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Rice as an alternative feed ingredient in swine diet

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Abstract

Rising feed costs have made it important to explore and study alternative feed ingredients for cost-effective animal production. In addition to this, it is desirable to find efficient and functional alternative ingredients for traditional feed ingredients in pig feed, considering the stress of the pig and the sensitivity of the disease. Rice is produced around the world, like corn, the energy source in typical pig feed. Although the nutritional quality varies depending on the degree of milling, rice, except whole grains (paddy rice), contains more starch than corn, and its structure and granule size are easier to digest than corn. In addition, the fact that rice has fewer non-starch polysaccharides(NSP) and anti-nutritive factors is also effective in improving digestibility, and various polyphenols can help improve immune response, which can be beneficial to the gastrointestinal environment and pig health. Many studies have been conducted on rice focusing on things such as degree of milling, substitution rate of corn, size, and processing methods. Most results have shown that rice can be partially or completely used to replace corn in diets without negatively affecting pig growth and production. While further research should focus on the precise biological mechanisms at play, it was confirmed that the use of rice could reduce the use of antibiotics and pig removal, and protect pigs from gastrointestinal diseases, including diarrhea. From this point of view, rice can be evaluated as a valuable feed ingredient for swine diet.

Keywords (3 to 6): Alternatives, nutrition value, rice, pig

Introduction

In the animal production industry, it has become important to explore and research alternative feedstock for cost-effective animal production due to the rising cost of feed [1]. It is needed to find efficient alternative ingredients to traditional feed ingredients in swine diets. There have been many attempts to find alternative feed ingredients as energy sources in pig diet with competitive feed costs [2 - 4]. As a result, several candidates, including distillers dried grains with solubles (DDGS), copra meal, palm kernel expellers, and other by-products have been identified as alternatives to replace corn [5, 6]. While the proposed alternatives have the advantage of being able to supply energy at an efficient price, they tend to contain numerous fibers that are difficult for pigs to digest and in addition, they rely heavily on imports [7 - 9].

Post-weaning stress, a major challenging event in pig production is one of the most important factors of high mortality and morbidity in nursery pigs [10, 11]. Weaning stress may lead to reduced feed intake, poor growth,

and increased susceptibility to disease [12, 13] and in addition, also causes dramatic changes in intestinal physiology and immunology [14 - 16]. Immaturity in the immune system in the weaned pigs can reduce the immune response to the pathogens and increase the sensitivity of weaned pigs to disease [17]. Thus, it is necessary to develop a diet that is not only highly digestible but one that also has functional ingredients.

Rice is a seed of grass species widely cultivated as a source of food and, Asia has a suitable climate for producing rice, which is richer than other grains. Rice is the world's third most grown staple crop, with 741.5 million tons being produced annually, providing 50 percent of the world's calories along with corn and wheat [18, 19]. Rice is an excellent source of carbohydrates, has a higher starch content than corn, contains the most useful -NSP for humans, and is more expensive than other grains [20, 21]. Therefore, the use of rice as animal feed has been restricted.

Current changes in eating habits has led to increased consumption of wheat, meat, and fruits instead of rice [22]. With the development of agricultural technology, rice production in Asia has gradually increased; thus, the decrease in rice consumption increases the stock of rice [23]. Therefore, there have been many attempts to use rice and their by-product as feed ingredients. In addition, if rice is used as an energy ingredient in swine diet, it is independent of import and has been shown to be highly applicable to the swine industry.

The type of rice differs depending on the cultivation area and variety. The products generated according to the processing stage are largely divided into whole grain (paddy rice), unpolished rice, polished rice, and their byproducts including rice bran, broken rice, and rice mill produced during the milling process as feed [24]. Therefore, in this study, the nutritional value of rice in swine production will be reviewed.

Physicochemical Features of Rice

The physical structure of grain plays an important role in preventing the loss/destruction of nutrients in the grain from internal and external factors during storage [25]. In the end, the structural characteristics of grains also contribute to the chemical properties and decomposition of nutrients during digestion [26, 27].

