IV. POST-HARVEST PROCESSING TECHNOLOGY OF SWEET POTATOES IN SICHUAN, CHINA

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Abstract

Sweet potato is one of the important crops in China, its growing area and yield rank the first in the world. Sichuan Province has the largest growing area of sweet potatoes in China which amounted to 873,000 ha with total yield of 3,314,000 tons in 2000. Therefore, production of sweet potatoes is of great importance to agricultural production and increase of farmers' income in this province.

The whole process of production of sweet potatoes can be divided into three periodic stages: fast increase, stagnation and fast growing again in which post-harvest technology has played an important role. Post-harvest technology of sweet potatoes dominated by instant vermicelli and straight vermicelli processing came into being in early 1990s and this technology has been improved in practice ever since. And up to now, quite sophisticated technology and complete sets of equipment have been developed because such technology and equipment are suitable for current production conditions, and by utilizing this technology people have explored and tapped the potential of the market. Now this technology has been disseminated positively.

Development and application of post-harvest technology of sweet potatoes have played an important role in promoting the operational model of the industry in the form of Company Plus Farming Household in Sichuan. Based on the concept of processing on production bases, a batch of enterprises engaged in processing instant vermicelli and straight vermicelli has grown up. These enterprises, running in enterprise mechanism and carrying out standardized management in production under total quality control, have gained reputation and created their own product brands. At present, some 150,000 tons of straight vermicelli and 30,000 tons of instant vermicelli are produced every year in Sichuan with output value of 1 billion yuan. Farmers at the production bases earned 700 million yuan. Products are sold all over the country.

There are some problems encountered by the post-harvest processing industry of sweet potato. They are as follows: single type of the post-harvest technology. Market volume for sweet potato products dominated by vermicelli is almost saturated. Low extraction rate of starch from sweet potato, thus causing much waste of raw material. New technological process that is better for food safety needs to be improved and popularized. Solutions to address the pollution on rivers caused by production of starch in production bases need to be studied.

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A. Introduction

Sweet potatoes can easily adapted to poor soil condition and have strong adaptability to advance natural conditions. During its growth, it requires less than 1/2 and 1/5 of nitrogen and irrigation water than that required by growing rice, but its output (converted into calories) is 50% higher than that of rice and as much as twice of potato. Its functions of biological features in food and biological energy have attracted great attention of the industry. Sichuan Province is endowed with favorable conditions for growth of sweet potato industry. But there are some areas requiring improvement: the government shall make favorable policies for supporting the growth of the sweet potato industry, set forth related technical specifications, carry out research and improvement on new post-harvest technology of sweet potato, improve the operational system of enterprises and explore the market volume of products, research and develop better-quality equipment so as to increase the extraction rate of starch and improve its quality and better food criteria, solve the problem of environmental pollution. Sweet potato, named *Ipomoea batatas* Lam in Latin, was originally grown in tropical area of American countries and was introduced to China some 400 years ago. It is one of the important crops in China and its growing area and yield rank the first in the world.

