Analysis of Comprehensive Utilization of Coconut Waste

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Abstract This paper describes and analyzes the coconut cultivation in China, and the current comprehensive utilization of waste resources generated during cultivation and processing of coconut. The wastes generated in the process of cultivation include old coconut tree trunk, roots, withered coconut leaves, coconut flower and fallen cracking coconut, mainly used for biogas extraction, direct combustion and power generation, brewing, pharmacy, and processing of building materials; the wastes generated during processing include coconut water, coconut coat, coconut shell and coconut meal, mainly used for processing beverages, pharmaceutical products, activated carbon, medium and feed. This paper analyzes and explores some problems in the process of comprehensive utilization of coconut waste in China, such as insufficient understanding, inadequate development and lack of research efforts, and finally puts forth the corresponding development countermeasures.

Key words Coconut, Waste, Comprehensive utilization

Coconut, a typical tropical tree oil crop, is a member of the family *Arecaceae* (palm family). It is the only accepted species in the genus *Cocos*. The term coconut can refer to the entire coconut palm, the seed, or the fruit, which, botanically, is a drupe, not a nut. The spelling cocoanut is an archaic form of the word. The term is derived from 16th - century Portuguese and Spanish *coco*, meaning "head" or "skull", from the three small holes on the coconut shell that resemble human facial features. Tender coconut water, an ideal natural refreshing beverage, contains a lot of vitamin B, vitamin C, minerals and 18 kinds of essential amino acids. The raw coconut flesh is edible, and can also be processed into coconut milk, coconut oil, coconut shred and desiccated coconut. They are now almost ubiquitous between 26°N and 26°S except for the interiors of Africa and South America. Coconut palms are grown in more than 80 countries of the world, with a total production of 61 million t per year. The main origin includes the Philippines, Indonesia, India, Malaysia and other countries[1-4].

In recent years, with people's growing demand for coconut products, the cultivation scale of coconut has been expanded, generating a lot of wastes in the course of cultivation and processing of coconut. These wastes are often discarded or burned directly, not only polluting the ecosystem environment, but also wasting a lot of resources, which is not conducive to the implementation of China's sustainable development strategy. Therefore, understanding and grasping the comprehensive utilization of coconut waste and analyze the existing problems, plays an important role in promoting the development of comprehensive utilization technique of coconut waste in China.

1 The situation of China's coconut cultivation and coconut waste

1.1 The situation of China's coconut cultivation The coconut cultivation in China has a history of 2000 years, and the main growing areas are mainly concentrated in Hainan Province, whose coconut production accounts for over 90% of the national total production. The coconut is cultivated in some other regions in a small amount, such as Shangchuan and Xiachuan in Guangdong, Xishuangbanna in Yunnan, Beihai in Guangxi and southern Taiwan. In 2010, the coconut cultivation area in China was about 40 370 hm^2, and the national coconut production was about 250 million; the coconut cultivation area in Hainan Province was 39 160 hm^2, and the production was 230 million[5-6].

In recent years, with the improvement of people's living standards and the development of tourism, the demand for coconut and its products is increasing, and the wasteland suitable for the coconut cultivation in China is being constantly developed and utilized.

1.2 Coconut waste resources The coconut wastes refer to the byproducts produced in the process of coconut cultivation and processing, mainly divided into two categories: (i) old coconut tree trunk, roots, withered coconut leaves, coconut flower and fallen cracking coconut in the process of cultivation; (ii) the byproducts produced in the process of coconut processing, such as coconut water, coconut coat, coconut shell and coconut meal.

The fruit production period of coconut is about 50 years, each mature coconut tree has 22 leaf blades on the average, and the number of leaves coming forth annually is about 12[7]. Every year a large number of wilted coconut leaves and the coconuts over the fruit production period are cut down or burned by the coconut growers. The flowering period of coconut is 7 to 9 months at most, and only a small part of pistil buds are fertilized and bear fruit. The coconut flower juice is from the tender spathe of coconut. Winter low temperatures lead to fallen cracking coconut. Through a sampling survey, the average rate of fallen cracking coconut reaches 5.5%[8-9], and there are about 160 million cracking coconuts.

Coconut peel is divided into epicarp, mesocarp and endocarp; coconut flesh and coconut water are wrapped in the endo-

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carp. The epicarp and mesocarp of coconut is known as coconut coat, accounting for 33% – 35% of the weight of the entire coconut. The endocarp is commonly known as coconut shell, accounting for 12% – 15 % of the weight of the entire coconut. Coconut water accounts for 22% – 25% of the weight of the entire coconut[10]. Coconut meal is the remainder of desiccated coconut after being squeezed or extracted. For every t of coconut processed, 33 kg of coconut meal is obtained.

2 Comprehensive utilization of coconut waste

2.1 Utilization of waste generated in the process of cultivation

2.1.1 Energy utilization technologies. (i) The production of biogas. Rural waste is an important component of rural energy, and well solving the energy shortage in rural areas and rural environmental pollution to develop the circular economy is the important content of building a new socialist countryside.

