Review of Cadmium Pollution in Preboiled-Rice

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Abstract: Based on the preboiled-rice processing technology, the distribution and form of cadmium in rice seeds were analyzed and summarized. The origin and development of preboiled-rice and its processing technology were elaborated in detail. The characteristics and hazards of heavy metal cadmium, the existence and distribution of cadmium in rice, the detection of cadmium content in rice seeds and its processing and reduction technology were discussed scientifically and systematically. To explore the possibility of processing rice contaminated with cadmium into usable rice. To reduce a certain degree of metal cadmium and improve the use quality of preboiled-rice, and to provide a reference for the process of rice soaking cadmium in the process of preboiled-rice processing, to expand the ideas for the rational use of cadmium contaminated rice,hoping to greatly reduce the waste of food, and at the same time to play a certain guiding role in the development of rice processing industry.

Keywords: Preboiled-Rice; Rice; Cadmium Pollution; Cadmium

1. Introduction

Rice is one of the most important food crops on the earth. It accounts for 21% of the food calories of the world's population. It is reported that the world's total annual output of rice has reached 700 million tons, accounting for one third of the world's total grain production. Asia is the main producing area of rice, its average annual total output and planting area of rice have reached about 90% of the world, more than 800 million people in our country take rice as the main grain, the total output and consumption of rice in our country rank first in the world, is literally the "rice kingdom". Due to China's vast territory and large population, researchers have taken food and clothing as the primary task for a long time in the past. Through natural selection and artificial planting and breeding, China's rice varieties have reached more than 50,000. The rice planting area in China is mainly bordered by the Qinling Mountains and the Huaihe River, and indica rice is mainly planted in the south of the Qinling Mountains and the Huaihe River. With the southward extension, the proportion of indica rice is gradually increasing. Japonica rice was mainly cultivated in the north of the Qinling Mountains and the Huaihe River, with the increasing japonica planting area the further north. As the main grain crop in our country, rice is the basic material for people's survival and the basic material for maintaining social stability and development.

Since the reform and opening up, the economy of our country has developed rapidly, especially the heavy industry, but the development has also brought many new problems. A large number of industrial wastewater are discharged into rivers at will,causing river water and soil pollution. Heavy metals in the polluted soil will accumulate in plants, and then accumulate in human body through the food chain or net, which brings great hidden dangers to human life safety. The Ministry of Land and Resources has announced that about 12 million tons of food in the mainland of China are polluted by heavy metals every year, and the direct economic loss is more than 20 billion yuan.If these problems of food flow into the market, the consequences are difficult to predict. Rice has a strong adsorption capacity for heavy metals, among which the cadmium pollution of rice is even more "cadmium color change". In recent years, the cadmium content in rice has frequently exceeded the standard in some areas of China, such as the cadmium pollution incident in Longjianghe River in Guangxi in 2012; From the cadmium rice incident in 2013 to the cadmium pollution incident in Daxin County of Guangxi in 2014, heavy metal pollution incidents have emerged one after another.In recent years, cadmium exceeding the standard in commercial rice in our country has also occurred frequently. For example, in 2009, The researchers selected 10 samples of commercial rice in Hangzhou, Zhejiang Province, and the cadmium exceeding rate reached 10%. In 2010, other researchers randomly investigated 112 rice samples purchased in the Hunan market, and the results showed that the average cadmium content in the samples was 0.28mg/kg. In 2011, Yang Fei et al. [1] determined the rice sold in the market of Guangdong Province, and the results showed that 5.5% of the 840 samples were cadmium exceeded the standard. In 2012, Chen Ruohong et al. [2] randomly selected 108 rice samples in Guangzhou, Guangdong Province, and the results showed that the cadmium exceeded the standard rate of 14.8%. In 2012, Zhou Na et al. [3] determined metal cadmium in 17 samples purchased from the market in Xiamen, Fujian Province, and the results showed that the cadmium exceeded the standard rate of 11.8%. Zhen Yanhong et al. [4] randomly purchased 91 samples in the domestic market, and the results showed that the cadmium content of the samples exceeded the standard rate of 10%. Zhang Liangyun et al. [5] randomly selected 70 rice samples from some markets and farmers in rice-producing areas such as Jiangxi, Hunan, Anhui and Guangdong, and the results showed that the cadmium content of more than 70% of the samples exceeded the standard. According to the sampling situation of scholars, the situation that the cadmium content in rice in the market of our country does not meet the standard is not optimistic. Because cadmium rice is a sensitive topic, there is no way to investigate how many tons of cadmium contaminated rice are produced in our country every year, and it is unknown how much cadmium exceeds the standard of rice inventory in our country. Therefore, it is of great significance to explore the rational utilization of a certain degree of cadmium-contaminated rice to avoid food waste and respond to emergencies.