B. Sweet potato post-harvest technology development

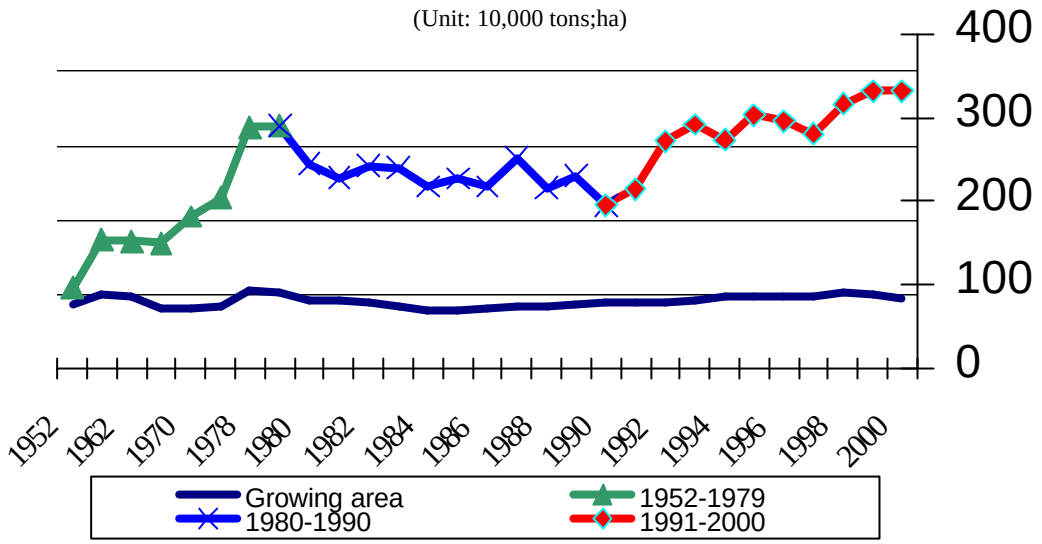
Sichuan province is the area with the greatest amount of sweet potato, with the growing area and annual yields accounting for 70% of all potato including taro. According to statistics, its growing area was 873,000 ha., yield 3,314,000 tons in 2000. Details are shown in Table 4.1. Therefore, production of sweet potatoes is of great importance to agricultural production and increase of farmers' income of Sichuan province.

Table 4．1. Statistics of sweet potato production in Sichuan, 1952-2000

Year	1952	1957	1965	1970	1975	1980	1985	1990	1995	2000
Area	108.9	125.3	102.5	103.9	105.3	117.1	99.4	113.6	122.9	120.7
Yield	138.8	220.5	214.1	260.2	289.8	349.4	325.2	279.6	433.4	452.7

Production of sweet potatoes can be divided into three periodic stages: fast increase, stagnation and fast growing again as shown in Chart 4.1. In the process of development of sweet potato and forming of processing industry, post-harvest technology has played an important role.

Chart 4.1. Three stages of sweet potato production (Sichuan)



During 1952-1979, sweet potatoes were mostly consumed as grain ration for the people and small amount was used as animal feed; during the period, output of sweet potatoes increased steadily. Also during this period of time, small amount of sweet potatoes produced was processed into straight vermicelli by traditional method. Vermicelli processed from sweet potatoes is good in taste but contains lots of fine sand with poor color and special odor disliked by most people, easy to break after cooking and low production yields.

During 1980-1992, with great increase of grain production of China, development of rural economy and prosperity of compound animal feed industry, amount of sweet potatoes used as grain ration of the people and animal feed decreased sharply. Sweet potatoes are mostly grown in poorly developed hilly and mountainous areas in Sichuan province. Therefore, great importance has been attached by governments at all levels in these areas to the post-harvest technology of sweet potato in a bid to increase farmers' income and create employment opportunities for local farmers. Compared to the potato processing technology that can be learnt experience from foreign countries, post-harvest technology of sweet potatoes lag behind. During this period of time, a small complete set of equipment for extracting starch from sweet potatoes was researched and developed in Sichuan.

However, due to higher cost of production of starch from sweet potatoes than that of the corn, sweet potato starch is relatively low priced resulting in low sales amount (see Chart 4.2). This has not functioned as an incentive to increase processing of sweet potatoes on a larger scale. By 1990, its growing area in Sichuan dropped to 790,000 ha., yielding 1,957,000 tons and the output was decreasing every year.

After 1992, with the hard work and support from the local governments, the

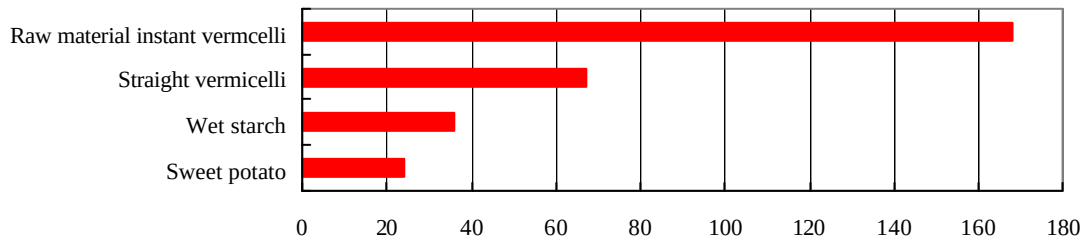
sweet potato processing technology dominated by producing instant vermicelli and straight vermicelli as well as operational model in system of Company Plus Farming Household came into being step by step. And in Sichuan, instant vermicelli industry developed into scale and breakthroughs in growing area and output of sweet potatoes have been achieved. In 2000, yield of sweet potatoes in Sichuan reached 3,314,000 tons.

