control as well as 30% BRF,3.83 ± 0.28, and 4.06 ± 0.40, respectively.

5.5 COOKING QUALITY OF NOODLES

The cooking quality of semi-steamed noodles is a key factor in determining the overall acceptability of the product. It encompasses several attributes that reflect how the noodles respond to the cooking process, including cooking yield, cooking loss, and water absorption. These parameters help assess the texture, firmness, and overall performance of the noodles after cooking. The cooking quality of various formulations of semi-steamed noodles is illustrated in Table 5.5.

Sample	Optimal cooking time (min)	Water absorption (g/g)	Cooking loss (%)	Cooking yield	
				(g/g)	(%)
Control	5.62± 0.34	0.92 ± 0.002	6.18 ± 0.23	1.92± 0.002	192.08± 0.28
10%BRF	7.5 ± 0	1.07 ± 0.001	4.50± 0.89	2.07 ± 0.001	207.80 ± 0.15
20% BRF	6.87 ± 0.21	1.05± 0.04	6.18 ± 0.09	2.05 ± 0.04	205.27 ± 4.13
30% BRF	5.205 ± 0.20	± 0.10	7.08 ± 0.06	1.92 ± 0.10	192.36 ± 10.89
30%BRF IM	5.62 ±0.21	0.84±0.06	6.49±0.06	1.84±0.06	184.22+6.06
40% BRF	5.62 ± 0.21	0.88 ± 0.01	7.25 ± 0.21	1.88 ± 0.01	188.38 ± 1.60

Table 5.5 Cooking quality of various formulations of semi-steamed noodles

5.5.1 Optimal Cooking Time (OCT)

The optimal cooking time was determined to be the longest for the control group with 0% BRF (5.62 minutes) and the shortest for the formulation with 30% BRF (5.20 minutes). It was observed that increasing the concentration of black rice in the noodles led to a decrease in cooking time.

5.5.2 Water Absorption

The water absorption of the noodles was 0.92g per gram of sample for the control and 30%, also 0.92g per gram of sample.The water absorption for control and semi-steamed black rice noodles remains the same because the semi-steaming process does not significantly alter the noodles' structural or compositional ability to retain water. Additionally, the presence of black rice does not drastically change the interaction between the noodles and water during absorption, maintaining uniformity.

5.5.3 Cooking Yield

The cooking yield was observed for the control (1.92g per gram of sample) and for 30% also (1.92g per gram of sample The cooking yield remains consistent for both control and black rice noodles because the black rice incorporation does not significantly affect the retention of water or the overall mass during the cooking process. This suggests that the substitution of black rice flour maintains the structural integrity of the noodles, despite altering some compositional factors.

5.5.4 Cooking Loss

The cooking loss of noodles exhibited an upward trend with the increasing concentration of black rice. The highest cooking loss was recorded for 30% BRF (7.08%), whereas the lowest was observed for the control (6.18%). This increase may be attributed to the reduced gluten protein, which is essential for binding the components together.

5.6 PHYSICAL PROPERTIES OF NOODLES

5.6.1 COLOUR CHARACTERISTICS

The color of semi-steamed noodles plays a crucial role in determining their quality, consumer appeal, and overall acceptance in the food industry. Color analysis involves assessing the hue, brightness, and uniformity of noodles, which can be influenced by factors such as steaming duration, flour composition, and processing conditions.

The color characteristics of the noodles are presented in Table 5.5. It was observed that the L values were highest in the control sample and gradually decreased with increasing concentrations of black rice, indicating that the products became darker as the black rice content increased.

The **L*** value represents the lightness of a sample, ranging from 0 (pure black) to 100 (pure white), indicating its relative brightness or darkness. The **a*** value defines the red-green spectrum, with positive values shifting towards red and negative values towards green. Similarly, the **b*** value reflects the yellow-blue axis, where positive values indicate a yellow hue and negative values a blue tone. The **dE** value quantifies the overall color difference between two samples, calculated based on variations in the L*, a*, and b* values.

Additionally, the L values of the extruded products further decreased after steaming and cooking, suggesting a continued darkening effect during processing. The positive a and b values indicate that the color of the products leaned more towards red and yellow hues, rather than green or blue.

