Food Processing Technology: Case Study on The Development of Rice Bioindustry

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Abstract. Currently, sustainable food production is the biggest challenge in the world. The rapid growth of population, agricultural land conversion and climate change are the key challenges in the agricultural sector. Therefore, natural resources need to be utilised optimally to increase value-added and product competitiveness. This paper reviews the development of rice bioindustry in Indonesia with regards to food processing technology and challenges. Regarding the development of rice bio-industry, farmers and rice milling entrepreneurs are not only directed to focus on milled rice but also directed to valorise the by-products from rice milling manufacture namely rice bran, broken rice, brewers’ rice and husks into high value-added products. To improve the economic value of premium quality rice, functional rice (parboiled, low glycaemic index rice), fortified rice, instant rice, and crystal rice should be produced. Husk can be processed into non-food products, such as biosilica. Additionally, straw can be used as raw material for paper, furfural, sugar and bioethanol, as well as biodegradable packaging and nanofiber. The development of the rice bio industry by utilising all parts of the plant supports the zero waste concept that can increase the income of rice farmers and entrepreneurs, will also improving the environment.

1. Introduction

Food security is becoming an important issue in Indonesia as the fourth most populous country in the world. In 2015, the population of Indonesia was more than 256 million people [1]. The Ministry of Agriculture has set a vision to achieve a sustainable agriculture-bioindustry system to produce healthy foods and high value-added products based on local resources for food sovereignty and farmers welfare [2]. The implementation of bioindustry based on seven priority commodities namely rice, corn, soybean, chili, shallot, meat and sugar constitutes compulsory programmes towards self-sufficiency and improved farmer welfare.

Rice or paddy rice without husk (*Oryza sativa* L) is the staple food for Indonesia. Recently, the main product of rice manufacture is milled rice or rice with the bran removed. The by-products will be broken rice, brewers’ rice and bran. Meanwhile, husk and straw are waste. The bran is raw material for feed, whereas the broken rice and brewers’ rice are raw materials for the flour industry. Besides, the husk and the straw are potential raw materials for the extraction of silica, functional polysaccharides and other materials [3,4,5]. The concept of a rice bioindustry is to utilise all the paddy plants into zero-waste. Therefore, rice bioindustry will increase value-added and competitiveness of agricultural food products, leading to export and import product substitution.
Up until now, in terms of rice commodity, the policies which support input for this bioindustry include the use of high-yielding rice varieties, massive investments in rural infrastructure, including irrigation, and ready availability of fertiliser. The policies which support the development of a rice bioindustry is Regulation of the Minister of Agriculture Republic of Indonesia Number 31 in 2017 concerning the quality of rice. In the short run, food security in Indonesia has been connected to the rice marketing system through price and the value chain [6].

This paper will discuss the development of rice bioindustry in Indonesia in terms of food processing technology and challenges. It covers, first, the development of the rice bioindustry; second, rice bioindustry products including food technology processing; and third, emerging challenges in the rice bioindustry. The paper concludes with a consideration of future constraints and options for the management of the rice bioindustry in Indonesia.

2. The development of rice bioindustry
Rice production in Indonesia reached approximately 81 million tonnes in 2017 [1]. Indonesia has put enormous effort into reaching self-sufficiency, particularly in rice, and it is, therefore, a great challenge for the government. The development of the rice bioindustry needs resources such as rice as the raw material, infrastructure including rice milling manufacture and machinery, capital, human resources, and management. The output of this bioindustry is to obtain export quality rice and other vertical diversified products, and the outcome is to increase the welfare of local farmers. A scheme of vertical diversification in the rice bioindustry is depicted in Figure 1.