Table 4. 2. Variety of starch produced in China, 2000

Variety of Starch	Output（ton）	Proportion（%）
Corn Starch	4,558,800	90.78
Cassava starch	336,200	6.70
Potato Starch	86,700	1.73
Sweet Potato Starch	3,800	0.08
Wheat Starch	34,300	0.68
Others	1,700	0.03
Total	502,150,000	100.00

According to the survey of two sweet potato starch producers in Sichuan, namely, Xingwan Company (producing sweet potato starch) affiliated to Nanchong Salt Factory and Longfeng Foodstuff Company, Changning County, Sichuan Province (producing instant vermicelli), sales price of sweet potatoes during harvest time is 0.24 yuan/kg, so 100kgs of sweet potatoes costs 24 yuan (0.24yuan/kgX100kg =24 yuan). And 24kg of wet starch can be extracted from 100kg of sweet potato that costs 36 yuan (1.50 yuan/kg x 24 = 36 yuan). 16 kg of vermicelli can be processed from 100 kg of sweet potatoes. If the sales price is 4.2 yuan per kg, the total cost will be 4.2 yuan/kg x 16 = 67.20 yuan. Raw material of instant vermicelli (75g per bowl) is 0.9- 1.3 yuan (whole sales price of 1 bowl cost is 1.6 – 2.0 yuan per bowl), 100 kg of sweet potato can be processed into 14 kg of instant vermicelli. The sales income will reach 14/0.075 x 0.90 = 168 yuan. Chart 4.2 shows the value of fresh sweet potatoes and its processed products.

Chart 4.2. Calculated income from 100 kg of sweet potato (yuan)



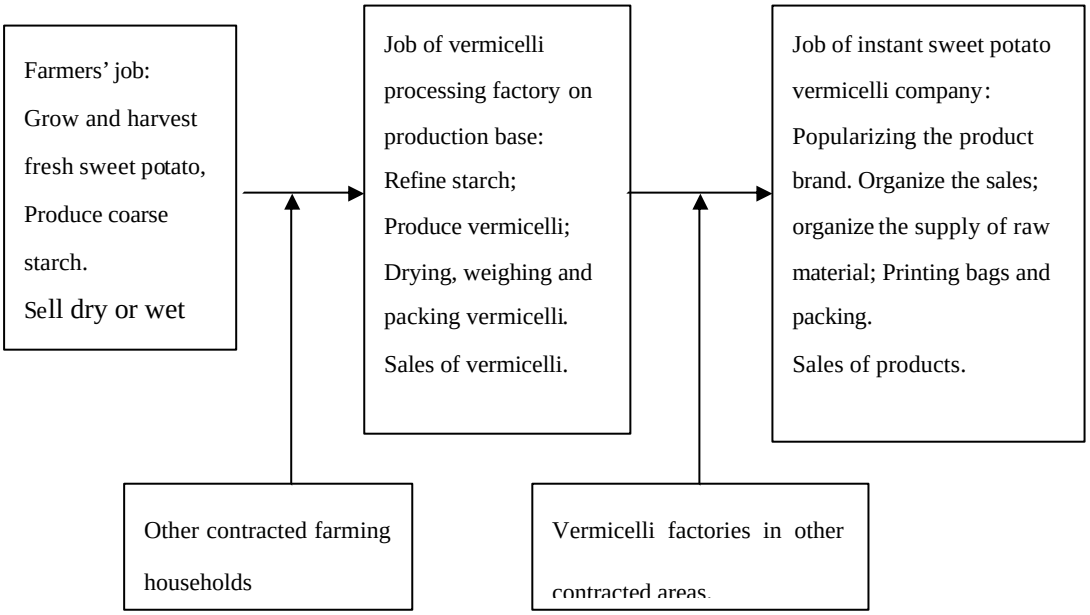
According to a survey in the rural area of Zhiyang and Nanchong Cities of Sichuan province in 2002, less than 20% of sweet potatoes was used as grain ration and about 30-40% used for value-added processing (1,200,000 tons), and 50% for