The seeds of rice, are a form of wrapping caryopsis with palea and lemma, which is a husk(hull) with one spikelet [28]. The hull protects the rice inside and prevents the infestation of fungi and pests from outside. The whole grain rice is consisted of husk, seed coat, nucleus, endosperm, and embryo (germ) and the brown rice is produced when hull is removed from whole grain rice in first processing. When milling brown rice, the germ and rice bran are removed and the white starch layer remains, which is referred to as white rice (polished rice). When making white rice from brown rice, 10% of the rice weight is lost. The weight ratio of each part constituting rice

is slightly different according to the type of cultivar. In general, paddy rice consists of rice hull (16%-26%), germ (1.5%-2.5%), bran (3.8%-6.7%), and endosperm (64.8%-79.7%) [29]. There are variations of rice depending on the region and cultivar. In addition, rice is available in a variety of colors such as white, red, purple, and black as the pigments in the pericarp determines the color of rice grain [28].

Rice appears to be used as a feedstuff since rice includes more starch compared with other conventional cereal grains [30]. However, paddy rice cannot be a food or feed ingredient in mono-gastric animals since 20 % of the weight of paddy rice consist of rice hulls, which are composed of considerable amounts of crude fiber: lignin and silica [31, 32] (Figure 1).

Nutritional Composition of Rice

The nutritional composition of rice varies slightly, depending on the subspecies (e.g., *Indica, Japonica*), climate, soil, and cultivation methods. In general, rice hulls account for 20% of the weight of paddy rice and is composed of a considerable number of fibrous components, such as lignin and silica [32]. The amount of white rice, brown rice, germ, and bran produced from whole grain rice varies depending on the degree of milling. The major nutrient components of brown rice and white rice are carbohydrates (70%-90%), proteins (7%-8%), and fats (1%-2%), and most of the carbohydrates are starch [33], [34]. The gross energy values per 100g of brown rice and white rice are approximately 370 kcal [34].

White rice is a rich and digestible concentrate with low fiber content and high digestible nutrients compare to other rice products. Compared to white rice the brown rice has been known to have relatively lower carbohydrates, but higher protein, fat, and vitamins because the brown rice contained bran and germ.

The major components of rice bran are carbohydrates (35%-40%), crude protein (10%-15%), crude fat (15%-20%), and in addition phosphate and vitamin B groups are also abundant [34]. As such, rice bran contains excellent sources of protein, vitamins and minerals. However, there are many NSP in rice bran, which is difficult for pigs to digest [35]. Thus, in terms of digestion and utilization, white rice has a nutritional value almost 25% higher than rice bran [36].

The rice germ contains approximately 28%, 20%, and 18% of carbohydrates, fat, and crude protein, respectively[37], so the ratio of main nutrients is much higher than that of rice or rice byproducts, and in addition the germ is also rich in vitamin B and phosphate compounds[37, 38]. The rice germ has excellent nutritional value as a feed ingredient for swine diet, but it occupies a very small portion in rice, and has poor stability during storage due to the presence of highly active lipoxygenase [31]. Therefore, to minimize oxidative rancidity reaction and

maintain nutrients, it is stored by blocking contact with oxygen in the form of whole grains.

Starch is a natural polymeric carbohydrate in which many glucose units are connected by α -glycoside bond [39, 40]. It is essentially made from two structurally different polymers: amylose (linear; α -1,4) and amylopectin (branched; α -1,4 and α -1,6). Depending on the plants, starch generally consists of 70%-80% amylopectin and 20%-30% amylose [41], whose molecular number is smaller than that of amylopectin [40]. In addition, amylose composed of α -1,4 glycosidic bonds is easily hydrolyzed by animal digestive enzymes e.g. α -amylase [39, 43, 44]. Unlike starch, structural polysaccharides such as chitin, cellulose, and peptidoglycan are bound by β -glycosidic bonds and are highly resistant to hydrolysis. Therefore, it requires microbial enzymes to breakdown [45].