There are five stages towards a rice bioindustry: (1) farmers need to separate the straw and remove the wastes therefore, the rice grains are able to be dried without postponing, maintaining the quality of the grain (water content: ~18% w/w); (2) the storage of dried-milled rice at water content ~13-14% increases the opportunity of purchase by the Indonesian Bureau of Logistics or storage at local rice granaries; (3) farmers boards which have a rice milling unit (RMU) (at capacity 1.5 tonnes/hour) offer to mill the rice grains from the farmers therefore, they are able to sell milled rice; (4) a rice bioindustry has a short supply chain and local farmers organisations therefore, they can be allowed to access the production inputs for their agricultural business; and (5) the profit will flow at the farmer level [7]. Currently, in Indonesia, rice milling produces ~80% head rice, 10-15% broken rice and brewers’ rice, which can be processed into flour and rice starch, while rice bran (10%) is then processed into rice bran oil, rice bran instant and its processed products. The modern RMU has a screen to separate head rice, broken rice, brewers rice, and wastes. On the other hand, the manual screening will be conducted at the small scale RMU. The goal of a rice bioindustry is to produce a high yield of head milled rice, increase the quality (export quality) and increase the performance regarding packaging and labelling.

In terms of waste, the husk is a component of grain which is quite high, around 20%. Husk can be processed into non-food products such as biosilica, liquid smoke and briquettes. As a waste, straw is usually left in the rice fields. Straw however contains high cellulose, which can be used as a raw material for paper, furfural, sugar and bioethanol, as well as biodegradable packaging and nanofiber.

In general, the current status of the rice bioindustry in Indonesia is still under-developed. The government has supported many programmes to facilitate this bioindustry such as high-quality seeds assistance, monitoring special effort to enhance self-sufficiency of rice, machinery, insurance for crop failure, and many more.
3. Rice bioindustry products

3.1 Parboiled rice
Parboiled rice is a kind of processed rice commonly found in several countries in Asia. Hydrothermal treatment is the primary process in parboiling. This process is conducted before milling. The concept underlining this process is the partial gelatinisation of rice starch and hardening of the rice kernel. The aim of this process is to minimise breakage losses during milling of rice.

Three steps are involved in the parboiling process: steeping, steaming and drying [8]. The dried rice grains are soaked in water at a certain temperature for a predetermined time to increase water content by 30%. Afterwards, the grains are steamed and dried until reaching a water content of 12%. This level of water content is safe and ready for storing and milling. Research results show that parboiled rice contains more carbohydrate (~91%) than un-parboiled rice (~88%).

In the process of parboiling rice, nutrients such as vitamins, minerals and dietary fibre are diffused into the endosperm. Therefore, parboiled rice has a higher content of nutrients compared to un-parboiled rice. However, the protein and fat content are slightly decreased. This process of parboiled rice has been found to increase the quality of milled rice (high percentage of head rice) [8][9].

3.2 Instant rice
Instant rice is targeted at urban people who need food prepared rapidly as well as emergency food in a disaster situation. It needs to be rehydrated, and its quality after rehydration is essential for
consumer acceptance [10]. A critical process which needs to be taken into account is drying as well as the soaking process and the addition of additives [11][12][13]. Regarding instant rice processing, in a previous study, rice was soaked in Na-Sitrat 5% for 2 hours and cooked using a rice cooker, then frozen and subsequently dried in an oven [14]. The rehydration time was just 4 minutes, and the yield was 80%. It has been found that the amylose content had a negative correlation with rehydration time and had a significant effect on starch retrogradation.

3.3 Low glycaemic index (GI) rice
The glycaemic index (GI) shows the effect of carbohydrate on blood glucose. GI is influenced by food processing, dietary fibre, amylose, protein fat, and anti-nutrient agents [15]. Consumption of rice as a source of carbohydrate, which has a low glycaemic index (GI), will help control blood glucose levels. Low GI food will produce a slow blood glucose response when consumed. Low GI rice is obtained by parboiling [9] and the application of green tea [16][17]. The parboiling process reduced the GI by 16-32%, as well as the starch digestibility, whereas amylose, dietary fibre, vitamins and minerals increased [18].