animal feed or rot.

Wide application of post-harvest technology of sweet potatoes such as the instant vermicelli and straight vermicelli of sweet potato in the growing area helps greatly for increasing farmers' income. At present, some 150,000 tons of straight vermicelli and 30,000 tons of instant vermicelli are produced every year in Sichuan with output value of 1 billion yuan. Farmers at the production sites earned 700 million yuan. Products are sold all over the country.

C. Sweet potato post-harvest utilization mode "company plus farmers"

Development of post-harvest processing technology of sweet potato helps positively set up of operational model of Company Plus Farming Household in sweet potato industry.



The operational system of Company Plus Farming Households for instant sweet potato vermicelli industry was set up gradually through interaction of production and technology. Farmers will extract coarse starch by themselves or ask other farmers to help after sweet potato is harvested locally and they make money by selling dry starch (100:16.5) or wet starch (about 100:24) and the income from this business is 40-50% higher than from selling fresh sweet potatoes. Meanwhile, the problems such as the storage of sweet potatoes, transport and residues after processing have been solved, creating opportunities of employment for rural labors and increase farmers' income.

Factories of instant vermicelli usually purchase coarse starch for refining and such factories are usually located in production bases. They usually supply sweet potato vermicelli as raw materials for the instant vermicelli producers that have

created their brand. Also there are some factories producing instant vermicelli and sell their own products in the name of their own brands, and employ local farmers.

Through processing instant vermicelli and straight vermicelli on the production bases, number of enterprises have set up to carry out standardized production under total quality control and built up their brand reputation. Currently there are some well-known enterprises such as Guangyou, Guoji, Pangda, etc., producing tens of thousands of tons of vermicelli per year. Table 4.3 shows the names of famous enterprises engaged in producing instant vermicelli.

Table 4. 3. Production capacity of the major factories in Sichuan

Enterprise	Trade Mark	Capacity (Ton)	Output in 2002 (ton)	Output Value in 2002 (Yuan)	Address
AS Food Co. Ltd.	Baijia	10,000	9,000	120,000,000	Chengdu Economic & Technological Development Zone, Longquanyi District, Chengdu, Sichuan, China Post Code: 610100
Guangyou Sweet Potato and Food Products Co. Ltd.	Guangyou	10,000	4,000	65,000,000	High-tech Development Zone, Mianyang City, Sichuan Province, China. Post Code 621000
Guoji Industrial Co. Ltd	Biandan Guniang	12,000	3,500	80,000,000	Jialing District, Nanchong City, Sichuan Province, China. Post6 Code: 637005
Nanchong Hongya Foodstuff Co. Ltd	Pangda	11,000	1,463	27,800,000	Nanchong City, Sichuan Province, China. Post Code: 637102

Source: AS Food Co. Ltd., Guangyou Sweet Potato and Food Products Co. Ltd., Guoji Industiral Co., Ltd. and Hongya Foodstuff Co., Ltd.

