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Red rice (*Oryza longistaminata*): Functional and nutritional properties and their utilization in the development of the value-added extruded product

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Abstract
Extrusion is high-shear, high-temperature processing. Most starch-based mixtures that are used to manufacture extruded snacks are typically high in carbs but deficient in other necessary ingredients. Consumers are now more and more interested in eating healthy meals. Pasta and baked goods are examples of products made from grain that is regarded as basic foods for human dietary needs. Utilizing whole grains in extruded foods is a very appealing way to create nutritious breakfast cereals. But wheat possesses the characteristics of gluten. It is less healthy because of this characteristic. Additionally, even among those who do not have celiac disease but prefer to lead a gluten-free diet, gluten-free foods have become more and more common in new recipes for cereal-based meals. Therefore, making extruded products healthful in addition to red rice flour is a very good option. Red rice is well known for having a high level of antioxidants because of the bioactive compounds found in the bran layers, such as phenolics and anthocyanins. In addition, the amylose, protein, fat, ash, water, and total phenolic content (TPC) of the rice flour as well as its pasting properties were assessed. The nutritional profiles, phenolic content, antioxidant capacity, technological characteristics, and colour characteristics of red rice flours and the extrudates that correspond to them were assessed in this study.

Keywords: Antioxidant, extruded food, less glutamic content, phenolics, red rice

1. Introduction

Many people all throughout the world get most of their nutrients from rice. As a result, it can be used as an efficient matrix to supply inadequate micronutrients to a large proportion of the world's population (Mishra *et al*., 2012; Saha and Roy, 2020a) [53, 74]. Due to this concept, fortified rice was created using a variety of methods, including brushing, wrapping, sonicating, sprouting, parboiling, spraying, and extruding rice (Saha and Roy, 2020a) [74]. Extrusion is by far the well-liked of them all. The flour from the shattered grains is used for fortification by extrusion. The acquired flour is then combined using nutrients, turned into a dough by the addition of water, and then transformed into rice-like goods (Mishra *et al*., 2012) [53]. A promising technology for processing rice is extrusion cooking, which can be used to meet customer demands for morning cereals that are convenient, attractive, tasty, and high in nutritional value. Chemical and structural characteristics may alter following the extrusion process depending on the screw speed and input moisture (Bhat *et al*., 2019) [5]. Food extrusion, a quick, high-temperature process, has grown in popularity for the ongoing manufacture of both inventive and classic items (Brennan *et al*., 2011; Darmadjati *et al*., 2001; Samyor *et al*., 2018) [7, 13, 76]. Annual wheat harvesting involves a sizable geographic area and involves about 600 million tonnes. Wheat has been successful because it produces a high yield in a variety of environments. Wheat dough has special processing abilities that enable it to be used in a variety of baked goods, including bread, biscuits, and pasta (Anonymous, 2014) [2]. In terms of technology, extrusion is the technique of applying pressure on food ingredients so they can pass through a die (Brennan *et al*., 2013) [8]. This may include shaping the material into new shapes or expanding it through kneading, melting, or other shearing processes (Karwe, 2009, Main, 2000) [37, 46]. Consumers today want "free" food in order to boost their health and well-being. Gluten-free (GF) foods have gained popularity as customers believe these are healthier alternative options. Gluten-free food may be inadvisable for common people because of reported nutrient deficiencies. In observatory data about gluten-free pasta made using whey, egg white and soy flour, it was noticed that egg white shortens the boiling time and increases its firmness (Phongthai *et al*., 2017) [68].

Red rice is processed into flour to make red rice flour. Making red rice into flour has several advantages, including as expanding its applications, making it easier to use, creating a product with greater nutrition, and allowing it to blend with other flours and components. Red rice is used because red rice flour contains a lot of anthocyanins, a flavonoid chemical with the capacity to function as an antioxidant that is essential for human health (Hernawan and Meylani, 2016) [29].