The safety of food crops, especially rice, is a problem worth thinking about and solving. In order to reduce the accumulation of cadmium in human body, all countries in the world, the World Food and Agriculture Organization and the World Health Organization Codex Commission have set the limit standard of cadmium in rice. The limit of cadmium in rice is 0.1mg/kg in Russia, 0.2mg/kg in food hygiene standards of European Union, South Korea and China, and 0.4 mg/kg in Food and Agriculture Organization of the World and Japan. According to the limits of cadmium in rice in various countries, it can be seen that Russia has the most stringent requirements for the limit of cadmium in rice, and China has stricter requirements for the limit of cadmium in rice than Japan and FAO. Reducing the waste of heavy metal cadmium contaminated rice and the secondary pollution of cadmium has become an important part of the current scientific research work.

At present, our understanding of how cadmium is enriched in rice and the mechanism of cadmium affecting rice growth is limited to hydroponic experiments at the early germination and seedling stages of rice, and there are few varieties that can be tested. Although there are many studies on the reduction methods of rice exceeding the standard cadmium, there are few reports on the analysis of rice quality after the reduction. In the face of the phenomenon of cadmium exceeding the standard, in rice, can a certain degree of heavy metal cadmium be reduced by a certain process, and will the reduction method affect the quality of cadmium removal products? Based on the preboiled-rice processing technology, this paper reviews the research status of heavy metals in preboiled-rice, which provides new ideas for the rational use of rice with excessive cadmium, the rational use of cadmium contaminated rice, and the avoidance of food waste. At the same time, it also has a certain guiding role for the development of rice processing industry.

2. Research Status at Home and Abroad

2.1 Origin and Development Status of Preboiled-Rice

In the cultivation and production of indica rice in China, the phenomenon of emphasizing yield and ignoring quality improvement has been serious. Early indica rice has poor taste, low nutritional value, and coarse and hard rice. With the continuous improvement of living standards, people pay more and more attention to the taste quality of rice. preboiled-rice is gradually favored by people because of its advantages of high nutritional value, high yield, low rate of broken rice and easy storage. It is a valuable product that meets the needs of The Times. preboiled-rice is a kind of semi-cooked rice which is obtained from rice after cleaning miscellaneous rice and then processed by water-heat treatment, drying, hulling and rice milling. From the perspective of production technology, the production technology of preboiled-rice is a part of special rice processing.