D. Sweet potato starch extracting technology

Post-harvest processing technology of sweet potatoes with instant vermicelli and straight vermicelli as the major products came into being in early 1990s and it has been improving ever since in practice. Recently, systematic technology and complete sets of equipments have been developed as follows:

1. Technology and equipments for producing coarse starch

(a) Coarse starch production by farming households

At present, small-sized equipments for processing coarse starch from sweet potatoes with capacity of 800 kg of fresh sweet potatoes per hour has been developed suitable use for by farmers. Technology and equipments for coarse starch utilized by starch mills in rural areas can be described as follows:

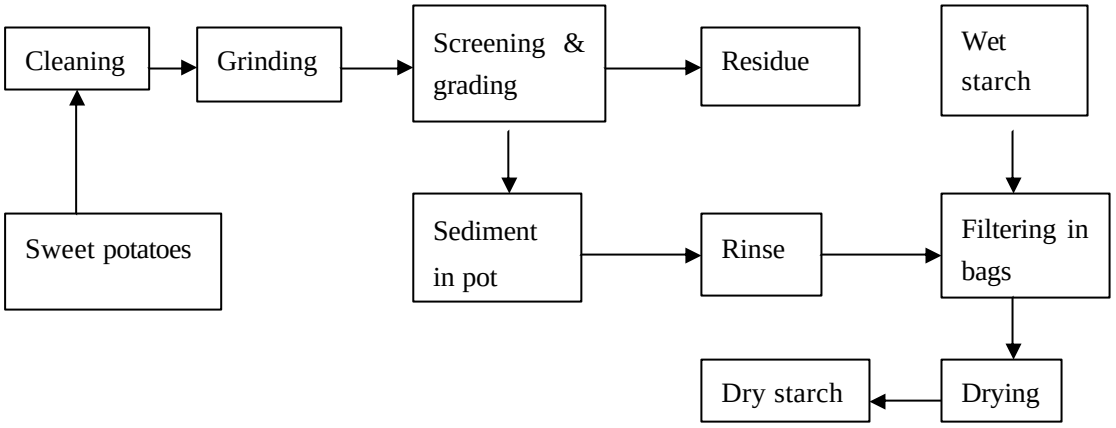


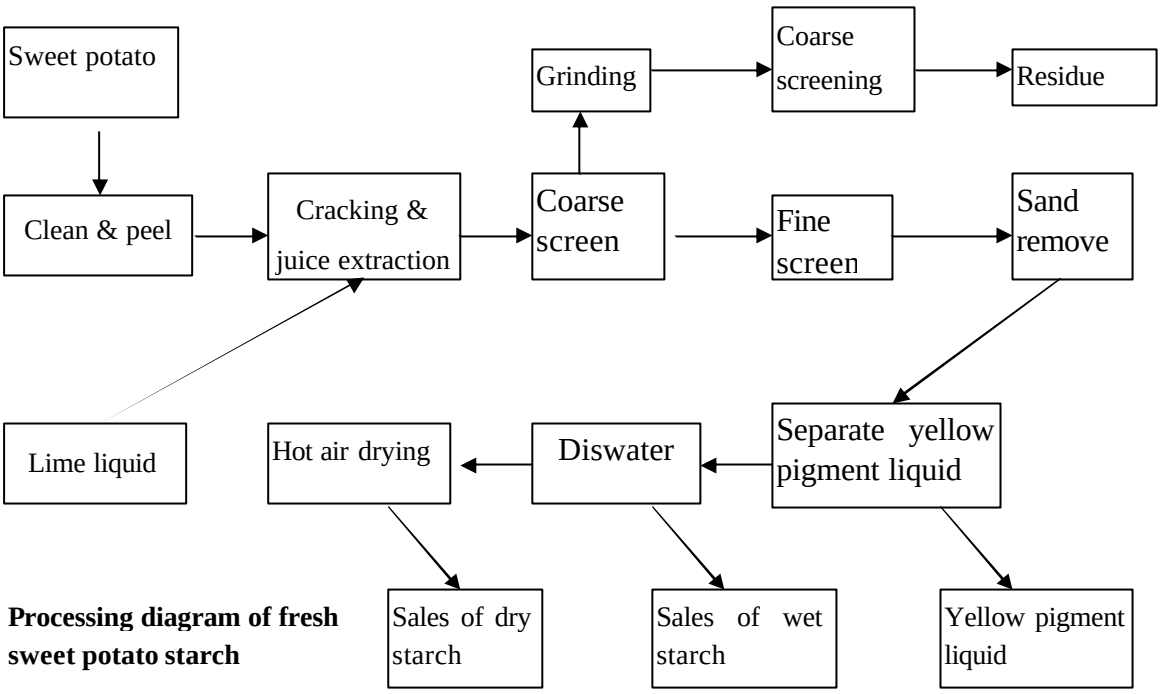
Table 4. 4. Specifications and estimated investment for equipments