2. Rice

In terms of global production, rice is the second most popular cereal crop. Among the most significant basic foods consumed by humanity is rice (Muthayya *et al*., 2014) [55]. Arroz-de-Veneza" and "Arroz-da-terra" are other names for red rice. The botanical name of rice is *Oryza sativa.* As well as the botanical name of red rice is *Oryza longistaminata.* Rice belongs to the Poaceae family (Pereira *et al*., 2008) [66]. Rice contains tannin pigment which gives the hulled rice a red or brown colour to the rice. China was the first nation to produce rice in the 14th and 15th centuries. the "Taitoumai" variety of red Indica rice. Other varieties of rice are eaten polished when red rice is eaten unpolished or partially polished due to maintaining the colour of pigmentation present in the bran layer. Red rice contains more nutrients compared to white rice. Rice contains lots of calories that are not good for our health (Laokuldilok *et al*., 2011) [41]. Generally, the consumption of red rice in Indonesian people is very less because they are habituated to eating polished rice when the red rice is eating unpolished, making them disappreciate while eating. A highly effective way to enhance the intake of red rice is to turn it into flour (Rewthong *et al*., 2011) [71].

2.1. Types of rice

There are various enhanced rice cultivars, notably Inpari (irrigated rice), Hipa (hybrid rice), Inpago (upland rice), and Inpara (swampy rice), according to the Indonesian Centre for Rice Research. Additionally, the ICRR introduced enhanced rice varieties such Sibundong, Inpari 27, Inpara 7, and Inpago7 (Goufo and Trindade, 2014) [21]. Rice comes in a wide range of colours and flavours, including brown, black, white, red, wild, jasmine, bomba, and coconut rice. A type of rice known as "red rice" has anthocyanin, which gives it its red colour (Pereira *et al*., 2008) [66].

2.2. Nutritional composition of rice

It is believed that rice's nutritional composition has a significant impact on its technological qualities. The stiffness, volume, and stickiness of cooked rice can change resulting from interactions between proteins, lipids and starch during cooking. (Martin and Fitzgerald, 2002) [48]. According to (Xie *et al*., 2007) [94] one of the most important aspects to take into account when analysing the cooking behaviour of rice is the amylose concentration since it directly impacts the stiffness of the grain and, therefore, the stiffness of cooked rice. Even though red rice is typically eaten as partially milled (Pereira *et al*., 2008) [66], discovered that it takes longer to cook well and had less amylose than white rice. When evaluating the rice's ability to be cooked and the flour's ability to resemble paste, viscosity is a crucial technological consideration. In rice breeding programs, the selection of alternatives with known quality benefits from the viscosity characteristics, according to as mentioned in (Zhang *et al*., 2008) [92], but is prone to varietal variances.

2.3. Composition of white and red rice

As suggested by (Strock *et al*., 2005) [84] 8.94% protein, 8.74% fibre, 0.36% fats and 0.30% ash are all present in polished white rice. Different concentrations of magnesium 23.3 to 58.1, manganese 0.7 to 2.0, calcium 11.6 to 34.9, zinc 0.2 to 0.3, iron 0.2 to 3.3 and potassium 81.4 to 151.2 mg 100 g^{-1} rice. Carbohydrates, vitamins, minerals, fatty acids, and amino acids these kinds of nutrients appear in red rice (Heinemann *et al*., 2005) [27]. The primary elements of red rice (nonspecific genotype) include zinc 3.3%, iron 5.5% mg 100 g^{-1} rice, fibre 2.0% and protein 7.0%. Red rice characteristics are subjected to varietal differences, as with any rice variety like-, growing conditions (climate, soil, location), types of processing, cooking time (35 to 41 m), the content of zinc (19 to 40 mg kg^{-1}), the content of amylose (15 to 25 mg kg^{-1}), noted fluctuations in productivity (6000 to 11000 kg ha^{-1}) and pot yield (200 to 250%) (Pereira *et al*., 2009) [67].