The amount of rice required for preboiled-rice processing accounts for about 20% of the world's rice each year. Thailand is a big producer of preboiled-rice, and its rice is mainly exported, ranking first in the world in export volume. The production of preboiled-rice in the United States, India and other countries is also not to be underestimated. preboiled-rice was first produced in India, which has a typical tropical monsoon climate with high average temperature and large precipitation. It is difficult to store rice under high humidity and high temperature conditions, and diseases, mildew, insect erosion and other phenomena often occur, which seriously affect the quality of rice. In order to change this situation, Indians tried to use the method of husking and storing rice after cooking. This method is not only simple and effective to solve the problem of poor rice quality caused by damp, heat, insects and other factors, but also makes rice easier to store. Later, this method was more and ore used by Europeans and Americans, who made technical improvements on this basis, and the nutritional value of preboiled-rice was greatly improved and it became a healthy food. There are various opinions on the origin of preboiled-rice in China. Some historical books record that preboiled-rice originated from the Wuyue era in the Spring and Autumn period. At that time, the State of Wu and the State of Yue were two rival states, and the State of Wu asked the state of Yue to offer rice seeds, but the minister of the state of Yue came up with a plan: they sent the preboiled-rice to the state of Wu, but no grain was harvested after the state of Wu planted it, and the state of Yue won a great victory, thus the preboiled-rice came. Another theory is that the first time preboiled-rice appeared in China was the Song Dynasty. Sichuan people love and can eat it, which can be reflected from ancient times. In 1101, Sichuan people invented the processing method of steaming before stir-frying to make delicious preboiled-rice, which opened the era of preboiled-rice. This is the germination of preboiled-rice. Before the founding of the People's Republic of China, the production of preboiled-rice in China was mainly manual processing, and large-scale mechanized production was not gradually realized until the 1960s. The harvest season of early indica rice is usually in the rainy season in the main producing areas of China. The harvested rice is prone to mildew, germination and insect erosion due to poor drying conditions. Later, people used the method of cooking and frying to make preboiled-rice, which solved the problem that early indica rice was not easy to store and keep due to water and mildew. At first, preboiled-rice was not made to improve its nutritional value. With the deepening of people's understanding of preboiled-rice, the improvement of its nutritional quality has become the main determinant for making preboiled-rice.

2.2 The Processing Technology and Technology of Preboiled-Rice

2.2.1 Process Flow

Rice → miscellaneous cleaning → soaking → cooking → drying → cooling/slow aging → hulling → milling/polishing → steaming rice

2.2.2 Introduction of Processing Technology

Removing impurities in rice is an important step before processing. After removing impurities, paspalum, and imperfect grains, it is necessary to classify and screen the grains according to their grain thickness, grain length, and grain width to ensure that the grain shapes of the same batch of soaked rice are similar. Grading screening can avoid the phenomenon of complete gelatinization of thin grain and partial gelatinization of thick grain due to different grain types in the process of soaking and cooking. The miscellaneous rice is soaked in the soaking tank. Soaking is the first process of preboiled-rice processing, which is the process of rice absorbing water and making its volume change. When the water content of rice is about 35%, it can ensure that the rice can be completely gelatinized during cooking. Soaking can be used in normal temperature soaking and high temperature soaking. Because rice soaked at normal temperature is easy to ferment and easy to produce peculiar smell, which will directly affect the quality of preboiled-rice, high temperature soaking is often used in actual production. The soaking temperature is generally controlled at 65 ~ 85℃, and the soaking time is generally controlled at 3 ~ 5 hours. In the process of soaking rice,water will gradually penetrate into the kernel, and the internal structure and nutritional composition of the grain will change. Some water-soluble substances such as B group vitamins and inorganic salts in the cortex and embryo will enter the endosperm with water. For example, about 50%-90% of vitamin B 1 will enter the endosperm from the embryo of rice, and some trace elements will dissolve out of the endosperm with water. The cooking process can fully paste the starch in rice. This process can not onlykill microorganisms, blunt the activity of various enzymes, but also prevent the decomposition of oils and rages. It has a significant impact on the shape and color of preboiled-rice, the rate of polished rice and the content of B vitamins. In the process of drying and cooling, the strength of rice grain gradually increases with the decrease of water content, the gelatinized starch becomes dehydrated and hard, the rate of crushed rice decreases and the rate of refined rice increases. Drying is a process in which water in rice is volatilized by heat, which involves both water change and heat transfer. At present, the commonly used drying methods include natural drying and artificial mechanical drying. IDas et al. [6] used infrared drying method to study the quality of preboiled-rice, and found that the intensity of infrared rays not only affected the evaporation of water, but also affected the color of preboiled-rice and the rate of finishing rice. Among them, drying and cooling have a great influence on the crackling rate. When the drying rate (the change of rice water per hour) is higher than 1%, the crackling rate will be greatly increased during rice hulling and milling. Therefore, the rice treated with damp and heat should be dried at an appropriate temperature. Reasonable temperature selection, appropriate water reduction and perfect technological process are the keys to ensure good rice quality. The techniques of hulling and milling are basically the same as those of ordinary rice, but the original structure of rice has been greatly changed by damp and heat treatment, and the husk is easier to be ground off. Therefore, the pressure between the rollers should be appropriately reduced during husking, which can greatly reduce energy consumption,reduce rice crushing rate, and improve the milling quality of preboiled-rice.

