

## Chapter 9

### Sweetpotato Processing and Product Research and Development at the Sichuan Academy of Agricultural Sciences

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#### Abstract

This article presents the technology developed by the Sichuan Academy of Agricultural Sciences (SAAS) in processing sweetpotato into food products including starch, snack foods, whole nutrition flour and their by-products. The technology can also be used to process potato, canna (*Canna edulis*), cassava and other agricultural products.

**Keywords** : potato, sweetpotato, food processing, starch, snack food, whole nutrition flour

#### Introduction

Sweetpotato is an important source of human food and animal feed. In Sichuan Province, China, it is popularly referred to as “the green golden mine” that should be fully developed. The annual sweetpotato production area in the Sichuan Basin (including Sichuan province and Chongqing municipality) is more than 1.33 million hectares. The total production is 23 million tons and ranks first in China. This production contributes 18.5% of total sweetpotato production in the world. This is greater than the total production of all countries in the world, except China. Thus, research and development of sweetpotato in Sichuan is very important.

Sweetpotato is mainly planted in hilly lands and mountainous regions in the Sichuan Basin. Typically, it is intercropped with corn and wheat, although it is

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occasionally planted alone after the harvest of wheat. The cropping system is wheat/corn/sweetpotato.

Sweetpotato is usually planted in nurseries in March, and transplanted from nurseries to the field from late May to early June. Harvest takes place from late October to early November, after a growing period of 150 to 160 days. The high yield of sweetpotato is due to favorable temperature, sunlight, and rainfall. Based on the experiment of the Sichuan Academy of Agricultural Sciences (SAAS), the use of newly-bred varieties can produce 70 to 75 tons per hectare when planted as a monocrop and 45 to 50 tons per hectare when intercropped.

Sweetpotato is a high yielding crop with wide adaptation and high resistance to drought. However, the actual yields range only from 16 to 17 tons per hectare, which is only 40% of the yield of new varieties. Thus, there is significant potential to increase production in Sichuan. During the past 20 years, the yield of rice, wheat and corn per hectare increased by 64%, 67%, and 43% respectively while the total production increased by 57%, 82% and 51% respectively. In comparison, the yield of sweetpotato only increased by 3.8% while total production declined by 5.7% during the same period. Why did the yield of sweetpotato almost stagnate? The research showed that this pattern was due to the backwardness of sweetpotato processing and utilization. At present, about 70% of the total sweet potato production is used as feed for pigs. Only 10% of total sweetpotato production is consumed as human food. Moreover, 10-15% of the total production is lost due to rotting because of high water concentration. Thus, there is a need for a continued effort to develop sweetpotato production towards: 1) enhanced processing and breeding research, 2) improved sweetpotato processing technology and equipment, 3) improved quantity and quality of sweetpotato varieties and their processing products, and 4) increased income of farmers.

Before the mid 1980's, the proportion of sweetpotato being processed was less than five percent of the total production while the major products are coarse starch and low quality general noodles. During the past fifteen years, SAAS and the International Potato Research Center (CIP) have jointly conducted the breeding of new sweetpotato cultivars and the development of sweetpotato processing technology and equipment. The results have been demonstrated and extended in Santai, Anyue, Nanchong, Mianyang, Yilong counties in Sichuan Province and other potato and sweetpotato planting areas throughout the country. The impact of the project was remarkable. For instance, the proportion of sweetpotato for processing increased to 10% in Sichuan recently. The breakthrough on the technology of sweetpotato whole nutrition flour, starch, noodles, potato and sweetpotato instant noodles and other snack foods have been made and they are good models for large scale sweetpotato processing in Sichuan, as well as in China in general.

## **Research and utilization of sweetpotato processing technology**

### *The noodles and starch technology*

Generally, the climate is cloudy, humid, and windy when sweetpotato is harvested. These climatic conditions create problems in the processing of sweetpotato into slices, starch and noodles. In response to this, in the early 1990s SAAS and CIP developed a small-scale processing technology. The technology includes small processing equipment and a corresponding technological process suitable for use by farmers. The technology increases the efficiency, reduces hard work, and improves the quality of processed sweetpotato into starch and noodles. In 1993, the National Committee of Science and Technology listed the technology as one of the “National Key Extension Program of Scientific Achievements”. It also won the Second Prize for Scientific Achievement in Sichuan Province in 1994. The set of machines of its technologies has been extended to more than 100 counties in over 20 provinces in China and abroad. Recently, the technology has been further developed and combined with refined starch and instant noodle production with medium and large scale enterprises, and has proven to be popular in Sichuan.