3. Health benefits and functional properties of red rice

3.1. Health benefits of red rice

For its nutritional value and health advantages, red rice has been valued throughout history. The rice named "Imperical rice," which was made for the Emperor is one of its common names. After black rice, red rice is the most abundant source of phytochemicals (Pengkumsri *et al*., 2015) [65]. In various Asian nations, including China, India, Japan, and Korea, red rice has a reputation for being healthier than other types of cereal. It prevents food shortages and cures diseases like vitamin A deficiency (night blindness) and vitamin B. The health advantages of its phytochemicals, particularly phenolic compounds and their antioxidant qualities, are given extremely healthy attention (Liu, 2017) [44]. The antioxidants included in red rice have a role in preventing colon cancer, hepatitis (liver illness), diabetes, and stroke. They are also crucial for brain function and lessen the impact of an ageing brain. The facts of anthocyanin present in red rice is 0.34 to 93.5 mg g^{-1} (Hernani, 2005) [28]. Proteins, minerals, fibre, and vitamin B are all abundant in red rice. Minerals that are selenium can increase endurance, as well as fibre can prevent constipation and vitamin B can nourish the digestive system and nerve cells (Fitriani, 2006) [18]. In addition to actively promoting particle absorption and the conversion of beta-carotene into vitamin A, red rice also contains compounds that are anti-inflammatory and antioxidant, which can help fight cancer (Frei, 2004) [19]. The greatest nutrients are found in black and red rice as compared to white rice. Obesity and chronic dietary-related illnesses including diabetes, hypertension, celiac disease, and cardiovascular disease are on the rise in every country in the world. Due to the prevalence of these disorders, food scientists and nutritionists are currently focusing on the relationship between dietary factors and a variety of sickness risks. Due to its significance in diets, rice has garnered increased attention from billions of people throughout the world (Saleh *et al*., 2019) [75].

3.2. Antioxidant properties of red rice

Red rice contains 6.79 to 12.23 mg of anthocyanin 100 g^{-1} (Indrasari *et al*., 2010). Red rice contains anthocyanins (antioxidants) which are present in every part of the grain, even on sepals, not only found in the pericarp. It also contains nutrients in a higher amount such as protein and fibre compared to other rice (Laokuldilok *et al*., 2011) [41]. Six categories of antioxidants have been identified in rice: Tocopherols, tocotrienols (vitamin E), phenolic acids, anthocyanins, proanthocyanins, phytic acids, and alpha-oryzanol (Goufo and Trindade, 2014) [21]. Red rice's anti-oxidant qualities are utilized throughout Asia and Oceania to create bread, vinegar, coloured pasta, alcoholic drinks, medications, and cosmetics (Pantindol *et al*., 2006) [62]. Red rice's antioxidant capabilities and health-promoting benefits have received particular attention for at least 20 years. The primary components of whole red or black rice are anthocyanins and proanthocyanins, which have been shown to reduce oxidative stress and benefit human health (Shao *et al*., 2018) [79]. Red rice has antioxidant properties that reduce the rate of oxidation. Antioxidants can prevent the damaging effect on the free radical tissue of red rice (Irie *et al*., 2004) [35]. Red rice has great potential and is incredibly nutritious, especially because of its antioxidant characteristics. It is used to make healthy food products, such as baby food (Masni and Wasli, 2019) [49].