2.3 Characteristics and Hazards of Cadmium

Cadmium has an atomic number of 48, belonging to group IIB element, a relative molecular mass of 112.41, metallic luster, and is insoluble in water. The color of cadmium is gray, and it is easy to oxidize with oxygen in the air to form cadmium oxide.The brown cadmium oxide on the surface is equivalent to a protective film to make the internal cadmium not easy to be oxidized. Cadmium is a highly toxic heavy metal element, and cadmium chloride is the most toxic among cadmium compounds . Cadmium is not an essential element for the activities of plants and animals. If rice fields are polluted by cadmium, it will lead to the reduction of microbial population in rice fields and seriously damage the ecological environment of rice fields, which will lead to the reduction of crop production. In addition, excessive accumulation of cadmium in the growth process of crops will affect the metabolism of crops. When the cadmium content of rice leaves is 2mg/kg, the yield can be reduced by 25%. If the human body accumulates excessive heavy metal cadmium, it will cause proteinuria, diabetes or amino acid urine, etc., and will also affect the human body's absorption of Ca and P, and then cause related diseases, which will lead to death in severe cases.

2.4 Sources of Cadmium Pollution and Treatment Methods

There are many sources of cadmium pollution, mainly including the random discharge of wastewater during mine development, the discarding of rubble, the burning of coal, oil and white garbage, the discharge of wastewater from cadmium-plating process, and the discharge of waste water and waste gas from other cadmium-containing process production, all of which will discharge cadmium-containing waste into the soil or the air, resulting in cadmium pollution of soil and air. Therefore, the heavy metal content of copper, cadmium and lead in the soil near the mine area and the highway is significantly higher than that in the soil of other areas. And the application of pesticides and phosphorus fertilizers are also one of the main factors of soil cadmium pollution, and the main culprit of cadmium content exceeding the standard in crops. Gao Zhuling et al. [7] found that phosphorus fertilizer contains high level of heavy metal cadmium, and the average content of phosphorus fertilizer in the world is 7mg/kg. The application of potassium fertilizer also has a great impact on the enrichment of cadmium content in rice. Potassium ions in potassium fertilizer in the early flowering stage of rice have a significant effect on the absorption of cadmium content in rice, while potassium ions in the late flowering stage have little effect on the absorption of cadmium in rice. Crops can easily absorb cadmium in the soil and transfer it through the food chain and food web. A large amount of cadmium is eventually enriched in the human body, which causes irrecoverable damage to the human body. For the pollution caused by "three wastes", laws and regulations should be improved and enforcement should be strengthened to curb the emission of pollutants from the source.