Characteristics of different varieties of rice differ due to the ratio of amylose and amylopectin. The 'waxy' starches contain less than 15% amylose, 'normal' 20%–35% and 'high amylose' amylose starches greater than approximately 40% [46]. In this result, *Indica* is less viscous because amylose contents in *Indica* (25%-30%) is higher than in *Japonica* (15%-22%) [47]. Besides, the size of the starch granules varies depending on plant species [48]. The starch granules in rice are relatively small (apporoximately 2 μm), while potato starch granules are relatively large (more than 100 μm) [49].

Hence rice contains various polyphenols (e.g. tocopherol, tocotrienol, and γ -oryzanol) having an antioxidant function but also γ -aminobutyric acid which has been known to a bio-active compound. [50, 51]. These compounds have been reported to have the effect of improving immune responses by stimulating innate immunity [52-53]. Therefore, the use of rice as a feed ingredient has therapeutic benefits for many gastrointestinal diseases such as diarrhea, gut health, and inflammatory bowel diseases in human nutrition [54]. The antioxidant and physiologically active ingredients are known to be more present in pigmented rice including brown rice, purple rice, and black rice than in white rice [55]. Because for example, anthocyanin is present as a pigment in rice bran, and tocopherol exists in rice germ [37, 55]. White rice is obtained after milling both rice bran and rice germ.

Anti-nutrient factors in rice such as phytic acids, trypsin inhibitors, and lectin, are is low, and they are usually present in rice bran and embryos [56-57]. Phytic acid binds to minerals such as zinc, copper, iron, magnesium, niacin and calcium preventing their absorption. Trypsin inhibitors make it difficult to digest proteins. Lectin (Haemagglutinin-lectin) binds to specific carbohydrate receptor sites in the intestinal lining and impede nutritional absorption. However, since lectin and trypsin inhibitors are heat sensitive, they are deactivated during the heating process. They are usually present in rice bran and can be easily separated during the milling process [56, 58].

Feeding Value of Rice Compared to Corn

Rice is an excellent source of carbohydrates, contains more starch and low NSP compared with corn, known as a traditional feed ingredient, but it more useful for humans and more expensive than corn [20, 21]. This is because starch, which has the highest proportion of rice, has a high nutritional value [20]. In terms of various benefits, especially in the case of rice starch, characteristics such as unique flavor, taste, small granules, hypo-allergenic property, and digestibility [21, 59]. Starch granule size could also affect the digestibility of energy [60, 61]. It has been found that the size of starch is smaller in rice than in corn [46, 62]. The larger the starch granules, the smaller the surface area to volume, which leads to less binding to the enzyme and consequently reduce the potential for hydrolysis [63 - 65]. Therefore, the digestibility values are supportive of better performance of pigs fed rice than those fed corn [21, 39]. White rice is a rich and digestible concentrate with low fiber content and high digestible nutrients than corn [36]. Therefore, white rice has approximately a feeding value 25% higher than rice bran and 12%-15% higher than corn [36].

It seems, however, a waste to employ white rice as feedstuff for animals because the milling process requires higher cost, and some nutrients including vitamins and fatty acids can be destroyed after the milling process. On the other hand, paddy rice has a low processing cost, but it has too much fiber content that is difficult for pigs because of the rice hulls. For the above reasons, Li reported that brown rice, could be the best to be feedstuff to pigs [66].

Compared with corn, brown rice has similar concentrations of gross energy, crude protein, and ether extract, but, in fact, the amount of starch, essential amino acids, and fatty acids in brown rice are comparatively higher than corn [66-71] (Table 1).

Application of Rice for Swine Diets

Compared to various rice by-products, white rice has been studied extensively as a feed component of animal diet (eg, pigs, poultry).- Studies have focused mainly on the particle size [72, 73], processing methods [65, 74], and substitution rate of corn [75]. Many studies have shown that white rice can replace a proportion of corn in swine diets without negative effect in pigs [20, 72]. Yang et al. (1992) reported that there was no negative effect on the growth performance and carcass composition when rice was fed instead of corn in growing-finishing pigs [76].