3.3. The phenolic compound of red rice

The rice grain's bran and embryo, which together made up 59.2% of the total phenolic acids, contained the majority of the phenolic acid, one of the secondary metabolites (Shao *et al*., 2014) [78]. It is essential to the antioxidant system. Red rice, of all rice kinds, is frequently utilized in Japan for functional foods as it contains a lot of phenolic components (Itani and Ogawa, 2004) [36]. Free phenolic acids are at least as frequent as bound phenolic acids, those that are most typical of the three phenolic components (Shao *et al*., 2014) [78]. The two phenolic acids identified as most prevalent in coloured rice are ferulic and p-coumaric acid (Gangopadhyay *et al*., 2016) [20]. The total phenolic compound (TPC) is made composed of all substances that have phenol groups, including phenolic acids, flavonoids, anthocyanins, and proanthocyanins (Goufo and Trindade, 2014) [21]. When compared to its non-pigmented rice genotypes, coloured rice, for example, red or black rice, has a highly rich phenolic component content. The pericarp of rice, which makes up around 2-3% of the rice caryopsis, is where the phenolic component of rice is mostly found. It may be divided into three main classes, including flavonoids, proanthocyanins, and phenolic acid. The most prevalent phenolic compounds are flavonoids and phenolic acids. They often come in both soluble (conjugated) glycoside forms and insoluble forms. The stomach and small intestine absorb the free and soluble linked phenolic molecules (Acosta-Estrada *et al*., 2014) [1].

4. Rice flour properties

Rice flour may be used as a cereal component to make gluten-free goods since it is natural, hypoallergenic, colourless, and bland-tasting. Rice often contains just a tiny quantity of prolamin, therefore it is required to add the right additives, like dairy products, emulsifiers, and gums, to make the system more consistent or vicious. As an alternative, modifying the rice flour is a sensible strategy. The physical alteration of rice flour has been used by many researchers in the past (Gujral *et al*., 2004) [23]. A significant portion of rice flour, or around 80%, is starch, which when heated may gelatinize and have the ability to bind water, making it useful as a food processing ingredient. Without experiencing any chemical treatment, extrusion cooking is a practical way to enhance the functional qualities of rice flour. Additionally, by using this method, starch retro-gradation is prevented when starch-rich food goods are stored. Additionally, physically altered flour is the preferable material with the lowest amount of health risk (Hagenimana *et al*., 2006) [24]. Researchers found that the kinetics of digestion dramatically slowed down as the size of the rice flour's particles increased (Farooq *et al*., 2018) [17]. There isn't as much information available about the effective moisture diffusivity of rice dough and baked items as there is for other meals (Hamdami *et al*., 2006) [25]. Understanding moisture diffusivity is necessary for the proper planning and optimization of the food production cycle, which includes drying, rehydrating, extruding, packing, and storing (Zogzas *et al*., 1996) [93]. The diversity of amylose content, which reflects rice flour's innate characteristics related to gel formation, is another way that rice flour is identified (Hu *et al*., 2020) [32]. The main traits of rice starch to be discussed are their amylose content or amylose-amylopectin ratio, pasting behaviour and gelatinization (Nishita and Bean, 1977) [58]. Rice flour is comparatively insensitive to water molecules because of the complex structure of ingredients in rice flour (Arendt and Dal Bello, 2008) [3]. In the transitional phases between other stages, particularly ones between particular starch grains, and rice proteins, as well as other phases, water molecules can be discovered (Roozendaal *et al*., 2012) [72].

4.1. Red rice flour properties

One alternative option is to turn red rice into flour, it will be more durable for storing, making it simpler to blend with another material, have the ability to be fortified with additional nutrients, and speed up subsequent processing. The flour will be a very useful product that will meet life's requirements for great mobility (Indriyani *et al*., 2013) [34]. One of the semi-finished red rice products is red rice flour, which has the advantages of being formed, having a longer shelf life, being simple to blend (to make composite), is fortified with nutrients, and cooking more quickly when necessary (Darmadjati *et al*., 2001) [13]. Although it looked that the initial gelatinization temperature was reduced during the polishing process, there were no discernible patterns in the impact on viscosity when the starch granules broke. The viscosity value changes as the granules disintegrate depending on the amount of milling (0, 30, and 60s of polishing duration) and the composition of the various constituent elements. According to (Park *et al*., 2001) [64], the viscosity of ruptured starch increased while the starting temperature of gelatinization dropped with increasing polishing degrees, however, this difference was not statistically significant. Furthermore, it was said by (Hasjim *et al*., 2013) [26] that differences in the degree of carbohydrate structure in rice flour, including particle size, molecular branching architecture and sugar granule level, were identified and linked to starch gelatinization and paste characteristics.