Soil is the basis for all life. Heavy metal pollution in soil has strong hidden and irreversible hazards, especially cadmium pollution, which is one of the factors leading to ecosystem damage. At present, all countries in the world attach great importance to the study of cadmium pollution control methods. The metal cadmium in the soil is absorbed by the roots of crops, and after entering the plant body, it is mainly transported from the stem and leaf of rice to the grain through the phloem together with the assimilates. In this process, cadmium will selectively combine with proteins in the form of complex. Therefore, cadmium pollution will accompany the whole development process of rice growth, and the growth period before heading is the main period for cadmium accumulation in rice. When Mo Zheng et al. [8] studied the accumulation and distribution of cadmium in rice plants, they found that the cadmium content in rice roots was significantly higher than that in stems, followed by grains, while the cadmium content in leaves was the lowest. The researchers showed that under the same soil environment, the cadmium adsorbed by rice was much higher than that of other crops, which indicated that the enrichment of cadmium in rice roots was stronger than that of other crops such as wheat and corn, and different crops had great differences in cadmium enrichment ability, among which Chinese milk vetch had the strongest cadmium enrichment ability,followed by rice, and the same variety of rice also had great differences in the enrichment ability of different heavy metal elements.

Soil cadmium pollution is also the most basic reason for the emergence of cadmium in rice. At present, most of the measures to prevent and control cadmium pollution in rice at home and abroad focus on how to inhibit the accumulation of cadmium in the growth process of rice. There are many methods to prevent and control the accumulation of cadmium in rice, such as changing the existence form of cadmium in paddy soil to reduce the content and migration efficiency of cadmium. On the other hand, new varieties of rice resistant to CD can be developed to prevent the accumulation of CD in rice. Although phytoremediation is one of the effective ways to control cadmium pollution, there is no mature application case in China at present because the cadmium exceeding the standard produced in the remediation process is difficult to produce the economic value of replacing food crops and the remediation cycle is long. It is an ideal prevention and control technology to remove cadmium pollution in paddy soil by planting some plants with cadmium super-enrichment ability in paddy fields. At present, plants such as sunflower, wheatgrass and cadmium-resistant cannabis have remediation functions, which has laid a solid foundation for the development of phytoremediation technology. Application of amendments is an effective means to control the migration of cadmium from soil to rice.The use of suitable amendments such as zeolite, glauconite, lime, organic fertilizer and silica-containing materials is an effective way to control cadmium pollution.

The mechanism of action of different amendments on cadmium is very different. The application of lime in the soil makes the soil alkaline, and hydroxide ions can form cadmium hydroxide precipitation with cadmium ions to reduce the migration of cadmium. Silica-containing materials are similar to litholite, which can reduce the migration of cadmium by complexing with heavy metal cadmium into insoluble compounds. The addition of zeolite can adsorb cadmium in the soil and reduce its activity. However, the application of organic fertilizer affects the absorption of cadmium by rice by changing the existence state of cadmium in paddy soil through organic matter. The effect of the application of amendments on the original soil morphology is not known, so the use of amendments technology needs further research. Therefore, it is necessary to study the dynamic changes of CD during rice growth and to master the CD content in various tissues of rice at different growth stages and the CD content in soil at different stages, so as to truly understand the main periods of CD enrichment and the CD accumulation in various tissues and organs during rice growth.