Sample		Colour			
		L*	**a***	**b***	**dE**
CONTROL	After Extrusion	52.02+0.41	1.64 ± 0.24	10.57 ± 0.51	29.42 ± 1.09
	After Steaming	65.46±0.61	2.40±0.04	13.61±0.15	29.42±0.61
10% BRF	After Extrusion	37.72+0.87	2.78+0.16	2.57+0.04	54.96+0.86
	After Steaming	45.14+0.56	3.15+0.02	4.26+0.04	47.65+0.56
20% BRF	After Extrusion	29.84+0.63	2.91+0.08	1.03+0.04	41.51+0.60
	After Steaming	34+0.55	3.14+0.06	2.34+0.04	58.75+0.54
30% BRF	After Extrusion	27.71+0.77	2.94+0.05	0.55+0.05	65.08+0.77
	After Steaming	29.42+0.47	3.23+0.08	1.23+0.06	63.31+0.46
30% improver	After Extrusion	29.03+0.52	2.31+0.04	0.62+0.06	64.21+0.63
	After Steaming	30.46+1.42	3.05+0.08	1.47+0.10	62.26+1.41
40% BRF	After Extrusion	29.00+0.71	2.66+0.03	0.15+0.05	63.80+0.71
	After Steaming	31.36+0.70	3.5+0.12	1.35+0.05	61.40+0.69

Table 5.6 Colour analysis of noodles formulations at different stages of production

Table 5.5 outlines the instrumental color analysis results for noodles subjected to different processing stages, including extrusion and steaming. The color properties of each formulation were examined at each stage to determine how the processing techniques influenced the final product's appearance.

5.7 SENSORY EVALUATION

The sensory evaluation of semi-steamed black rice noodles was conducted using formulations containing 10%, 20%, 30%, and 40% Black Rice Flour (BRF), along with a 30% BRF formulation improved with added improvers like gluten and corn starch. The evaluation focused on appearance, texture, flavor, and overall quality.

Results indicated that noodles with 10% BRF exhibited a mild purple hue and soft texture but lacked the characteristic firmness of noodles. Increasing BRF to 20% enhanced pigmentation and introduced subtle nutty flavors, with an improvement in chewiness. The 30% BRF formulation achieved the best sensory balance, characterized by deep purple color, optimal firmness, and a rich black rice flavor without bitterness. While the 40% BRF sample showed intense pigmentation and pronounced flavor, it was slightly brittle and less cohesive. The 30% BRF formulation with an improver further enhanced sensory appeal, delivering superior elasticity, glossy appearance, and balanced flavors, establishing it as the most preferred choice for optimal sensory attributes.

	CONTROL	10%BRF	20%BRF	30%BRF	30% BRF with improver	40%BRF
Appearance& Colour (15)	13.5	10.6	11.7	13.3	12.7	11.1
Firmness (10)	8.8	6.1	6	7.1	7.3	5.5
Aroma& Flavour (15)	11.1	10.4	10.9	12.7	11.9	10.7
Discreteness (15)	12.3	10.8	11.6	13	12.7	12.3
Chewiness (10)	7.6	6	5.9	7.4	6.8	5.5
Taste & Mouth feel (15)	11.9	9.9	10.1	12.1	12.2	10.8
	10.86666667	**8.966666667**	**9.366666667**	**10.93333**	**10.6**	**9.316667**