4.2. Importance of drying in red rice flour

As a way to preserve grains throughout transportation, drying is a crucial step. When rice is harvested, its moisture level is normally approximately 20%, dropping to 13% during storage. The study of rice drying has mostly focused on method optimization, mostly based on physical characteristics like breaks and splits, with a focus on methods of continuous drying, like intermittent and sun drying (Mukhopadhyay and Siebenmorgen, 2017) [54]. In the preparation of flour, drying is one of the important steps. The action of drying involves lowering a material's water content to a predetermined level (Lidiasari *et al*., 2006) [42]. If the material is heated uniformly during the drying process, each of the moisture will evaporate. The finest physical, chemical and sensory properties were found in red rice flour that had been dried for two hours (Indriyani *et al*., 2013) [34].

5. Wheat

There are three most important crops in the world 1st is wheat, 2nd is rice and 3rd is maize. under climate change maintaining grain quality for human nutrition is critical. The scientific name of wheat is *Triticum aestivum* L. Wheat is one of the most important staple grains in the world. Over worldwide 672 million tonnes of wheat are produced in 2012 (Anonymous, 2014) [2]. Increasing environmental stress or climate change affects the quality of wheat production and yield. Wheat is an extremely important staple food source among the few crop species. Wheat is mainly important because its seed can be ground into flour, semolina, etc., which is a basic ingredient for bread, biscuit, cake, and other bakery products, as well as pasta, etc (Lindsay, 2002) [43].

5.1. Gluten properties of wheat

The storage proteins that create a network called gluten in the dough are what give the dough its viscoelastic qualities (Schofield, 1994) [77]. As a result, throughout the course of more than 250 years, in order to understand the structures and characteristics of gluten proteins and provide the groundwork for improving end-use quality, much research has been done on these proteins (Shewry *et al*., 1986) [80]. Prolamins are a class of proteins that were first identified by their solubility in alcohol-water solutions, often containing 60-70% (v/v) ethanol (Osborne, 1924) [61]. Since then, this description has been increased to include similar proteins that, because they are found in polymers stabilized by interchain disulphide links, are insoluble in alcohol-water mixtures in their natural condition. Gluten is made up of these monomeric and polymeric prolamin units in wheat, which are known as gliadins and glutenins, respectively (Shewry *et al*., 1995) [80]. The genotypes of red rice and black rice can serve as suitable substitutes for patients with celiac disease or gluten sensitivity since they are both hypersensitive and gluten-free (Melini *et al*., 2019) [50]. In a previous experiment, our research team used the response surface approach to fine-tune the extrusion settings to produce 100% coloured rice flour breakfast cereals that were free of gluten and had favourable expansion, texture, and colour qualities (Meza *et al*., 2019) [51].

4.4. Wheat flour
A few of the technologically relevant enzymes included in wheat flour are amylase, protease, lipase, Oxygenase, polyphenol oxidase, and peroxidase. The majority of alpha-amylase is found in the pericarp of wheat grains, which is distinct from the aleurone layer and seed coat (Kruger and Tipples, 1980) [40]. Most protease is found in the endosperm, aleurone layers and germ (Evers and Redman, 1973) [16]. The scutellum and embryo are both rich in Lipoxygenase (Blain and Todd, 1955; Miller and Kummerow, 1948) [6, 52]. The majority of the enzymes in bran layers are polyphenol oxidase and peroxidase. Despite the fact that they are inactive when grain and flour are kept, these enzymes become active when water is introduced and are essential in determining the functional qualities of flour (Honold and Stahmann, 1968) [31]. Through a variety of break and reduction rollers, the wheat kernel is continuously reduced as part of the roller flour milling process. Due to this, many flour streams are produced, each with differing amounts of endosperm, bran, and germ. As a result, the levels of activity of various enzymes in various flour mill streams change, and as a result, do their functional features. There are multiple data available on the levels of ash and protein in different flour mill streams (Dick *et al*., 1979; Dube *et al*., 1987; Holas and Tipples, 1978; Nelson and Loving, 1963; Nelson and McDonald, 1977; Ranhotra *et al*., 1990) [14, 15, 30, 56, 57, 69].