2.5 The Existence and Distribution of Cadmium In Rice

The distribution of CD in different rice fractions was not uniform, and the CD content in different rice tissues was significantly different. Zhang Chaohai et al. [9] studied the enrichment of heavy metals Pb, Cd, Zn and Cu in the soil in rice, and found that the enrichment of Cd, Zn, Cu and Pb in each component of brown rice decreased in turn. Exogenous selenium has an antagonistic effect on the absorption of cadmium. L Lin et al. [10] found that exogenous selenium can significantly reduce the content of cadmium in leaves, roots and stems. Wu Qitang et al. [11] used pot experiments and hydroponic experiments to study the absorption effect of cadmium by different varieties of rice, and the results showed that the enrichment of cadmium in different varieties of rice was quite different. Li Zhengwen et al. [12] showed that different rice varieties have obvious differences in the absorption and accumulation of cadmium due to different genotypes, and the accumulation concentration of cadmium in different parts of the rice plant is very different. Cadmium in rice is affected not only by soil, but also by rice variety, growing climate and other factors. SH Laurie et al. [13] found that the differential enrichment of element content in the same kind of plants is the result of the joint action of genes and growth environment. "Recently, we have made a big progress in rice breeding, reducing the cadmium content in rice by knocking down the Cd2-containing or Cd2-adsorbing genes," said Yuan Longping at the 2017 National Rice New Varieties and Technology Exhibition. The technology has a certain effect on improving the cadmium content of some crops in China, but there is still a long way to go in the promotion of the road. The researchers analyzed the cadmium content in rice bran, rice and milled rice, and found that the heavy metal cadmium in rice gradually decreased from the surface to the inside, and 40% cadmium in rice grain was enriched in the aleurone layer, which accounted for 9% of the total weight of rice, while only 45% cadmium was enriched in the endosperm, which accounted for 71% of the total weight of rice. There are many organic ligands that can bind to heavy metals and electron donors to form complexes in grains, such as amino acids, porphyrins, nucleosides, proteins, and nucleic acids.

2.6 Development Status of Cadmium Detection Technology in Rice

There are many methods for the determination of cadmium content in rice, but no matter which method is used, the samples need to be digested before determination.There are four common digestion methods: dry ashing digestion, wet digestion, pressure digestion tank digestion and microwave digestion. The pressure digestion tank digestion method is to add the sample, nitric acid and hydrogen peroxide mixture into the teflon jar in accordance with a certain proportion, and then put it into a constant temperature drying oven at 120 ~ 160℃ after being closed, and rely on heat to increase the pressure in the teflon jar to dissolve the sample. Dry digestion and wet digestion are common digestion methods. For dry digestion, samples heated to smoke-free in an electric furnace are ashing in a muffler, and then dilute the ash with dilute nitric acid, and finally determine the constant volume. Wet digestion is to drop the sample in a certain proportion of mixed acid (nitric acid and perchloric acid) soaking overnight, and then digestion on the electric heating plate, until the digestion liquid is colorless and transparent or slightly yellow, the final determination of constant volume. However, these two digestion methods are complex to operate, and the digestion degree of the same batch of samples is quite different, so it is necessary to screen whether the second digestion is needed one by one. The loss of cadmium content in the sample is large, the experimental error is large and the test safety factor is low. Microwave digestion is the use of microwave digestion instrument under high temperature and high pressure conditions for sample pretreatment, dozens of samples can be digested at one time, this method is simple to operate, save reagents, high safety and the same batch of digested samples digestion degree. Sun You 'e et al. [14] studied the influence of four common digestion methods on the determination of cadmium content in rice, and the results showed that microwave digestion had a high degree of automation, better accuracy, and more convenient and simple test. The researchers compared the influence of microwave digestion and wet digestion on the determination results of cadmium in rice, and found that the microwave digestion method had a smaller relative standard deviation and a higher recovery rate of standard addition, which was better than the wet digestion method.

At present, colorimetry, graphite furnace atomic absorption spectrometry, atomic fluorescence spectrometry and flame atomization are the four commonly used methods for cadmium determination, which are also the four methods recommended by the national standard for the determination of cadmium in food. In addition, there are voltammetry, inductively coupled plasma mass spectrometry, rapid dipstick detection methods, etc.