### *Sweetpotato starch processing technology*

Figure 1 illustrates the traditional processing of early sweetpotato starch by hand. The starch processing method newly developed by the project is shown in Figure 2.

The project has improved the processing of sweetpotato into starch by means of the “sour liquid” method, choosing the right type of smashing machine (saw drum or hammer machine), choosing with the best sieve design (a curved sieve plate with specific mesh size), and improving the refining technology. With these improvements, the starch extraction rate increased from 13 to 15 percent, work efficiency rose from 2.3 to 4 times, power consumption dropped by 50 percent, and starch quality was greatly improved. As a result, profits from using the new technology was 1.9 to 3.9 times more than what they were with the traditional method of processing sweetpotato into starch. The starch derived from the improved process is widely used in for making instant noodles and other products.

### *Sweetpotato noodles processing technology*

Figure 3 shows the traditional method of processing sweetpotato noodles. The traditional process takes a long time and efficiency is low due to the complex procedure. The study found that the basic principles in processing sweetpotato noodles like mixing,

making gelatinous soup, and precipitation of starch heavily depend on factors like moisture content, temperature, pH value of the mixed starch paste, and the amount of salt.

After analyzing the relationship between these factors and the quality of noodles, the best mechanized procedure for good quality noodles processing is detailed in Figure 4. Figure 4 shows that the use of machines has taken off the arduous task of pounding by hand. As a result, work efficiency has increased. The distinct taste of noodles made by manual processing was maintained even though the processing was mechanized. Furthermore, work efficiency doubled resulting to a profit increase of 1.5 to 1.7 times more than the traditional method. SAAS has designed, enhanced and manufactured different sets of relevant starch and noodle equipments such as mixer, vacuum mixer, noodle-boiler, noodle-separator, and freezer for mass fabrication in medium and small scale. It has also collaborated with machine manufacturers. The Rei Fa Food Company in Anyue County, Sichuan province has successfully adopted the technology system including the machinery. The extension and utilization of the machines have shortened the process of making sweetpotato noodles. Thus, more medium-sized noodle enterprises which have realized the advantages of the new system are eager to adopt the technology and machine.

## **Research and popularization of instant potato and sweetpotato noodles (IPSN)**

### *Characteristics of the product*

The new technology to produce nutritional starch instant noodles from sweetpotato was a product of years of starch and noodle research by the SAAS in cooperation with CIP. The project has developed two methods in making instant noodles: extruding method and sheeting method. The product from sheeting method is also called the nutritional starch instant noodle (IPSN) because of specific ingredients and processing procedure. The IPSN has many advantages when compared with products produced by the manual extruding method. These include:

a. Storage convenience and ease in preparation.

Like instant wheat noodle, IPSN is ready to eat after soaking in hot water (>80°C for 5 minutes, unlike the ordinary noodles that need to be cooked in boiling water for ten minutes. This makes IPSN suitable for regular family meals and snacks.

b. More nutritious

IPSN contains more dietary fiber, amino acids, mineral elements, and vitamins than the normal starch noodles. The higher nutritional value of IPSN

comes from a mixture of potato and sweetpotato flour and other ingredients compared to normal noodles which come a mixture of 100% potato or sweetpotato starch only.

c. Better mouth feel and shape

This is made possible by the advanced sheeting technique and the use of machines that have better design. The noodles do not easily break after being soaked for a long time and has a more chewy texture than the normal noodle.

*Characteristics of the technology*

a. Special process and advanced technique

In dextrin (heating) process, a special technique and machine are used to continuously carry out the whole production process while the quantity and quality of noodles are guaranteed. The cooperative enterprise of SAAS was the first to successfully use the technology, which has already been awarded a patent by the state.

b. Cheaper and easily combined with existing processing equipment

Lower investment is needed to procure the machine. At the same time, it can be easily combined with the existing primary starch processing machinery in the manufacturing plants. As a result, higher profits accrue to the farmers and the basic processors.

c. Wider application

This technology is not only suitable for sweetpotato starch and flour mixes, but also for mixing in starch from potato, corn, pea, canna (*Canna edulis*), cassava and others, depending on the desired taste and texture of the final product.