6. Extrusion process
Extrusion cooking is a method of food processing that involves a number of unit activities, including mixing, cooking, kneading, shearing, shaping, and forming. In terms of technology, extrusion is the technique of applying pressure on food ingredients so they can pass through a die. This may include shaping the material into new shapes or expanding it through kneading, melting, or other shearing processes (Karwe, 2009; Main, 2000) [37, 46]. There are multiple processes in this process, including mixing, degassing, mechanical and thermal heating, shaping, and expanding (Kokini *et al*., 1993; Paul and Guy, 1994; Saha and Roy, 2020a) [39, 74]. A promising technology for processing rice is extrusion cooking, which can be used to meet customer demands for morning cereals that are convenient, attractive, tasty, and high in nutritional value. The extrusion process affects the structural and chemical properties, which might change according to the feed moisture and screw speed (Bhat *et al*., 2019) [5]. Additionally, it may have an impact on the amounts of phenolic compounds and antioxidant activity. A decrease in total phenolics and antioxidant activity has been noted by some authors (Gujral *et al*., 2012) [22]. Among others, a rise in phenolics following the extrusion of rice (Xu *et al*., 2016) [91]. High temperature, pressure, and shear forces are used in this technology to create greatly expanded, low-density materials with distinctive textural qualities. (i.e., crispness, crunchiness) This technology uses a high temperature, pressure, and shear to produce highly expanded, low-density materials with unique textural characteristics (i.e., crispness, crunchiness). Extrusion is divided into three categories: cold, warm, and hot extrusion depending on the process temperature. All of these procedures make use of rice flour that has been broken down; it is then combined with food ingredients and the dough is created by kneading it with water. The variations are caused by the temperatures during dough production and reformation. Hot extrusion is done above starch melting temperatures, whereas cold extrusion takes place below starch melting temperatures (Paul and Guy, 1994). At temperatures that result in the partial melting of amylopectin, a middle procedure known as warm extrusion takes place. Only during heated extrusion can amylopectin get mostly melted. The gelatinization level is indicated by this melting process. Numerous attempts have been made to create extruded goods using these techniques (Paraman *et al*., 2012) [63]. Response surface methodology (RSM) is suggested for studies on extrusion processing since it enables investigating the links between the responses and the experimental levels of each factor and determining the ideal circumstances. The goal of this study was to use the Response Surface Methodology to examine how the substitution of corn flour for whole grain wheat flour, extrusion conditions, feed moisture, and the third and fourth cooking zones affected the quality parameters (sectional expansion, density, texture, colour, and water activity) on the development of expanded breakfast cereals, including texture after soaking in milk (Triveni *et al*., 2001) [87].