Atomic absorption spectrometry is a more commonly used method, which includes graphite furnace atomic absorption spectrometry and flame atomic absorption spectrometry. The former is mainly used to determine trace amounts of metal cadmium in food, and the lowest detection limit is 0.1μg/kg. This method has high accuracy and good sensitivity, and has become the preferred method for determining cadmium in food in daily work. Some samples are seriously interfered by the matrix during the determination. Therefore, certain body modifiers are often added to increase the ashing temperature and eliminate the matrix interference. Marge et al. [15] found that the ashing temperature and atomization temperature were significantly increased after adding the mixed matrix modifier of ammonium dihydrogen phosphate and magnesium nitrate when measuring the cadmium content in mushrooms. Li Gengbi et al. [16], when measuring trace molybdenum in plant samples, found that the signal of molybdenum atoms increased by 104% after adding the mixed matrix modifier of sodium carbonate and calcium chloride, which could improve the determination sensitivity. When the cadmium content of the sample is high, flame atomic absorption method can be used, and the detection limit of this method is 5.0μg/kg. The researchers used Amberlite ion-exchange resin combined with catechol to make special materials, and determined cadmium, cobalt and nickel by flame atomic absorption method, and found that the detection limits of the three elements were 0.27, 0.59 and 29μg/kg, respectively. The results showed that the detection limit of the method would be reduced under certain conditions.

The colorimetric method is to determine the absorbance value of the sample corresponding to a specific wavelength, and then qualitatively and quantitatively analyze the cadmium content of the sample according to the absorbance value. This method is not only simple to operate, but also has low test cost. However, there are many interference factors and large error, which is the biggest deficiency of this method. Ye Ruihong et al. [17] studied the flame atomic absorption method and its improved method for the determination of cadmium content in brown rice, and found that the cadmium-potassium iodine-rhodamine B spectrophotometry method was simple to use and had the highest sensitivity of the instrument. Atomic Fluorescence spectrometry (AFS) is a method for quantitative analysis of the fluorescence intensity emitted by the atomic vapor of an element under the excitation of a certain wavelength of radiation energy. Although this method has high sensitivity, the detection limit is 12 times of graphite furnace atomic absorption spectrometry, which is not suitable for the determination of trace cadmium. It has strong applicability for samples with high cadmium content, so it is widely used in metallurgy, petroleum, biomedicine, material science and other fields.

Voltammetry is based on the principle of electrolytic cell, applying a certain voltage to the sample after digestion, so that the ions of the heavy metal elements to be tested will gather on the negative electrode after electrolysis, and then applying a reverse voltage to the electrode, and analyzing its content according to the current and voltage curve of the oxidation process. The researchers found that voltammetry can quantitatively determine the content of lead and cadmium in wheat, corn, rice and other crops, and this method has relatively low operation requirements and detection and use costs, anodic stripping voltammetry can be used as an alternative method to determine low concentrations of Zn, Cd, Cu, Pb, etc. in samples, and this method can determine the content of multiple elements at one time. The rapid test paper detection method is easy to operate and suitable for on-site detection, and the test paper is easy to carry. However, the method can only qualitatively or semi-quantitatively detect cadmium in food, which is greatly affected by human subjective judgment and the measurement error is also large.

In the 1980s, with the development of inorganic element and isotope analysis and testing technology, inductively coupled plasma mass spectrometry came into being. The method has high sensitivity, small relative standard deviation of the results, and can determine the content of multiple elements at one time. Dai Qi et al. [18] used this method to determine the content of five elements such as Pb and Cd in food with a single injection. The detection limit was between 8-80ng/L, and the relative standard deviation was less than 3.35%.

2.7 Research on Cadmium Reduction Mode in Processing

Soaking is an important step in the processing of preboiled-rice, and it is also an important step in reducing the cadmium content in rice. The researchers found that water could gradually penetrate into the endosperm of rice during soaking, starch was completely pasteurized during cooking, vitamins and minerals in the cortex and embryo would penetrate into the endosperm of rice with water, and some minerals would dissolve out. Soaking provided the possibility for the reduction of cadmium in rice. Liang Hui [19] treated mussel cooking liquid with chitosan of a certain pH gradient, and the results showed that the adsorption ability of chitosan to cadmium increased with the increase of pH value. This indicates that chitosan has a certain adsorption ability for cadmium. Xu Yanxia et al. [20] soaked rice with citric acid and NaCl solution, and found that with the increase of citric acid concentration, the cadmium reduction rate of rice gradually increased. Although this method can provide a reference for the rational utilization of rice with cadmium exceeding the standard, the cadmium reduction rate of brown rice is low and needs to be improved. The researchers compared the effects of constant temperature natural fermentation and electrochemical assisted fermentation on the determination of cadmium in rice, and the results showed that the latter had a better effect, with a cadmium reduction rate as high as 61%. Protein will be lost in the fermentation process, so the cadmium bound to protein in the rice flour products will migrate to the fermentation broth, resulting in the reduction of cadmium content in rice flour. Although rice flour products with low cadmium content can be obtained by fermentation technology, the effect of this method on rice quality needs to be further studied.