Table 5.7 Sensory evaluation of noodles formulations

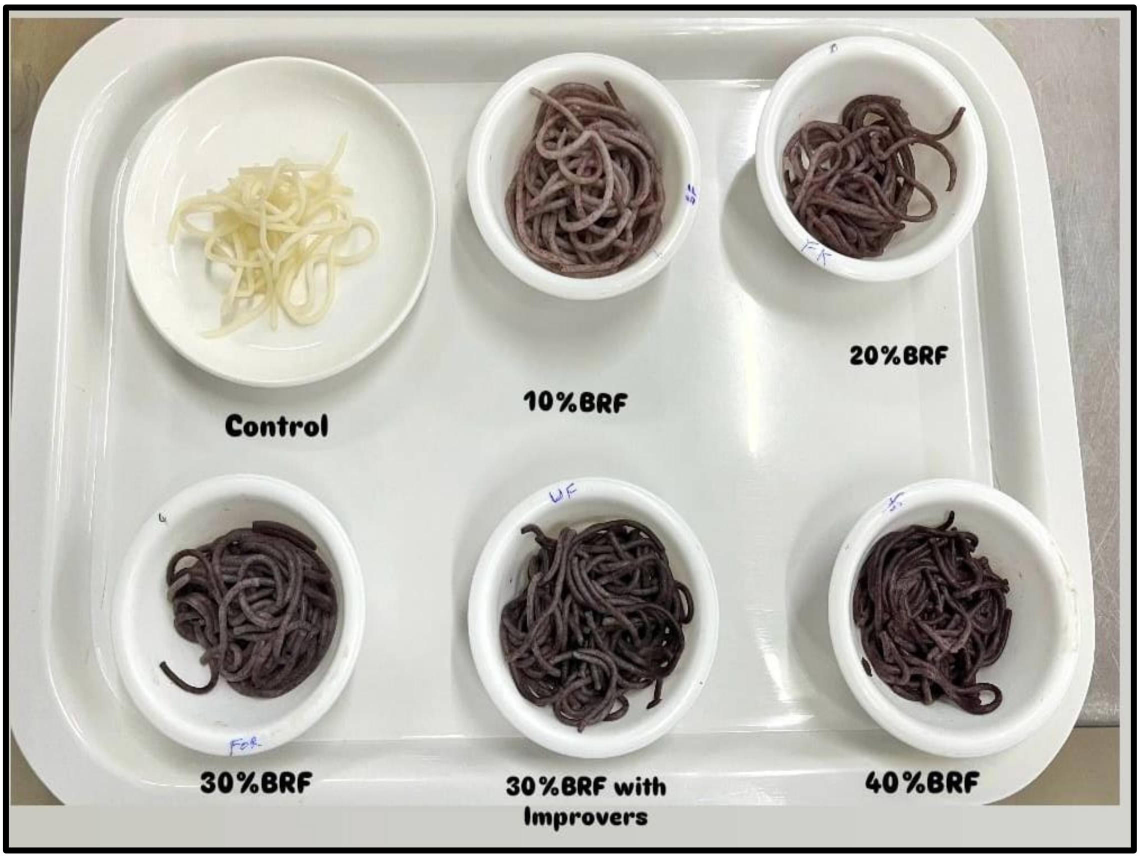


Figure 5.3: Noodles prepared for sensory evaluation

5.8 PHYTOCHEMICAL ANALYSIS

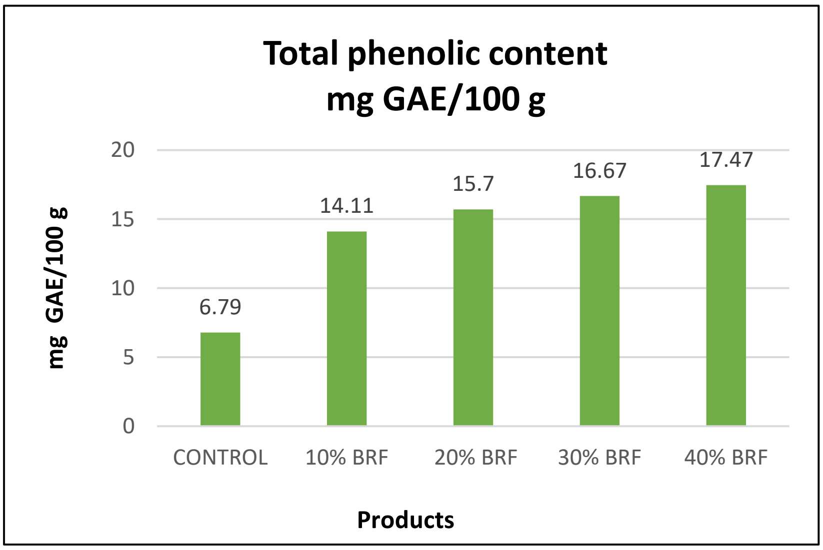
5.8.1 TOTAL PHENOLIC CONTENT

Phenolic compounds protect body tissues from oxidative damage by functioning as antioxidants. They also help prevent food spoilage and preserve its nutritional value. The total phenolic content (TPC) of noodles was measured using the Folin-Ciocalteu reagent method, with gallic acid as the standard. A linear calibration curve for gallic acid was constructed, and the calibration equation used was $y = 0.0108x – 0.0063$ ($R^2 = 0.9812$). The average amount of total phenolic compounds in the raw materials and noodles is presented in Table 5.6 and Graph 5.4 respectively.