3.4 Fortified rice
It has been known that rice contains limited niacin and is low in several minerals such as iron. Fortification is the addition of various micronutrients to improve the nutritional quality of the food. Washing, cooking, heating, extrusion and drying all affect the biological function and stability of fortified products. In addition, temperature, time, oxygen and food composition also influence the nutritional quality of fortified products [19]. The addition of minerals to rice is implemented before rice milling using spray mixing such as in iodised rice or by dry blending. In addition, fortification can occur after rice milling by the addition of vitamins and iron. Currently table salt in Indonesia is fortified with iodine to reduce the incidence of goitre. However, it has been suggested the fortification would be more effective if applied to rice rather than table salt.

Fogging rice with a 1 ppm iodine solution produced cleaner and more glossy grains without any dust and bran from milling. This process can increase milling quality and the head rice yield by 2%, while reducing the amount of broken and brewers’ rice by 1-3% [20]. Based on the daily need of an adult for 120 µg of iodine per day, fortification at the rate of 1 ppm is achieved by the consumption of 200 g/day of rice.

3.5 Crystal rice
Crystal rice is light white rice obtained through multilevel polishing and vapour fogging. The performance of milled rice will be lighter and more glossy [21]. The vapour fogging is conducted to remove the aleuron embedded on the surface of the rice grains. Whiter and glossier milled rice is preferred by the consumers rather than plain milled rice. In addition, crystal rice has a longer shelf life. Based on previous research, crystal rice also had a better carbohydrate content (~81%) than milled rice (~79%) [22]. It was due to the removal of aleurone and phytat from the rice surface.

3.6. Valorisation of rice by-products
Rice bran has been utilised as animal feed in the rice bioindustry. However, opportunities are now emerging for the use of rice bran in the form of rice bran oil [23], rice bran instant, rice bran cookies [24], and rice bran bread [25]. The stabilisation of rice bran oil is a pre-requisite due to lipase-enzyme which will otherwise convert the oil to a free fatty acid (FFA). A variety of methods such as cold storage, sun-drying, steaming and expelling can stabilise the rice bran, or by using chemical stabilisers such as sodium metabisulphite. Stabilised rice bran from rough rice can be safely stored for up to one year at ≤22°C in gas-permeable packaging. However, the maximum safe storage life for parboiled rice bran is estimated to be less than 3-4 months.

Additionally, rice bran has been produced as a functional food [26,27], and rice bran instant porridge has also been developed commercially. Rice bran contains high dietary fibre, particularly
soluble dietary fibre, which assists in reducing blood glucose and insulin response, increasing HDL-cholesterol and maintaining LDL-cholesterol. It also contains oryzanol and tocopherol, which generate vitamin E, as well as tocotrienol as an antioxidant [28].

Previous studies showed that the moisture, crude protein, fat and mineral contents were significantly increased with the addition of rice bran. Average width, thickness and spread factor of cookies also increased with the addition of rice bran. The addition of rice bran (15%) into bread increased consumer acceptance. The addition of rice bran into foods is intended to build a gel-like or viscous texture which inhibits glucose absorption and reduces blood cholesterol level, as well as acting as a bulking agent [29].

4. Challenges in rice bioindustry

However, the development of the rice bioindustry faces many challenges. The first challenge is an improvement at the rice milling unit (RMU) in order to produce high-quality export rice. Currently, the Ministry of Agriculture has supported farmers in all regions of Indonesia by the provision of machinery such as combine harvesters, power threshers and other machinery. Secondly, higher quality paddy seed is required to produce a higher yield of grains. The Ministry of Agriculture has produced varieties of seeds which are resistance to pests and diseases. Thirdly, technology is essential to diversify products in the market to meet changing market demands to reduce the dependency on rice. Finally, the universal conclusion from this review is that good economic policies can ensure food security on a sustainable basis in Indonesia.

5. Conclusion

Rice is a staple food which not only fulfills the nutrition needs, taste and appetite, but is also a functional food. Rice production nowadays puts more attention on a bioactive component of the product as well as the physiological properties for human health. Vertical diversification in paddy processing, for food and non-food purposes, increases business opportunities. Therefore, the paddy bio industry must be implemented in agricultural producing countries such as Indonesia to support self-sufficiency, increase the value-added, and the competitiveness of agricultural products. The sustainability of the rice bioindustry requires proper management and commitment from all stakeholders as well as political support.

6. References

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