The Construction of a New Rice Industrial Chain: A Case Study from the View of Circular Economy

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Abstract: There are currently several problems that exist in the rice processing industry, including a low amount of deep processing and low resource utilization. Using a rice processing enterprise as a study case, we propose the construction of a new rice industrial chain guided by the circular economy concept and we analyzed the economic returns, ecological effectiveness, and social benefits from the extension of circular economy. This paper aims to provide beneficial information that agricultural enterprises can use to develop the circular economy method.

Key words: rice processing industry; circular economy; 3R principle; industrial chain construction

As an old Chinese saying goes: “Food is the paramount necessity for the people”. Grain production and processing are considered to be important for guaranteeing national food security and society stability. However, with the primary product being rice, the additional value and growth of grain products are limited in the traditional processing industry. Improving traditional grain processing technology is important for increasing economic and social benefits. The traditional grain processing industry produces fewer pollutants than other industries, but many of its by-products are treated as waste, contributing to resource-wasting and environmental pollution. Based on the perspective of industrial ecology, the circular economy concept has been introduced into processing industries along with the “3R” principles for sustainable development. Use of this method is expected to capture the additional value of grain products, enhance economic benefits to the agribusiness, and decrease the input of social resources. Constructing a new scientific grain industrial chain based on the concept of circular economy would create a win-win situation for economic development and environmental protection.

1 The concept of circular economy

Circular economy is a new concept with respect to the linear economy characterized by high consumption, high discharge and low output. To realize the goals of ecological economy, it is necessary to follow ecological laws, including the principles for rational use of natural resources and environmental capacity, and to harmoniously bring the economic system into the recycling process of the natural ecosystem (Feng and Yan 2007). By implementing the “3R” principle, “Reduce, Reuse and Recycle”, we can achieve lower resource consumption, high-efficiency production, and lower pollutant output (Fig.1). This will make the economic system more compatible with the natural ecological system; thus, attaining sustainable development of the economy, environment and society (Shen 2007; Lin 2004). The circular economy demonstrates new concepts of system, economy, value, production and consumption (Wu 2005). It never disregards production

![Fig. 1 The “3R” principle in circular economy (Shen 2007).](image-url)
and consumption by humans in the natural ecological system, but searches for harmony between humans and nature.

2 Current situations in the rice processing industry

China is a dominant producer and consumer of rice in the world, with an annual rice output of about 0.2 billion tons, occupying 1/3 of the world rice yield and 2/5 of the national grain output. There are 0.8 billion people in China consuming a total of 0.13–0.14 billion tons of rice each year. Rice and its products are one of the largest and most stable grain consumption markets in China (Wang 2005). There is a large gap in the sophistication of the rice processing industry between China and other developed countries due to differences in technical equipment and processing level. Also because of underdeveloped rice storage and processing, high rice yields did not bring in high economic benefit, which affected the gradual development of the rice industry.

2.1 Underdevelopment of rice processing equipment

In recent years rice equipment has significantly improved in China, however, it still lags behind developed countries. The main differences in the equipment are in performance and technology. The performance differences relate to low production, high energy expenditure and short trouble-free time, which is equal to about 1/3–2/3 the trouble-free time of developed countries. The technology differences concern the slow advancement of technology and poor auto-control technology for automated production (Yao 2004). Approximately 80% of the equipment and technology used in rice processing enterprises in China is at the level of developed countries in the 1970–1980s, 15% is at the 1990s level, and only 5% reaches the international advanced level (Liu 2007). The differences in equipment significantly restrict the scale efficiency and growth of the rice processing industry in China. The lag in technology also induces low resource utilization and high production costs, further influencing the decrease of product quality.

2.2 Low level of rice deep-processing and high attrition rate after processing

Most of the rice processing equipment in China is underdeveloped, so the industry chain is very short. In some high-level rice processing countries, such as the United States of American and Japan, there are over 350 secondary processing products from rice. The value-added ratio of processing products from original rice is approximately 1:4 to 1:5 (meaning the value from rice processing is four or even five times than original rice). On the contrary, most of the rice processing companies in China only have the ability to produce primary products such as polished rice. The ability to perform refined processing is very low and the value-added ratio is only 1:1 (Liu 2007). Since the level of deep-processing is limited, the attrition rate of rice in storage is 9% in China, 8% higher than in developed countries. The attrition rate after processing is about 3%–7.5% (Gao and Wang 2006). Of the 0.0338 billion tons of rice processed and stored every year only 1400 tons, or 11.7% of the rice products, are deep-processed (Gao and Wang 2006). The low processing ratio reduces the potential value of the production and causes significant waste, however, it is unfavorable to improve the quality of engineering, and difficult to prolong the processing industry chain.