After being ground, coconut leaves and fallen cracking coconut are excellent carbon-rich materials like wheat straw and corn stalk, providing the material basis for the survival of microbe and production of biogas. Using the dry anaerobic digestion to produce biogas[11], it can not only protect the environment, but also provide a large number of organic fertilizers. The process is shown in Fig. 1. School of Mechanics and Electrics Engineering of Hainan University has conducted a research on the use of dry anaerobic digestion of coconut waste to produce biogas, and studied the effects of high fiber and solid rate of the coconut leaves and deciduous fruits on the production of biogas, but it is currently limited to the laboratory-scale research.

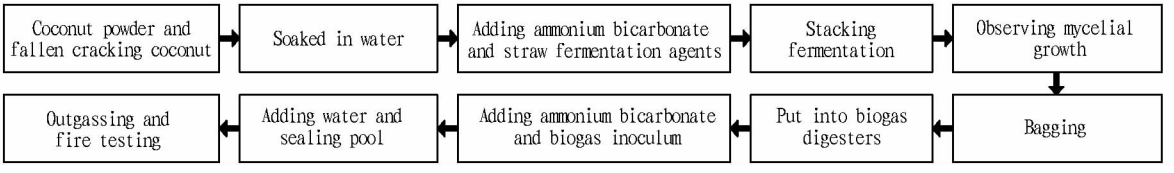

Fig. 1 The process of producing biogas from coconut waste

(ii) Direct combustion and power generation. The shortage of electricity in China has affected the normal life of residents, so it is necessary to tap new electricity generating fuel to alleviate the crisis. Using biomass for direct combustion and power generation is called biological power generation, which uses biomass material for direct combustion to produce heat and convert it into electrical energy. It is an important research and support program during the period of "Eleventh Five-Year Plan"[12]. The use of direct combustion to deal with withered coconut leaves, fallen cracking coconut and fibrous roots, not only can bring good environmental protection effects, but also bring economic profit to farmers.

2.1.2 Changing waste into resource. Fresh coconut flower juice is translucent and sweet natural liquid beverage ingredient, rich in sugar, protein, carbohydrates and lots of trace elements, and the sugar content is as high as 14.8% – 16.4% (mainly sucrose)[13]. Chen Hua *et al.*[14] studied the continuous collection method of coconut flower sap, and drew the conclusion that every single coconut could annually produce 200 to 300 L of coconut flower juice, and farmers' income merely by collecting coconut flower juice was 3 000 – 4 500 yuan per 667 m^2 of land.

The main coconut growing countries in Southeast Asia, take the coconut flower juice as a kind of food raw material, used for the processing and production of the coconut flower juice sugar, coconut flower juice wine, coconut flower juice beverage and coconut flower juice vinegar. In China, the Coconut Research Institute of the Chinese Academy of Tropical Agriculture has successfully explored a variety of methods for processing coconut flower juice, and successfully developed natural coconut flower juice wine and natural coconut flower sap vinegar.

For the coconut more than 50 years old, the tree height is generally 15 to 25 m, the diameter is 0.2 – 0.5 m, and the coconut production is low, but the coconut wood processed using boron diffusion method, with delicate hard texture and beautiful pattern, can be used as high-quality timber, to alleviate the shortage of domestic timber. The houses and furniture built with coconut wood have low cost and good resistance to moisture.

In addition, the Philippines and Thailand use coconut wood to process various crafts such as pots, dishes, vases, *etc.*, and achieve remarkable economic returns. At present, the coconut wood in Hainan Province has not yet been better developed and utilized.

The dried fibrous roots of coconut can be used as medicinal material, to cure physical weakness and waist and knee pain, with sedative effect. Coconut leaf can be used for erecting thatched shack, knotting fences and mats; it can also be made into hard bone broom[15].

2.2 The utilization of waste generated during processing

2.2.1 Utilization of coconut water. The flesh of old coconut is thick, and the components of coconut water are complex. The main nutrients include sugar, a lot of minerals, protein and rich vitamins. And protein contains 18 amino acids needed by the body. The studies of Zhang Muyen[16] shows that the protein in coconut water is composed of 9 subunits with molecular weight in 13.6 – 64.5 kDa, which is one of the reasons for high nutritional value of coconut water. Coconut water is not only a kind of nutritious natural drink, but also of some medicinal value, such as promoting digestion, diuretic effect, detoxifying, beautification and disinfection, and adjuvant therapy.

Coconut water also plays a role in preservation, and the preservative made of coconut water can save green vegetables, and delay its withering speed. Microbiologically, coconut water can make the mature cells of higher plants rapidly and irregularly di-

vided, stimulating the plant growth, which can be used as the liquid medium of microorganism[18-17]. Furthermore, coconut water can be used as the materials for producing alcohol, vinegar and mannitol; its content of potassium is high, so it can also be directly used as fertilizer.

2.2.2 Utilization of coconut coat. The dry weight of coconut coat contains 70% of coconut shell powder and 30% of coconut coat fiber. For 1 t of desiccated coconut produced, there will be 0.85 t of coconut coat fiber and 1.9 t of coconut shell powder wasted[19]. Coconut coat fiber is mainly composed of cellulose, lignin, hemicellulose and other components. Coconut coat fiber has strong toughness and corrosion resistance, which is mostly used to produce the fiber yarn for carpets, brooms, brushes, ropes, bags and mats.