Sample	TPC (mg GAE/100 g)
Wheat flour	11.7 ± 0.02
Black Rice flour	86.99 ± 0.70

Table 5.8 Total phenolic content of raw materials

The total phenolic content (TPC) of the noodles ranged from 6.79 ± 0.04 to 16.67 ± 1.01 mg GAE/100 g of sample. Among all the samples, the highest TPC was observed in the noodles with 40% BRF (40BF), while the control sample had the lowest. The TPC values for noodles with 10%, 20%, 30%, and 40% BRF substitution were 14.11 ± 0.83, 15.7 ± 0.66, 16.67 ± 1.01, and 17.47 ± 0.64 mg GAE/100 g, respectively. In contrast, the control sample showed a decrease in phenolic content compared to pure wheat flour, which had 11.7 ± 0.02 mg GAE/100 g.



Graph 5.4: Total phenolic content of noodles

According to Leenhardt et al. (2006), the decrease in total phenolic content may be attributed to the degradation or damage of antioxidant-active compounds in flours caused by thermal processing. Heat can modify the molecular structure of phenolic compounds, potentially decreasing their chemical reactivity or limiting their extractability due to partial polymerization (Altan et al., 2009).

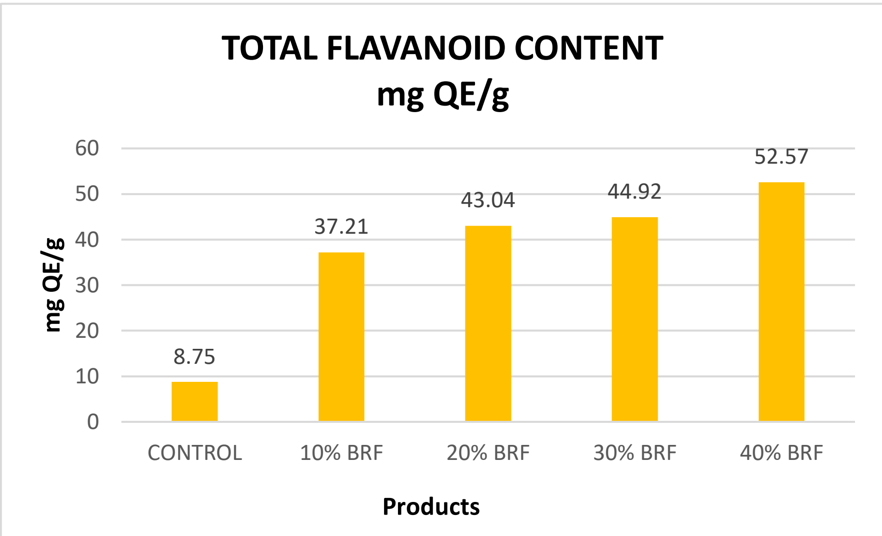
5.8.2 TOTAL FLAVONOID CONTENT

A linear calibration curve for quercetin was used, described by the regression equation $y = 0.0016x + 0.0047$ with an R^2 value of 0.9835. The average total flavonoid content in the raw materials and noodles is shown in Table 5.7 and illustrated in Graph 5.5.

Sample	TFC (mg Quercetin/g)
Wheat flour	15.91 ± 1.49
Black Rice flour	152.47 ± 1.94

5.9: Total flavonoid content of raw materials

The total flavonoid content in the raw materials—wheat flour and black rice flour—was 15.91 ± 1.49 mg quercetin/g and 152.47 ± 1.94 mg quercetin/g, respectively. In the noodle samples, flavonoid content ranged from 8.75 ± 2.65 to 44.92 ± 0.07 mg quercetin/g. The highest flavonoid concentration was observed in the sample containing 40% black rice flour (BRF). The flavonoid content in noodles with 10%, 20%, 30%, and 40% BRF was 37.21 ± 6.01, 43.04 ± 0.85, 44.92 ± 0.07, and 52.57 ± 3.28 mg quercetin/g, respectively. The control sample showed a lower flavonoid content compared to wheat flour, likely due to the loss of flavonoids during processing.



