Utilization of rice bran for wheat flour substitution in noodle product development: a review

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Abstract. Rice bran is a by-product of polishing in the rice milling process. Rice bran contains numerous bioactive compounds with a beneficial effect on human health, namely dietary fiber, flavonoid, tocopherol, tocotrienol, and gamma-oryzanol. Since the trend of healthy food has been rising, rice bran has been taken an interest to use in functional food development. Noodle products are often developed as a functional food due to widely consumed foods and as a great carrier to deliver bioactive compounds. The utilization of rice bran could change noodle quality attributes which influences market acceptance. Dietary fiber in rice bran could affect noodles cooking quality and texture profile. Stabilization of rice bran before use could reduce adverse effects of rice bran on noodles' quality. Noodle processing such as kneading and cooking could affect antioxidant compounds. The aim of this paper is to review rice bran substituted noodle quality, including nutritional product value, factors affecting noodle characteristics, and methods to improve rice bran noodle quality. This paper discussed not only noodles enriched with white rice bran but also with red and black rice bran. Thus, it could provide broad information to support further rice bran utilization in noodle development.

1. Introduction

FAO [1] reported that the world production of rice paddy and milled rice are 755.47 and 503.90 million tonnes in 2019. Bran is the main by-product of rice milling and comprises 8-10% of the total weight of rice, but it is susceptible to rancidity by the presence of lipase [2]. Rice bran utilization is limited because it's prone to rancidity, while it contains numerous phenolic acids, flavonoids, vitamin E, phytosterol, \( \gamma \)-oryzanol, gamma-aminobutyric acid or GABA, and dietary fiber. Bioactive compounds are present in different forms and concentrations in rice bran due to their variety of rice, namely white rice, red rice, and black rice. Due to its bioactive compounds, rice bran can give a health-promoting effect such as cholesterol-lowering ability, anti-diabetic, and antioxidant activity [3, 4, 5]. For example, free sterols and \( \gamma \)-oryzanol can inhibit HMG-CoA reductase, bile acid, and lipase activity through their binding ability towards the enzymes [3]. Dietary fiber could bind with bile acid and reduce amylase accessibility to its substrate, thus could delay glucose and cholesterol absorption in the intestine [4]. Fractionated vitamin E from rice bran has been studied in animal diets to decrease total cholesterol and LDL cholesterol levels [5].

In the last few years, the market size for functional food products is increased due to the consumer's awareness of healthy diets [6]. Rice bran utilization in noodle products is overcome not only by the excessive amount of by-products but also by the potential to increase the economic value of rice bran in
developing countries that produce rice. Rice bran utilization can increase nutritional value and give health-beneficial properties to noodle products, but it affects noodle physical quality. Therefore, this paper aimed to discuss the effect of rice bran substitution on noodle quality and essential factors in noodle production in an effort to reduce the deleterious effect of rice bran. This model is built based on the result of a literature review from several studies related to rice bran and noodle production.

2. Material and methods
This paper was organized using the systematic review as the main method to survey and analyze the recent literature. A literature survey has been carried out from quantitative and qualitative empirical studies published in several leading international journals such as the Journal of cereal science, the journal of food science and technology, cereal chemistry journal, and other journals. Literature within the scope of the review has been collected and extracted using an aggregator database including Scopus, Crossref, and Google Scholar, and using publisher database, including Elsevier. Paper traced by using keywords related to rice bran and noodle production such as “rice bran antioxidant”, “rice bran stabilization”, “rice bran fractionation”, “fiber-enriched noodle”, and “hydrocolloid and noodle”. After screening based on the contents of these articles, only 26 as the final samples for further review and analysis.

3. Rice bran bioactive compounds
Bioactive compounds in rice bran could vary due to their rice variety, milling methods, and length of the milling process. Red and black rice bran have a greater amount of total phenolic acid than brown-colored bran obtained from white rice polishing, but they have a similar phenolic acid composition [7]. Anthocyanin accumulation in rice pericarp gives a dark purple color on black rice, while red rice bran color is mainly given by proanthocyanidin [8, 9]. Phytosterols in rice bran consist of free sterol, steryl ferulate, and steryl glycoside, whereas γ-oryzanol is a mixture of steryl ferulates [10]. Dietary fiber in rice bran mainly consists of insoluble dietary fiber, namely lignin, cellulose, and hemicellulose [4]. Rice milling using the abrasive method could produce rice bran with higher fiber content than the friction method [11]. A longer milling time could obtain a greater amount of bran with lower γ-oryzanol content [12]. Various bioactive compounds that have been detected in rice bran are presented in Figure 1.