Li Liuzhen *et al.* [20] combine the coconut coat fiber material with the vegetation planting techniques for slope protection, to establish the sustainable protection system in the slope of abandoned mines, highways, rivers and dams. This technology can make plants withstand rain erosion, and the organic matter degraded from coconut coat fiber can provide plenty of nourishment for the vegetation.

Coconut shell powder has the characteristics of heat preservation, moisture preservation, porousness and breathability, and its water-holding capacity is 8 times its own weight[21]. Zhou Chang *et al.* [22] use different proportion comparisons between grass peat and coconut shell powder to conduct soilless cultivation experiment on the lettuce. The test results show that with the increasing proportion of coconut shell powder in the medium, the lettuce production also increases.

Gao Huanzhang *et al.* [23] use seven different types of ground substance to cultivate acacia seedling, to through five repetitive tests. The results show that the root weight, diameter and seedling height of seedling cultivated using coconut shell powder ground substance are the greatest (1.625 g, 2.53 mm, 19.56 cm, respectively). At present, the coconut shell powder in the horticultural cultivation is gradually replacing plant ash and grass peat to become an ideal growing medium.

2.2.3 Utilization of coconut shell. The dried coconut shell contains 63% of cellulose and 36% of lignin. The coconut shell has high lignin content, hard texture and good resistance to moisture, so it can be carved into a variety of crafts and made into lampshades, musical instruments, bowls and other utensils. Coconut shell charcoal powder can be used as the wad for chemical industry, which is applied to sugar refining, pharmaceutical glycerine and oil processing and other fields.

Another important function of coconut shell is for the production of high quality activated carbon. 1 t of coconut shell charcoal carbonized through pyrolysis, can produce 300 kg of coconut shell charcoal; by further refining, we can get 120 kg of activated carbon. Coconut shell activated carbon is composed of unique pore structure and surface functional group, with the features of high fiber, high density, uniform distribution of pores and strong ability to adsorb gas, widely used to purify air and drinking water, filter toxic gas, refine oil, extract precious metals, catalyze carrier, produce sugar, food, reagents[24-30].

2.2.4 Utilization of coconut meal. Coconut meal, rich in cellulose, hemicellulose and lignin, is the high quality raw material for processing dietary fiber. Dietary fiber can lower the blood sugar, serum cholesterol concentration, which has a unique effect for the diabetes and atherosclerosis patients.

Yang Chongqing *et al.* [30] adjust the pH value to make it isolated from the isoelectric point PI and remove the protein of coconut meal; use the acid degradation method to remove the coconut meal starch to extract dietary fiber. This method is simple, with short cycle, no need of special equipment, suitable for the coconut processing plant's comprehensive utilization of coconut.

The coconut meal contains high protein and arginine, but the content of lysine and sulfur-containing amino acids is low. The price of coconut meal is much lower than that of soybean meal, cotton meal and vegetable meal. The coconut meal is granulated or powdered, and a certain amount of amino acids and enzymes are added, to produce coconut meal feed. Tests show that taking a certain amount of coconut meal feed to mix with the original feed to feed the livestock and poultry, does not affect its growth rate and feed efficiency[31-33]. Using this method can reduce farming costs, and mitigate the shortage of feed resources in China.

3 Problem analysis and suggestions

3.1 Insufficient understanding of coconut waste resources

In southern China, every year there are a large number of coconut wastes, but its use technology is not mature, and the comprehensive utilization degree is very low. In many places, the coconut farmers directly scrap the coconut waste or adopt conventional incineration and composting, resulting in a waste of resources, environmental pollution and ecological destruction.

Therefore, the government should strengthen guiding the awareness of comprehensive utilization of coconut waste, so that people's awareness of coconut waste's economic, environmental and social values is promoted; formulate the long-term planning of comprehensive utilization, increase financial input, and support scientific research units' study on the integrated utilization technology of coconut waste.

3.2 Inefficient comprehensive utilization of coconut waste resources In the coconut waste, in addition to the production of some low value-added products or raw materials, such as coconut shell charcoal, coconut coat fiber, coconut shell and wood crafts, other use patterns of coconut waste remain in the theoretical and small-scale pilot phase, with low level of resource-based utilization.

Therefore, it is necessary to strengthen the study on the supporting technology and related technologies, organize research institutes and related processing enterprises for joint research to increase the use ways and means of coconut byproducts, and focus on the research of key technologies to achieve the commercialization and industrialization of coconut waste resources.

3.3 Inadequate research efforts in the development and utilization of coconut waste At present, it lacks efforts in researching coconut waste utilization in China, and especially the collection, crushing and transportation equipments of waste generated during coconut cultivation is outmoded. Both the biogas production and direct combustion and power generation, need the collection, crushing and transportation equipments; if we can not provide the above techniques and equipments, the comprehensive utilization is impossible.

The government should increase investment in the development and utilization of coconut waste, to support the research and development of equipments and related technologies for the collection, crushing, transportation and processing of waste during coconut cultivation, to create conditions for the comprehensive utilization of coconut waste.

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