

Comprehensive Development Techniques and Utilization of Chestnut Byproducts

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Abstract In order to further promote the chestnut industrial chain, a large number of chestnut byproducts (chestnut leaves, chestnut shells, chestnut flowers, etc.) are produced every year. These chestnut byproducts will be comprehensively developed and utilized in different degrees, such as in-depth research and development in the fields of animal husbandry, agriculture, and cosmetics, so as to achieve the effects of accelerating the high-quality development of chestnut industry, realizing the green cycle of resources, reducing waste and promoting the development of rural industries.

Key words Chestnut byproduct; Animal husbandry feed; Agricultural fertilizer; Comprehensive utilization

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Chestnut (*Castanea mollissima* Blume), a plant of *Castanea* in Fagaceae, is widely distributed in the mountainous areas of 26 provinces (autonomous regions) and cities in China. It is an important economic forest tree species^[1]. According to the statistics in 2018, the planting area of chestnut in China has expanded to 341 000 hm², nearly 6 times that of Bolivia, the second largest chestnut producer, and the yield has reached 1.965 million t, 23 times that of Bolivia^[3]. With the continuous expansion of the planting area of chestnut, a large number of chestnut byproducts will be produced correspondingly. Chestnuts and its byproducts have the concomitant function of both medicine and foodstuff, and they contain high amounts of trace elements such as protein, flavonoids, iron, calcium and zinc, and various vitamins, and have obvious medicinal effects such as invigorating the spleen and nourishing the stomach, stopping bleeding and relieving swelling, strengthening tendons and bones, nourishing yin and tonifying blood. Chestnut leaves are cold in nature and have the effects of clearing away heat, diminishing inflammation and relieving pain. Chestnut flowers are neutral in nature, slightly bitter and astringent in taste, and have the functions of clearing away heat and drying dampness, stopping bleeding and removing blood stasis. Chestnut shells have medicinal effects on diabetes and whooping cough. Chestnut roots can be used to treat hernia.

At present, the planting area of chestnut in Tangshan City is

more than 2.8 million mu, with an annual output value of about 3.7 billion yuan. Especially, Qianxi County, which has a cultivation history of more than 2 000 years, was recorded in *The Book of Songs*, *Strategies of the Warring States*, *The Commentary of Zuo*, *The Analects of Confucius*, *Compendium of Materia Medica*, and *Nongzheng Quanshu*. During the period of the Republic of China, the county annals recorded: "Yijing has abundant production and the farthest marketing, making chestnuts its major product". Yijing mainly refers to the area around Qianxi County, where the special geographical conditions are characterized by "Seven tenths of mountains, two tenths of water, and the rest being by half fields and half roads and estates", gneissic soil, and mountainous hilly climate and weather. At the end of the last century, the planting area of local chestnut trees was widely promoted. The planting area of chestnut in Yanshan mountain area was 147 300 hm², and a large amount of chestnut husks, chestnut leaves (the output of which is about equal to the output of chestnuts), chestnut shells, chestnut flowers and secondary fruit were produced every year. In recent years, chestnut leaves, chestnut flowers and chestnut husks have been increasingly developed, researched, and utilized. Developing ecological and organic green chestnut industry has become the development trend of chestnut industry.

Application of Chestnut Byproduct Development Techniques

Application of chestnut byproducts in local production: chestnut shells and branches are used as additives for the base materials of *Grifola frondosa* and *Lentinula edodes*. It is reported that chestnut flowers are rich in total flavonoids with a content of about 4.9% (calculated by rutin), and thus have obvious oxidation resistance^[3], as well as obvious mosquito repellent effect^[4]. The essential oil extracted from chestnut flowers has obvious effects in mosquito bites and skin protection. Chestnut flower wine can be made by mixing chestnut flowers with other ingredients through fermentation, distillation and other processes. Chestnut flowers

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can be dried and crushed to 200 meshes, and then made into animal feed additives, which are used to inhibit the occurrence of diseases such as *Escherichia coli* and improve the immunity of animals. Chestnut leaves contain high crude protein, and are used as coarse feed for ruminants. Moreover, Chestnut leaves have antioxidant activity. In the study of antioxidant activity of chestnut leaves, it was found that crude polysaccharide and sugar in chestnut leaves showed strong antioxidant activity^[5].