Rice hulling and milling are also important processes to reduce cadmium content in rice. According to the uneven distribution of cadmium in rice tissues, some scholars reduced cadmium in rice by removing skin embryos and improving processing accuracy. The researchers found that with the upgrading of processing depth, the removal rate of cadmium in rice gradually increased, up to 24.1%, the removal rate of cadmium in brown rice can reach up to 30.56% through milling. With the increase of milling time, the cadmium content of brown rice gradually decreased and leveled off with the bran layer and outer endosperm layer. The methods of hulling and milling are only applicable to the rice with low cadmium content exceeding the standard. The rice with serious cadmium content exceeding the standard can not be obtained by hulling and milling only.

3. Conclusion and Prospect

With the continuous fermentation of cadmium pollution events in rice and the continuous production of cadmium exceeding the standard in rice, the research on the rational and safe utilization technology of cadmium exceeding the standard in rice can alleviate the adverse effects caused by cadmium pollution in rice, reduce the inventory pressure of cadmium contaminated rice, and ensure food security. The distribution of cadmium in rice showed high heterogeneity, with a high accumulation of cadmium in the aleurone layer of rice grain. Cadmium concentration in embryo and cortex of rice was significantly higher than that in endosperm and glume. The distribution of CD in different rice products was different during grain processing. Although a lot of esearch has been conducted in the field of safe utilization of cadmium-contaminated rice in recent years, there is no effective method to completely solve all the cadmium-exceeded rice in the current inventory. The development trend of the safe utilization of rice with cadmium exceeding the standard in the future is to carry out multi-means and multi-ways to classify rice with different cadmium exceeding the standard:

(1) Based on the changes of cadmium content in steaming, cooking, drying, hulling and milling process of preboiled-rice, a correlation model was established. On the premise of moderate processing of rice, the limit value of cadmium content in safe rice was obtained through mechanical processing, and the safe utilization

process conditions of rice with low cadmium exceeding standard degree were established.

(2) The effects of citric acid concentration, soaking time and soaking temperature on the cadmium content of rice were studied, the flavor problem of the product after solvent extraction was further solved, the process conditions of solvent extraction were improved, and the cadmium degradation process of rice during soaking was optimized.

(3) The effects of citric acid on rice milling characteristics, cadmium content of rice at different milling times, and the effects of citric acid on the color, milling quality, amylose content, minerals, gelatinization characteristics, cooking quality, texture characteristics and sensory evaluation of preboiled-rice were studied.

(4) Cadmium content was determined by separating husk, embryo, cortex and endosperm of rice before and after soaking. The changes of cadmium content were analyzed to understand the migration mode of cadmium during soaking. The effect of

soaking on the distribution of cadmium in brown rice was studied through dynamic rice milling time, and the migration mode of cadmium during soaking was comprehensively grasped. On the basis of reducing cadmium content in rice, high value-added rice processing products could be developed, each part and component of rice could be fully utilized and the waste of rice could be reduced.

(5) Continuously develop new rice processing technology, strengthen the research on the change of nutritional quality of rice in the research of cadmium reduction technology in rice, and optimize the safe utilization technology of rice with cadmium exceeding the standard that can effectively reduce the cadmium content in rice and maintain the nutrition and quality of rice.

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