It is necessary to introduce the circular economy concept into the rice processing industry to overcome the current problems. The leading enterprise should be used as a model to construct the new industrial chain. This is expected to drive other mid-small enterprises to work towards the goal of sustainable development in agricultural production and rural economies.

3 Analysis of the construction of new rice processing industrial chains under the circular economic concept

3.1 The construction of new rice processing industrial chains

The traditional rice processing industry generates by-products such as grade rice product, broken grain, wrap and rice-husk (Table 1 and Fig. 2) after processing of raw materials. Secondary products are usually regarded as raw materials of forage; as a result benefits to the planting industry are low. Constructing new rice processing
industrial chains under the circular economic concept is an effective way to increase the value of rice processing. Using the industrial chain of Putian Donantion Grain Processing Co. Ltd. as an example, it can be seen that by-product processing can be expanded under the basis of the traditional rice process industrial chain (Fig. 3). This method can help attain comprehensive utilization of waste, increases in economic and social efficiency and decrease pressure on resources and the environment.

(1) The recycling of rice-husk. Utilizing all of the rice-husk during rice processing can increase the rice-husk’s value by three times. The heat from fueling rice-husk can be substituted for the electrical energy used for producing the heat in rice processing, reducing the input of resources. After producing heat by burning the rice-husk, the rice-husk ash can be used to extract high value active carbon and anhydrous sodium metasilicate (Xu et al. 2009; Li et al. 2010; Li et al. 2011).

(2) The comprehensive utilization of rice bran. Although rice bran can be used directly as raw materials for forage, its core economic potential has not been developed. Rice bran contains abundant grease that is equivalent to Chinese soybean and it contains a lot of vitamins and minerals (Schramm et al. 2007; Niu et al. 2009; Yan 2006). If rice bran is put into the market, the marginal benefit is only 1000 CNY t\(^{-1}\). If rice bran is used to develop rice bran oil, the utilization rate of this product will improve and it can promote economic efficiency in the industry within a background of increasing food oil prices. Use of the waste from bran oil extraction as the downstream forage industry’s raw material fully reflects the “3R” principle of circular economy and industrial reorganization.

(3) Comprehensive utilization of broken rice. In the traditional industry chain the majority of broken rice is sold as raw material to beer and food processing enterprises which use them as sources of starch sugar syrup. If used fully the value of broken rice would increase by five times. For suppliers of a primary raw material, the economic benefits and development of broken rice is limited. If enterprises were active in developing a new industrial chain by themselves, a wide and potential market that coincides with rising starch syrup prices could be established.

3.2 Benefit analysis of new rice processing industrial chains

3.2.1 The energy efficiency of using rice-husk for fuel
Rice-husk accounts for 17% of rice and mainly contains fiber with 70% burnable materials, 7%–9% ash content and 20% silicate. In rural areas it is often used as fuel or manure, however in processing enterprises, due to large amounts of rice-husk occupying a large area, it often causes environment pollution and a tremendous amount of waste. Using rice-husk as a substitute for coal or electric energy in grain processing can support food drying, and the processing of Xinghua rice noodle, furfural pulp, and rice bran oil. It has been reported that rice-husk’s calorific value is 12 560–15 070 kJ kg\(^{-1}\), which is equal to half the value of coal (Xu et al. 2009; Li et al. 2010) (Table 2). Rice-husk fuel could be used to effectively meet the demands of energy production.

The dry cost of rice using rice husk as fuel is less than half of the cost of coal (Table 2). Each year the company processed 591 509 tons of rice grain and produced 100 556 tons of rice-husk. By adopting the rice-husk for fuel, 50 278 tons of coal and 30.167 million CNY in energy...
Company produces 65066 tons of rice bran each year and 10 000 CNY ton price of protein powder made from the broken rice is glucose syrup the price would increase. For example, the processing could be conducted to refine broken rice into albumen powde, rbyproducts can be used more efficiently (a famous local snack in Fujian Province), starch syrup and albumen powder. If further processing of broken rice increases the economic value of the products by more than 98%. The enterprise gains an added annual produce value of 134.76 million CNY and saves 50 278 tons of coal through the recycling of byproducts. It can be suggested that by introducing the circular economic principle into the industrial chain, production can be extended from a single chain to many chains, producing a symbiotic industrial web. This in turn not only increases the value of the products, but reduces energy expenditure and decreases pollutant emissions, providing both economic and ecological benefits.