Feed for animal husbandry

With the development of chestnut industry, the contents of nutrients in several byproducts of chestnut are shown in Table 1. As can be seen from Table 1, chestnut leaves and flowers contain a certain amount of crude protein. Especially, chestnut flowers contain high flavonoids, which have antioxidant, anti-inflammatory and inhibitory effects on the growth of germs and viruses. Chestnut flowers and chestnut leaves have been developed as the main byproducts. Healthy chestnut flower feed is added for pigs at a ratio of 11% to improve the disease resistance of pigs. It is used in Chai chicken and laying hens at a ratio of 7.5% to improve the egg production rate and reduce the mortality rate^[6]. Chestnut leaves are used as coarse fodder for forage animals by two methods. In the first method, chestnut leaves are crushed and then used as coarse fodder for forage animals. In the diet of

forage animals, the one-time addition amount of polyethylene glycol is 0.03% – 0.05% according to the weight of forage animals, and the intake of chestnut leaf coarse fodder reaches the maximum every day^[7]. In the second method, chestnut leaves and their byproducts are crushed with a 20-mesh sieve, and 20% of bran is added as the carrier of fermentation. A prepared EM bacteria liquid is directly inoculated, and with the humidity of about 30% and the temperature at 20 – 30 ℃, the materials are sealed and fermented for more than 15 d (the fermentation time could be prolonged at lower temperature), and then used as animal feed. Inoculating EM and other bacteria liquid for sealed fermentation is beneficial for the degradation of protein macromolecules by microorganisms into small molecular substances which are easy to absorb, such as small peptides. Meanwhile, a large number of beneficial microorganisms are propagated during the fermentation process, which produces a large number of organic acids and reduces the pH value of chestnut byproducts. It properly improves the palatability of fodder, and can be used in animal husbandry production. Moreover, animal manure can be used to cultivate earthworms and other basic materials, achieving the effects of enhancing the industrial chain, realizing the green cycle of resources, reducing the cost of animal husbandry and improving economic benefits.

Table 1 Determination of nutritional components of several chestnut by-products

Name	Crude protein // %	Crude fiber // %	Crude fat // %	Flavonoid // %	Coarse ash	Calcium (Ca)	Total phosphorus
Chestnut leaves	7.60	22.7	5.44	0.38	9.86	1.82	0.33
Chestnut flowers	9.20	2.7	1.50	4.90	4.40	0.69	–
Chestnut shells	3.46	38.0	0.40	–	–	–	–
Chestnut husk	4.14	36.1	–	–	–	–	–

Returning to the field in a manner of agricultural compost

Chestnut byproducts have high nutritional content and can be used for composting biological fertilizers. In real life and production, most of chestnut byproducts are discarded or burned with low utilization rate. Wu^[8] found that when chicken manure (main material) and rotten leaves such as chestnut shells used as auxiliary materials were mixed and fermented, and the decomposition state was the best. When the dry weight ratio of chestnut waste and cow dung was equal, the compost could reach the harmless standard and maturity requirement after 20 d of fermentation. When chestnut waste was crushed and mixed with animal manure according to the ratio of ≥1 : 1, the mixture could be used as the base material for breeding *Hermetia illucens* L., transforming waste protein into animal protein, and finally, the waste could be returned to farmland, extending the industrial chain of chestnut byproducts.

Cosmetic field

When the components of chestnut flowers in different flowering periods are extracted, and extracting chestnut flowers in the blooming period can achieve higher total flavone compound and vitamin concentrations. The extract has strong anti-inflammation effect, and is often used for extracting essential oil and making drinks. This result is similar to that found by Wang *et al.*^[9], showing that the extraction rate of essential oil from chestnut flowers in full bloom could reach 6.808% under the best technological

conditions.