Type	Description	Installed capacity	(kg)	Overall Size (m)	Quantity	Estimated investment (Yuan)
XS-300	Multi-functional Inclined Washer of Sweet Potatoes	2.2	215	2.15× 0.64× 1.90	1	6,800
GM-500	Grinder	15.0	350	1.10× 0.65× 1.30	1	10,100
CMF-300	Separator	5.5	230	2.60× 0.60× 1.25	1	6,600
JC-1000	Discoloring & Sand-removing Machine	3.0	190	1.25× 1.20× 2.15	2	8,400
GL-800	Residue & Starch Separator	1.5	95	1.90× 0.60× 0.76	2	5,900

Source: Guangyou Sweet Potato and Food Products Co., Ltd.

(b) Sweet potato starch for large-scale production

The following diagram shows in flow chart figure, capacity of processing 1-3 tons of fresh sweet potato per hour; rather high extraction rate and efficiency can be achieved by use of this process:



Processing diagram of fresh sweet potato starch

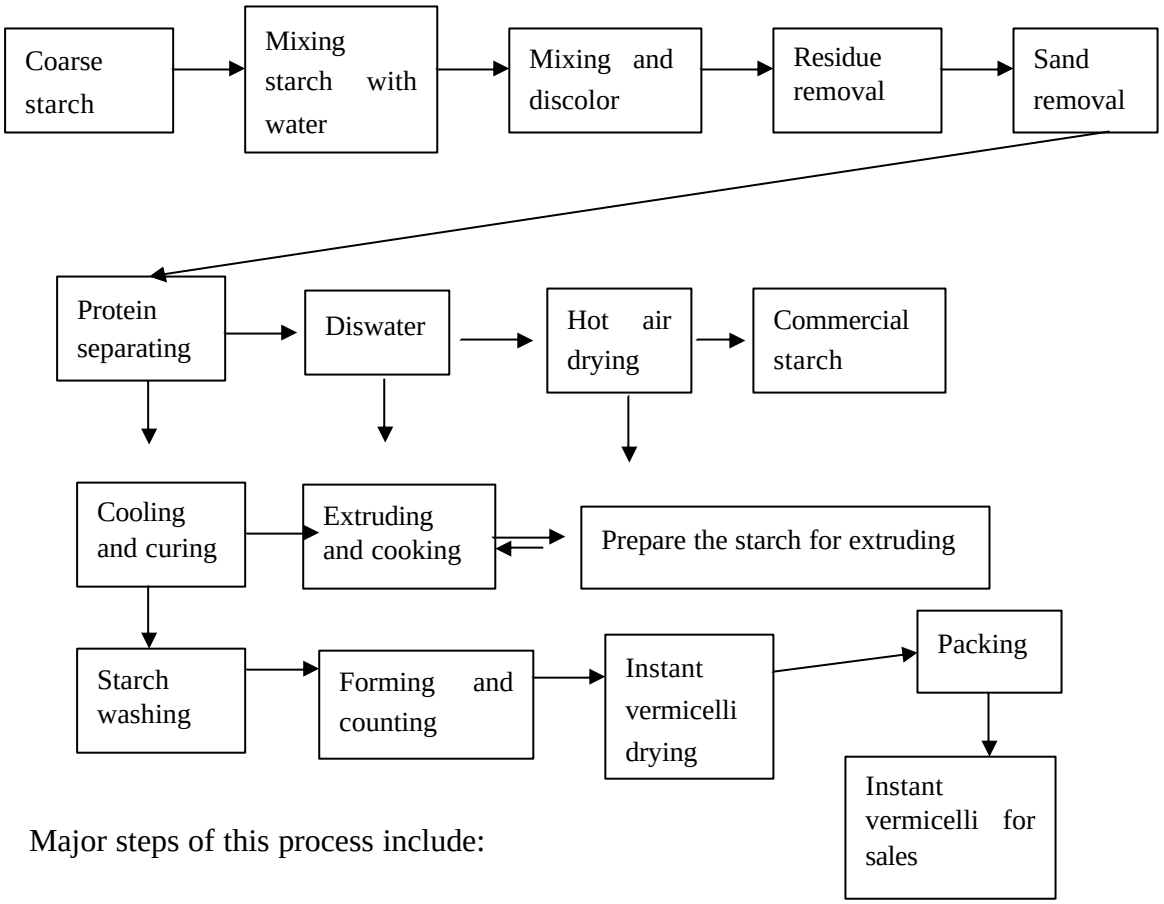
Table 4.5. Performance, specifications and estimated investment