3.2.4 Ecological benefits of resource recycling and energy-saving

Rice-husk waste was used as fuel energy in the present case study in which waste recycling was considered. Refining rice bran and broken rice into fine products such as Xinghua rice noodles, rice bran oil, rice bran meal, starch syrup, rice protein, activated carbon, etc., can significantly increase the recycling utilization rate of resources by more than 98%. The enterprise gains an additional annual produce value of 134.76 million CNY and saves 50 278 tons of coal through the recycling of byproducts. It can be suggested that by introducing the circular economic principle into the industrial chain, production can be extended from a single chain to many chains, producing a symbiotic industrial web. This in turn not only increases the value of the products, but reduces energy expenditure and decreases pollutant emissions, providing both economic and ecological benefits.

Note: Data from Putian Donantion Grain Processing Co. Ltd., 2009.

Table 2 A comparison of common fuels.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Rice-husk</th>
<th>Coal</th>
<th>Diesel</th>
<th>Natural gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price (CNY kg⁻¹ or m⁻³)</td>
<td>0.1</td>
<td>0.6</td>
<td>5.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Heat value (kJ kg⁻¹)</td>
<td>13 800</td>
<td>29 000</td>
<td>46 200</td>
<td>36 540</td>
</tr>
<tr>
<td>Dry cost (evaporative 1kg water)</td>
<td>0.05</td>
<td>0.12</td>
<td>0.65</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Note: Data from Putian Donantion Grain Processing Co. Ltd., 2009.

3.2.3 The economic benefits of using rice bran to produce other products

The current market price of rice bran is 1500 CNY ton⁻¹. Rice bran is often used as forage to produce raw materials, but this is of low economic value. Rice bran contains a lot of nutrients, including approximately 15% oil, and through further processing the oil can be extracted. Rice bran oil, which can be used in food and medicine, has a high market value because it is edible and can help lower blood fat and cholesterol with long-term consumption. There is a large market for rice bran meal extracted from rice bran oil and used as forage because of its low moisture, high protein, easy storage and stable ingredients. Currently, the price of rice bran oil is 6000 CNY ton⁻¹ and the price of rice bran is 1500 CNY ton⁻¹.

The Putian Donantion Grain Processing Company produces 65066 tons of rice bran each year and receives remarkable economic benefit through further processing of the rice bran (Table 4).

Further processing of rice bran to rice bran oil and rice bran meal increases the economic value of the rice to 40.4 million CNY total and 621 CNY per ton.

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3.2.5 The social benefit of extending the industry chain

In the development of agricultural industrial enterprises it is necessary to first construct agricultural bases to support 0.03 million hm² of top quality grain production. This construction will increase the income of 0.12 million farmers by taking advantage of enterprise lead role and rousing the farmers’ enthusiasm in rice planting. Finally,
increasing the economic benefits will also enhance the farmers’ income and drive development of the rural economy. Industry regurgitation-feeding in agriculture is expected to play an active role in solving the “Three Issues in Agriculture” (issues concerning agriculture, rural areas and farmers in China). Continuous extension of the industrial chain can improve employment for rural surplus labor. According to our studies, this industrial chain increased labor employment opportunities by 192 work posts, and gained about 606 million CNY of additional annual sales income and 8.07 million CNY in extra taxation.

4 Conclusion

The Chinese government has proposed to pave a new road for industrialization guided by the concept of scientific development. Grain processing enterprises have to adapt to the requirements of the market economy and create a new path to industrialization that features high scientific and technological content, good economic returns, low resource consumption, minimal environmental pollution and a full array of advantages for human resources. By reorganizing the industry chain, the by-products produced in grain processing can be effectively utilized based on the circular economic principle. This method not only increases the economic efficiency of enterprises, but also reduces resource investment and decreases pressure on the environment and resources. Through the development of intensive processing, agricultural industrialization enterprises are no longer only the supplier of primary products, but they can enjoy the full profit of the industrialization process. We believe that agricultural industrialization will significantly increase the value and efficiency of agricultural products, and effectively promote agricultural and rural economic development.

At the same time, we should realize that the implementation of circular economy is not a simple task. It needs to take various factors into account. In the construction of new circular economy model, the company we analyzed in the paper had considered all factors, such as the market size, the cost and the geographic location etc. And the pattern of this company may provide some beneficial experiences for other grain processing enterprises. But in the course of application, there is no perfect development model in circular economy for every enterprise, we should take their own characteristics, especially the enterprise scale and technical conditions, into consider, thereby explore a real eco-development path for the grain processing enterprises.

References


循环经济理念下新型稻米加工企业产业链的构建

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摘要：在对我国目前稻米加工业发展现状进行分析的基础上，针对目前稻米加工业精深加工水平不高，资源利用率低等问题，提出以循环经济理念为指导，构建稻米加工业新型产业链的思路，并以具体的企业为例，对稻米加工业发展循环经济的经济效益与生态效益、社会效益进行分析，为同类行业发展循环经济提供有利借鉴。

关键词：稻米加工业；循环经济；3R原则；产业链构建