Suggestions on Industrialization Development of Comprehensive Utilization of Chestnut By-products

Suggestions on industrialization development of chestnut by-products used in animal husbandry feed

First, in terms of research and development and quality control, investment should be increased in scientific research and development of chestnut byproducts. The nutritional components of chestnut byproducts should be analyzed to ensure their safety and nutritional value as feed, improve economic benefits and reduce breeding costs. Second, from the perspective of technology promotion, we can promote the advantages of chestnut byproducts as feed to farmers by holding special lectures and training courses, and help them understand how to scientifically mix feed and improve breeding efficiency. Third, from the perspective of market development, it is necessary to establish cooperative relations with livestock cooperatives or large-scale farms, and formulate long-term supply agreements to ensure the stability of market sales channels. Fourth, we should actively strive for government support policies, including research and development funds, subsidies and tax incentives, so as to reduce the cost of industrialization.

Suggestions on industrialization development of chestnut by-products used in agricultural compost for returning to the field

First, it is necessary to establish composting production lines. We should invest in building chestnut byproduct processing plants, develop special composting production lines, and adopt modern biotechnology to improve composting fermentation efficiency and soil improvement effect. Second, product standardization should be strengthened. The standard of chestnut byproduct compost should be formulated to explain its composition, fertilizer efficiency and use method in detail to ensure product quality. Third, in terms of market publicity and promotion, the propaganda of ecological agriculture should be strengthened while emphasizing the environmental and economic benefits of using chestnut by-product compost, so as to attract farmers to use it. The fourth is about pilot demonstration. Part of farmland can be selected for pilot demonstration and promotion to show the effectiveness of chestnut by-product composting and drive more farmers to participate through successful cases.

Suggestions on the industrialization development of chestnut byproducts used in cosmetics field

First, in terms of the research and development and extraction of components, enterprises can cooperate with universities and scientific research institutions to research and develop the extraction of effective components from chestnut byproducts and their application in cosmetics, so as to ensure that they have skin care or antioxidant effects. Second, it is necessary to establish a brand image, which emphasizing the concept of ecology, nature and health. We should actively promote product creativity, add cultural elements, and continuously improve product quality, thereby promoting the market awareness of chestnut byproducts in the cosmetics industry. Third, from the perspectives of construction of market channels, we should increase market research, clarify market demand, and sell products through diversified channels such as e-commerce platforms, drug stores and beauty counters to increase the opportunities for consumers to contact the products. Fourth, in terms of compliance and certification, it is necessary to ensure that products meet the requirements of relevant laws and regulations, such as obtaining organic certification and environmental protection standards, so as to enhance the market competitiveness of products.

These suggestions on industrialization development can effectively promote the industrial utilization of chestnut by-products and extend the industrial chain. It can achieve the effects of reducing the waste of resources, increasing farmers' income, reducing the cost value of agriculture and animal husbandry, increasing the added value of products, and promoting ecological agriculture and sustainable development.

Conclusions

More and more attention has been paid to the development and utilization of chestnut byproducts. The utilization value of chestnut byproducts can be greatly improved by expanding in agriculture, animal husbandry, cosmetics and food. In the local area, the related industrial chain mainly based on chestnut industry is

relatively developed, but there is still a big gap between the research of chestnuts and its appendages and practical application. Based on the research and development status of chestnut and its byproducts, this paper explored the potential utilization value, and provided some ideas for the majority of grassroots technicians to expand more production methods. Following suggestions were put forward:

(i) The rich resources of chestnut byproducts can be fully utilized to rationally plan the management mode of chestnut industry and realize the application of scientific management and intelligent platform and the development of chestnut industry chain extension.

(ii) Focusing on the scientific research results of chestnut processing byproducts, they can be transformed into productive forces. While accelerating the application and transformation, industrialization promotion can be conducted.

(iii) In-depth development of chestnut and its by-products performance research should be strengthened. The functions and mechanisms of crude protein, total flavonoids and procyanidins used in animal husbandry industry should be discussed in depth to better use of the homologous industrial chain of medicine and food, especially, the research, application and promotion in the field of cosmetics.

To sum up, rich chestnut byproducts can be comprehensively utilized and developed in terms of feed, fertilizers and base materials. Convenient production is more conducive to expanding production and endows the industry with a broader prospect in practical application. With the development of the industry, the high-quality development and comprehensive utilization of chestnut industry will be further promoted.

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