Type / Specifications	6D-0.5	6D-1	6D-2	6 D-3
Production (ton/shift)	0.5	1.0	2.0	3.0
Extraction rate	≥80%			
Installed capacity (kw)	35	50	65	95
Power Consumption	Electricity≤160kwhr/toncoal≤0.18 ton/ton of starch			
Land area (m^2)	250	400	540	650
Operator	8~10	10~12	12~14	12~16
Price for reference (yuan)	120,000 yuan	200,000 yuan	320,000 yuan	450,000 yuan

Source: Sichuan Research and Design Institute of Agricultural Machinery, Chengdu, Sichuan, China.

2. Technology and equipments for refining of starch, processing of vermicelli and high-efficiency drying of vermicelli

(a) Process of starch refining, straight vermicelli and instant vermicelli production:



Major steps of this process include:

Refining of starch. It is one of the major steps of processing vermicelli carried out by producers aimed at removing sand; dirt, glue, protein, pigment and bad odor remained in the starch so as to increase the white color and purity of starch.

Extruding and cooking process. Extruding and cooking by constant-temperature heater is used now instead of the traditional extruding and cooking methods used in the past, resulting in high efficiency and better quality of vermicelli.

Curing of vermicelli. In fact, this is a process in which the molecular structure of vermicelli changes from a to ß by cooling. Curing better means the vermicelli can be cooked longer for the straight vermicelli. But for instant vermicelli, moderate curing is enough otherwise it will be difficult to recover in water before eating.

Forming of vermicelli, counting and drying. This is one of the key steps in production of instant vermicelli which influences the quality (storage period, recovery in water)

and cost of production (energy consumption and productivity) as well.

(b) Equipments

Table 4.6 shows the main technical parameters and investment calculation of equipments for producing 0.5-8.0 tons of refined starch (information provided by Sichuan Research and Design Institute of Agricultural Machinery).

Table 4.6. Main technical parameters and investment calculation of equipments

Type / Parameter	6DZ-0.5	6DZ-1	6DZ-2	6DZ-4	6DZ-8
Output (ton/shift)	0.5	1.0	2.0	4.0	8.0
Installed power (kw)	30	37	53	70	113
Energy consumption	Electricity≤120kw.hr/ton starch，coal≤0.2ton/ton starch				
Water consumption	6~8ton/ton starch				
Land area (m^2)	250	400	500	650	800
Operator	4~5	4~6	5~7	6~8	8~10
Quality	Conforms to the requirements of starch quality and hygiene standard set forth by China				
Estimated investment (10,000 yuan)	10	25	40	70	120

Table 4.7 shows the main equipment and investment calculation for processing 60-250 kg of straight vermicelli per hour (information provided by Sichuan Research and Design Institute of Agricultural Machinery).

Table 4.7. Main equipments and investment calculation

Type / Parameters	6DFT-500Z	6DFT-1000Z	6DFT-2000Z
Output (kg/hr.)	≥60	≥120	≥250
Installed power (kw)	44	68	108
Energy consumption	Electricity≤150kwhr/ton starch, coal≤0.25ton/ton starch		
Water consumption	6～8 ton/ton of vermicelli		
Land area (m^2)	250	400	500
Operator	8～12	8～15	10～18
Estimated investment in equipment (10,000 yuan)	23	35	61
Quality	Conforms to the requirements of starch quality and hygiene standard set forth by China		

Table 4.8 shows the main parameters and investment calculation for processing 5,000-20,000 bowls of instant vermicelli (information provided by Sichuan Research and Design Institute of Agricultural Machinery).