Graph 5.5: Total flavonoid content of noodles

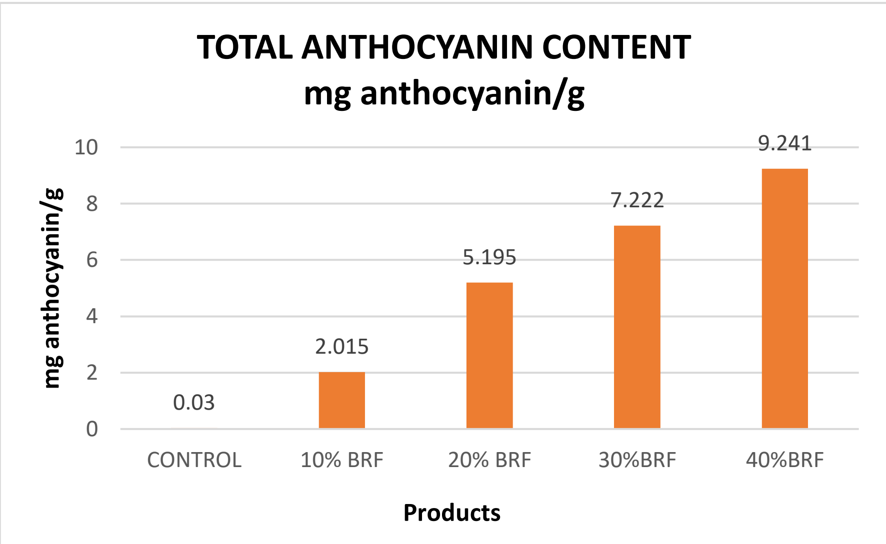
5.8.3 TOTAL ANTHOCYANIN CONTENT

Anthocyanins are water-soluble pigments commonly found in various plant parts such as leaves, flowers, and fruits. Their color varies depending on the pH level, due to the pH-sensitive nature of their chemical structure. At low pH levels, anthocyanins appear red; at neutral pH, they exhibit a purple hue; and in alkaline conditions, they shift to a blue color (Ibrahim et al., 2011).

Sample	**TAC (mg Anthocyanin/g)**
Wheat flour	0.006 ± 0.08
Black Rice flour	53.87 ± 0.49

Table 5.10 : Total anthocyanin content of raw materials

The total anthocyanin content in the noodles (Graph 5.6) and raw materials (Table 5.8) is presented below. Wheat flour contains negligible amounts of anthocyanins, as refined wheat flour typically lacks these pigments, unlike some specific wheat varieties. In contrast, black rice is rich in anthocyanins, primarily concentrated in its bran. Black rice flour recorded an anthocyanin content of 53.87 ± 0.49 mg/g. Among the noodle's samples, the highest anthocyanin level was observed in the 40% BRF sample, with 9.24 ± 0.41 mg/g. Anthocyanin content progressively decreased with lower BRF inclusion: 2.015 ± 0.007 mg/g for 10% BRF, 5.19 ± 0.065 mg/g for 20% BRF, and 7.22 ± 0.21 mg/g for 30% BRF. The control sample showed an extremely low anthocyanin level, similar to that of wheat flour.



Graph 5.6: Total anthocyanin content of Noodles

CHAPTER 5
CONCLUSION

CONCLUSION

The creation of anthocyanin-rich noodles with a blend of wheat and black rice flour (BRF) shows great promise for improving the noodles' functional and nutritional qualities. The noodles' proximate composition examination showed that their protein, ash, moisture content, and crude fiber levels were all balanced. The results of sensory analysis showed that incorporation of black rice at 30% was optimal in terms of important attributes namely firmness, discreteness, taste and mouthfeel. The cooking qualities of the noodles with black rice were within the desirable range in comparison to that of control. The addition of black rice enhanced the contents of total phenolic, flavonoid and anthocyanin in the noodles. The TPC values for noodles with 10%, 20%, 30%, and 40% BRF substitution were 14.11 ± 0.83, 15.7 ± 0.66, 16.67 ± 1.01, 17.47 ± 0.64 mg GAE/100 g whereas, the flavonoid content was 37.21 ± 6.01, 43.04 ± 0.85, 44.92 ± 0.07, and 52.57 ± 3.28 mg quercetin/g, respectively. It can be concluded that use of black rice in the production of noodles is a feasible approach in widening its application in popular food products. Considering the fact that Black rice-based food products are rare in the market at present, food product developed from aromatic black rice has the potential to capture the consumers who want exotic products.

CHAPTER - 6

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REFERENCE

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