Previous studies have shown that the digestibility of nutrients in pigs fed to rice was improved over those fed corn [77]. Furthermore, digestibility was found to increase when the rice was heat-treated and fed to pigs in a gelatinous form , created through gelatinization, which is conducted at a higher temperature for rice than other

raw grains [59, 65, 78]. In particular, Pluske et al. (1996) have shown that cooked white rice could protect pigs from swine dysentery [78]. They explained that by reducing the substrate for bacterial fermentation in the large intestine, it may have a significant impact on the gastrointestinal environment such as nutritional absorption, and microbial balance and population. Similarly, according to Che et al., the pig removal and antibiotic treatment rate of pigs fed to rice was lower than that of corn [75].

Although previous studies have focused on white rice mainly, in some countries, such as China and the United States, there has been some experiments with brown rice to replace corn in pig diets. Studies have shown that the partial or complete replacement of corn with brown rice in pig diets has no negative impacts on what?[66, 70, 79], but can improve feed efficiency and growth performance through improved apparent total tract digestibility [21, 65]. Interestingly, Kim et al. (2007) reported that the variety of rice had no effect on digestible energy (DE) [80]. Moreover, Liu et al. (2016) found that there was no difference in the value of DE regardless of the milling process of rice [81].

Conclusion

Alternatives are needed to stabilize supply and increase self-sufficiency by replacing corn in order to stabilize the rising production costs of pigs. Asia has a climate more suitable for growing rice than corn, and the recently the inventory of rice has been increasing. Thus, it is worth examining the value of rice a feed ingredient.

Various rice byproducts are already being used for animal feed, but their nutritional value is less than that of corn. However, rice grains are more suitable as alternatives as they have similar nutritional levels to corn. In the case of whole grains (paddy rice), the fiber content is high and while white rice has lower fiber content, the processing cost is high. Considering the processing costs and nutritional value, brown rice was found to be suitable for comparison with corn.

Further studies should be conducted, however several studies that evaluated growth and digestion rates have already suggested that a portion or complete replacement of corn with brown rice is possible. From this perspective, rice could be evaluated as a sufficiently valuable alternative as a swine feed ingredient.

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Figure 1. Product fractions from standard milling process of rice (Source: modified from [31]).



Item ¹	Corn ²	Brown rice ³	White rice ⁴
Gross energy, MJ/kg	3,930 (38.08)	3,810 (112.39)	3,976 (155.13)
Crude protein, %	8.33 (0.36)	8.31 (0.39)	8.05 (0.07)
Ether extract, %	3.10 (0.39)	2.44 (0.26)	1.16 (0.36)
Acid detergent fiber, %	2.90 (0.01)	1.31 (0.00)	1.85 (1.77)
Crude ash, %	1.19 (0.13)	1.05 (0.15)	0.66 (0.22)
Total starch, %	60.96 (1.58)	72.40 (0.00)	79.45 (5.86)
Calcium, %	0.02 (0.00)	0.03 (0.00)	0.04 (0.00)
Total phosphorus, %	0.28 (0.02)	0.33 (0.01)	0.18 (0.00)
Moisture, %	12.07 (0.26)	12.10 (0.00)	12.55 (0.64)
Essential amino acids (%)			
Arginine	0.39 (0.03)	0.77 (0.00)	0.62 (0.14)
Histidine	0.26 (0.02)	0.16 (0.06)	0.22 (0.05)
Isoleucine	0.30 (0.02)	0.38 (0.00)	0.37 (0.04)
Leucine	1.02 (0.07)	0.75 (0.00)	0.71 (0.05)
Lysine	0.27 (0.01)	0.35 (0.00)	0.37 (0.10)
Methionine	0.19 (0.01)	0.20 (0.00)	0.20 (0.03)
Phenylalanine	0.43 (0.04)	0.51 (0.00)	0.43 (0.05)
Threonine	0.29 (0.02)	0.32 (0.00)	0.31 (0.07)
Tryptophan	0.12 (0.11)	0.25 (0.12)	0.10 (0.00)
Valine	0.38 (0.04)	0.45 (0.00)	0.56 (0.09)
¹ Value are mean ± S.D ² Adapted from [66 – 71])		

Table 1. Proximate composition of corn, brown rice, and white rice (as-fed basis).

³ Adapted from [66, 70, 71]

⁴ Adapted from [68, 69]