Table 4.8. Main parameters and investment calculation

Type / Parameters	6DFS-0.5	6DFS-1.0	6DFS-2.0
Output (75g/bowl)	5000 bowls (bags)/shift	10000 bowls (bags)/shift	20000 bowls (bags)/shift
Installed power (kw)	37	54	77
Coal consumption (kg/hr.)	12	20	40
Land area (m^2)	220	300	400
Workshop (m^2)	>4	>4	>5
Operator	16～18	18～20	20～24
Estimated investment in equipment (10,000 yuan)	48	85	150
Quality	Conforms to food quality standard GB2713-1996 and SB80-81 set forth by China		

E. Suggestions for improvement on sweet potato processing

Sweet potatoes are resistant to poor soil condition and have strong adaptability to advance natural conditions. During its growth, it requires less than 1/2 and 1/5 of nitrogen and irrigation water as required by growing rice, but its output (converted into calories) is 50% higher than that of rice and as much as twice of potatoes. Its biological merit as food and biological energy have attracted great attention of the industry.

Post-harvest technology of sweet potatoes dominated by instant vermicelli in Sichuan has contributed greatly to agricultural production and increase of farmers' income of Sichuan province. The reason for wide application and dissemination lies in its suitability for current production conditions and exploration of the market.

1. Current problems with regard to the post-harvest technology of sweet potatoes

- Single type of technology: The market for sweet potato products dominated by vermicelli of sweet potato is almost saturated. At present, only about 30-40% of sweet potato is used for post-harvest processing, therefore, there is just small room to increase of output of sweet potato by relying on producing vermicelli of sweet potato.

- Starch processing mills run by farmers or farming households in the country are usually small in size, simple in facilities that cause low extraction rate of starch (it is about 65%, but 80% extraction rate can be achieved if specialized complete set of equipment is used) and serious waste of raw material.

- At present, some factories use Kal $(SO_4)_2.12H_2O$ and S as additives for producing vermicelli of sweet potatoes. With the increasing awareness of health hazard and more strict criteria of food safety, such practice has brought worsening influence on the sales of the processed sweet potato products.

- Currently, no facilities for waste water and waste residue treatment are used on the processing equipments for coarse starch, and such wastes pollute the rivers near sweet potato growing areas.

2. Improvement for sweet potato post-harvest utilization

- Government should pay attention to formulating policies for developing the sweet potato industry.

- Carry out research on new technology such as production of Ethanol as the fuel of Automobiles by use of sweet potatoes, sweet potato grain (in which starch of sweet potato serves as the main component, added in small amount of cracked corn or corn powder and so on), and improve these technologies for further exploring the market for sweet potato products.

- To set up Growers' Association of Sweet Potato: This kind of associations may promote contracts with companies or they can establish their own companies in the operational model of Company Plus Farming Households so as to protect farmers' interest and promote the production of sweet potato products as the industry level.

- Develop better equipments so as to increase the extraction rate and quality of starch, improve criteria of food safety, and alleviate environmental pollution caused by the industry.

- Set forth related technical specifications, standardize the criteria of product quality and methods of quality inspection.

References

China Yearbook of Agriculture, 2002. China Agricultural Publishing House.

China Yearbook of Agricultural Product Processing, 2001. China Agricultural Publishing House.

Jiang Limao et al., 2002. Documents on Research and Development of Sweet Potato Processing Technology, Sichuan Research and Design Institute of Agricultural Machinery.

Sichuan Statistics Yearbook, 2001. China Statistics Publishing House.

Wang Dayi et al., 2002. Statistics on Sweet Potato Resource, Crop Research Institute, Sichuan Academy of Agricultural Science.