6.1 Extruded products
Ready-to-eat (RTE) breakfast cereals have increased in popularity among extruded goods as a result of the convenience and usefulness promises made about them. These products, which are frequently drunk with milk at breakfast, are thought to be a good source of micronutrients thanks to their fortification with vitamins and minerals. Whole cereals are also a good source of dietary fibre, making them a nutritious choice. The bulk of cereal items are created from refined flour and contain less dietary fibre and other nutrients despite the recommendations, labelling, and marketing campaigns that highlight their health benefits. Comparative analysis of whole grain and health-promoting chemicals raw substance. The increase of dietary fibre in foods, particularly grain-based products like expanded ready-to-eat (RTE) breakfast cereals, has been encouraged by health and nutrition policies (including those of the Food and Agriculture Organization of the United Nations, the Food and Drug Administration, and the Whole Grains Council in the United States of America). In this situation, using whole grains in extruded products—such as whole-grain wheat flour—can be a good substitute for using refined grains to create healthy breakfast cereals (Oliveira *et al*., 2015) [60]. The cereal microstructure and texture are significantly impacted when refined flours are substituted with whole grain flours in extruded products. This problem must be resolved by modifying the combination of raw material characteristics and extrusion parameters (Brennan *et al*., 2008; Rzedzicki and Blaszczak, 2005) [9, 73]. Therefore, it has been difficult for the food sector to modify procedures so that they produce goods with a decent taste and texture.

6.1.1 Pasta
Consumers today want "free" food in order to boost their health and well-being. Gluten-free (GF) foods have gained popularity as customers believe these are healthier alternative options. Gluten-free food may be inadvisable for common people because of

reported nutrient deficiencies. In observatory data about gluten-free pasta made using whey, egg white and soy flour, it was found that egg white shortens boiling time and increases its firmness (Phongthai *et al*., 2017) [68]. The increase in celiac disease and immune reactions to protein gluten has created new market opportunities for pasta manufacturers, especially in the segment where gluten-free supplies are still limited. Eliminating gluten is difficult for a quality product because it is an important constituent of popular pasta textures. For gluten-free pasta, the firmness is mainly provided by starch, the degree of the gelatinization process plays a crucial role in the production process (Lucisano *et al*., 2012; Mariotti *et al*., 2011) [45, 47]. In fact, the use of pregelatinized starch let for the use of standard pasta while non-gelatinized starch sources require gelatinization during the process. Proteins, hydrocolloids and emulsifiers are also generally combined in formulations to improve the workability of gluten-free dough and the quality of the final product (Carini *et al*., 2014) [11]. The nutritional properties of gluten-free pasta are different from conventional products due to their low content of fibre, resistant starch and protein with high glycemic index and starch digestibility.

6.1.2 Noodles

In Thailand, red rice is used to make rice noodles, which are well-known traditional Asian dishes. Despite this, there aren't many scientific studies on this specific variety of noodles. Rice noodles are traditionally processed through a number of procedures. To create a rice slurry, rice grains either whole or broken are soaked. The slurry is heated for around three to five minutes. The noodle sheets are then taken and dried in a series of procedures to reduce moisture content (Wu *et al.*, 2015) [90]. Manufacturing one batch takes about 20 hours. This is why making traditional rice noodles has a reputation for being difficult and time-consuming. Additionally, because of the lengthy process involved in making rice noodles, there are variations in quality and, consequently, in customer satisfaction (Tan *et al*., 2009) [85]. Manufacturers of rice noodles must address these challenges. For the purpose of overcoming these drawbacks, rice noodles are prepared using extrusion technology. To modify the moisture content, rice flour is added before being extruded into rice noodles (Charutigon *et al*., 2008) [12]. The normal rice noodle dish made from rice flour with low amylose content (<20%), such as red rice flour, has a poor quality like texture, cooking loss and other sensory properties. It is brought on by the amylose's three-dimensional networks' slower growth (Wang *et al*., 2016) [88].

7. Conclusion

Extruded goods have been more popular in recent years, however, their use on the market is accompanied by health risks due to their refined flour content. This review revealed that, in comparison to other cereals, red rice is particularly nutritious. In order to make extruded items healthier, red rice flour can be fortified with wheat flour. Phytochemicals and antioxidants in red rice are quite potent. Red rice can retain more micronutrients when fortified through an extrusion method as opposed to other methods. The product's physicochemical, rheological, and microstructural qualities are influenced by additional processing parameters. Nutritional retention can be increased by mixing the flours of other grains with red rice. There may be sufficient bioactive molecules in these extrudates to support physiological processes important to health.

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