![Figure 1. Bioactive compounds found in rice bran.](image-url)
4. Rice bran bioactive compounds stability in noodle

Rice bran substitution in noodle products increased the concentration of fiber, polyphenol, and flavonoid, also increased antioxidant activity [13, 14, 15]. However, noodle processing could cause the loss of antioxidant compounds. Mixing and kneading the dough could decrease γ-oryzanol, phenolic acid, and vitamin E due to the continuous incorporation of oxygen that promote oxidative degradation of antioxidant [16, 17]. Disulfide bond scission can also form thyl radicals that could decrease antioxidant content in the product [18]. Several studies also use vacuum mixing to prevent oxygen contact with the noodle, such as in polyphenol enriched noodle processing [19]. It was reported by Wang et al. [20] that adding rice bran after mixing wheat flour and water first could result in higher retention of γ-oryzanol. Catechin can also degrade during mixing because it is less stable in pH 6 or higher. This can be overcome by using a lower amount of alkaline salt in noodle processing [18]. Both polyphenol and flavonoid compounds are sensitive to the thermal process, but polyphenol was more thermal sensitive [21]. Dry heating could cause catechin degradation, but it did not lead to vitamin E loss [17, 18]. Furthermore, noodle cooking increased total bound phenolic acid. This could cause by the strong interaction between phenolic compounds and protein or carbohydrate [16].

5. Rice bran noodle physical quality

Rice bran substitution in noodle products could affect noodle-cooking quality and texture as shown in Table 1. Rice bran particle could disrupt the gluten matrix and create a space between bran particle and matrix, providing a path to promote water absorption, which induced excessive starch swelling and rupture [22]. Higher amount of rice bran substitution generally increases fiber concentration which could decrease disulfide bonds formation in the dough, thereby inhibiting gluten aggregation and decreasing its ability to prevent starch to leach during cooking [23, 24]. Low amount of fiber may be dispersed and incorporated into the matrix, but fiber impact in gluten matrix could become significant in higher amount of fiber [23, 25].

| Rice Bran               | Noodle Products          | Noodle Physical Quality                                                                 | References |
|------------------------|--------------------------|-----------------------------------------------------------------------------------------|------------|
| White rice bran        | Dry noodle               | Bran substitution (2-20%) led to a significant increase water absorption and cooking loss, and shortened cooking time. | [14]       |
|                        | Dry Turkish noodle (erişte) | Rice bran substitution (10-30%) increased water absorption and volume expansion, but decreased adhesiveness, cohesiveness, and springiness. | [15]       |
|                        | Dry pasta                | Substitution of rice bran (5-25%) caused higher water absorption, volume expansion ratio, and cooking loss. | [22]       |
| Red rice bran          | Dry noodle               | Noodle with red rice bran substitution (5-25%) had higher water absorption.            | [26]       |
| Black rice bran        | Fresh noodle             | Black rice bran substitution (2-15%) did not significantly affect water absorption and cooking loss, but significantly decreased adhesiveness, cohesiveness, and springiness of the noodle. | [13]       |

Lower cohesiveness and springiness showed that noodles texture could disintegrate more easily and less elastic, while lower adhesiveness suggested that the noodles are less sticky [15]. Noodle adhesiveness is positively correlated with peak viscosity value, whereas the stronger binding force of fiber and water resulted in fewer gelatinized starch [23]. A higher concentration of fiber, flavonoid, and polyphenol could decrease peak viscosity, which would affect starch gelatinization [23, 27, 28]. Gluten strength could be weakened by fiber, flavonoid, and phenolic acid by inhibiting disulfide bond formation during mixing [23, 29]. Phenolic acid, flavonoid, and anthocyanin as strong antioxidant compounds could interact with thyl radicals resulted from disulfide scission in the mixing process. This can prohibit disulfide bonds from reforming [29].
6. Factors affecting rice bran noodle quality
Rice bran noodle production generally begins with the rice bran handling process including particle size control and rice bran stabilization. Other than the rice bran handling, the amount of water used in the dough and the addition of hydrocolloid and vital gluten during the ingredient mixing can also improve the noodle quality. These methods are the main factors that were used to reduce deleterious effect of rice bran on noodle quality. The effect of these factors is described in Table 2.

Table 2. Factors affecting noodle quality.

| Methods                              | Effects                                                                 | References  |
|--------------------------------------|-------------------------------------------------------------------------|-------------|
| Rice bran particle size reduction    | Producing smaller rice bran particles can minimize gluten matrix disruption, thus improving noodle flexibility. | [26, 30]    |
| Rice bran stabilization              | Inhibit the rancidity of the rice bran with minimal nutrient loss and prevent it from degrading noodle quality. | [2, 31]     |
| Adjusting water addition             | Minimize dehydration of protein that could lead to an adverse effect on gluten network formation. | [15, 32]    |
| Addition of hydrocolloid or vital gluten | Improve the gluten polymer network of the noodle, therefore improving noodle texture and cooking quality. | [26, 14, 33, 34, 35] |

6.1. Particle size
Particle size reduction by sifting can separate rice bran fractions with different particle sizes, specifically broken rice, rice embryo, coarse rice bran, and fine rice bran [36]. Sifting could decrease dietary fiber content in bran and lower antioxidant activity due to larger surface area that promotes oxidation of phenolic compounds, while small particle size can improve bioactive compound extractability [37, 38]. Particle size reduction can also be made by grinding, but it has not been used in rice bran noodle production. According to Cao et al. [39], rice bran was ground by hammer and ball milling after the extrusion process, which resulted in a more homogeneous particle size distribution of rice bran, also increased γ-oryzanol, GABA, and total phenolic concentration compared to control.

6.2. Rice bran stabilization
Rice bran is obtained through a milling process that allows lipase to reach and degrade rice bran oil which leads to the rapid rancidity of the bran, therefore stabilization is needed to inactivate the lipase enzyme [31]. There have been several heat treatments used to stabilize rice bran, such as oven drying, microwave, infrared radiation, extrusion, and drum-drying. Stabilization with oven drying requires a longer processing time compared to infrared and microwave stabilization. Hence it is considered to be less efficient [40]. Saji et al. [41] and Cao et al. [39] found that heating treatments could increase free phenolic compounds because heat stabilization can lead to the breakdown of cell wall structure and structural linkage related to bound bioactive compounds, thus releasing phenolic compound, γ-oryzanol, and GABA. γ-Oryzanol has been reported to be thermostable since it did not significantly reduce by oven drying, microwave, and infrared stabilization [40, 42]. Yilmaz et al. [42] found that high intensity infrared radiation with a short time can result in lower vitamin E losses by degradation. In several studies, rice bran is moistened before subjected to microwave heating by adding certain amount of water to prevent charring [14, 40]. In addition, microwave stabilization with a moistened rice bran could increase water absorption capacity by 14.8% [40]. Extrusion with various temperatures and moisture could also increase water holding capacity and swelling index of rice bran as extrusion along with grinding could destroy the ordered structure of rice bran starch [39].

6.3. Addition of water
The research conducted by Tuncel et al. [15] increased the amount of water used for noodles substituted with a higher level of rice bran. Rice bran was known to have higher water absorption capacity than wheat flour, and adding more high-water binding material requires more water to improve the dough mechanical properties [14, 43]. Insoluble fiber which presents abundantly in rice bran limits the
hydration of starch and protein in dough causing a solid-like texture of the dough which requires high mechanical strength in dough mixing [23].

6.4. Food additives
Several studies have used several food additives to improve rice bran noodle quality, such as CMC, gelatin, and vital gluten [14, 26, 33]. Hydrocolloids including CMC and gelatin are used in dry noodles to increase noodle-cooking yield and tensile forces, also decrease cooking loss [34]. Adding a fiber-rich material in noodle products can affect gluten network development and weaken the protein-starch matrix, resulting in a negative effect on cooking quality and texture [35, 44]. CMC can form a stable polymeric network around the starch granules, restrict excessive swelling, and inhibit the diffusion of amylose to the noodle surface [35]. Vital gluten is separated gluten from wheat flour which is commonly used in whole-grain products to achieve a stronger dough strength by improving the formation of intra-molecular and inter-molecular disulfide bonds, thus creating a strong tridimensional network which able to entrap starch granules [34, 35].

7. Product acceptance and further research opportunities
As discussed previously, several studies have been reported that rice bran substitution has a significant effect on noodle quality that could determine the product acceptance. Red rice bran substitution up to 15% resulted in the increase of noodle acceptance in aroma, taste, and texture [26], while white rice bran substitution decreased overall noodle acceptance due to a darker color and the addition of branny flavor of the noodle that was not desirable by young panelists [15]. A different result is shown by Ertaş [33], lower level of rice bran substitution increased taste acceptability as it gives a nice aroma to the noodle. Bran could add a desirable sweet and nutty flavor when substituted in pasta products [22]. Based on the research conducted by Al-Okbi et al. [45], the darker color of rice bran pasta products is comparable to the commercial high fiber pasta in the market. Rice bran noodle researches have been focusing on the substitution effect, therefore further studies on the development of rice bran noodle are needed. Different types of rice bran variety, handling methods, combination of food additives and process modification can be studied further to produce a good quality of noodle with notable amount of bioactive compounds.

8. Conclusions
Rice bran substitution can increase water absorption and cooking loss, improve nutritional value, and influence texture properties of noodle products. Rice variety, milling methods, and milling time can affect rice bran bioactive compounds. Rice bran noodle quality can be improved by rice bran particle size reduction, stabilization, addition of hydrocolloids and vital gluten, and adjusting the amount of water in the dough.

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