**Sweetpotato snack foods**

Sweetpotato snack foods are popular in Sichuan because of it is fairly sweet, has delicious flavor and a bright color. During the past ten years, SAAS has succeeded in developing other kinds of new potato and sweetpotato snack foods such as chips (made from sweetpotato roots or made from flour by steaming, slicing, drying, frying, seasoning, mixing, and packing), crispy sweetpotato cakes (a mixture of sweetpotato, egg and wax rice flour), low sugar sweetpotato candy, and vacuum-fried potato and sweetpotato sticks/chips. The technology developed by the SAAS for vacuum fried potato and sweetpotato sticks/chips is explained below.

Vacuum frying method is a new technology developed by SAAS. By frying at a

low temperature (80-90°C), the original flavor, color and nutritional composition of raw sweetpotato are well preserved. The medium and small-scale vacuum frying machines designed by SAAS are inexpensive and good quality. Thus, small to medium enterprises can easily acquire it. This technology can be used to produce many kinds of fried snack foods such as potato, sweetpotato, apple, carrot, pea, broad beans, banana, and meat. The procedure for vacuum frying method is shown in Figure 5.

## **Sweetpotato whole nutrition flour**

### *Characteristics of the sweetpotato whole nutrition flour*

The sweetpotato whole nutrition flour can be directly used as food or as raw materials for processing into other food products. The flour keeps all the nutrition elements of fresh sweetpotato that the starch does not have. It is called “sweetpotato whole nutrition flour” or “sweetpotato whole flour”. The research improvement by SAAS to develop this product included the following:

- a. The whole nutrition sweetpotato flour maintains the color, flavor, and most of the nutritional composition and curative elements of fresh sweetpotato roots such as vitamins, dietary fiber, polysaccharide-protein, physiological alkaline ingredients, soluble sugar, calcium, and phosphorus. The product is a healthy food with curative effect, thus greatly encouraged by the government and well-known scientists. A compositional analysis of the product by SAAS yielded the information shown in Table 1.
- b. The product is convenient to eat and has good taste and flavor. When the flour is mixed with water, it recovers the flavor of fresh cooked sweetpotato and tastes very well.
- c. The product can be stored for a long time, and is available all year round. By contrast, fresh sweetpotato roots can only be used within 4-5 months.
- d. The product can be used as raw material for making processed food products by households and by restaurants. There are many potential food products that can be made from whole nutrition sweetpotato flour: fried sweetpotato cakes, compound sweetpotato nutrition flour for instant food, extruded sweetpotato chips, sweetpotato breads, sweetpotato noodles or instant noodles, sweetpotato ice creams, and sweetpotato porridge.

The processing procedure of the sweetpotato whole nutrition flour is shown in Figure 6.

### *The technology of sweetpotato whole nutrition flour*

The whole sweetpotato nutrition flour technology has solved the problems of high cost of drying from high level water content of roots of 68-72 percent, darkening, and deterioration of taste during processing. The technology includes the application of economic (minimum) energy cost, microwave technology, super-fine flour making technology and swelling technology. These technologies are already patented in China.

The equipment and technology made processing of sweetpotato products from the flour possible all year round. It can also process other dried and powdered products such as pumpkin, corn, potato and carrot.

The small machine can produce high quality products with lower investment. At the same time, the technology is also suitable for large, medium and small-scale enterprises and is also compatible with the primary processing of processing systems of large enterprises. Thus, farmers can finish more primary processing, resulting in higher incomes.

### **Demonstration and extension of processing technology**

The demonstration and extension of sweetpotato processing technology to farmers and enterprises in Sichuan have been facilitated by the cooperation between CIP and SAAS since 1990. The local governments have also strongly supported the project. Therefore, the sweetpotato production and processing have greatly improved in Anyue, Shantai, Mianyang, Nanchong, and Guanghan counties of Sichuan. The increased income of farmers from improved technology has contributed to the promotion of local agricultural economy.

### *Sweetpotato whole nutrition flour*

Yilong County is one of the largest sweetpotato producing counties in Sichuan province. The average sweetpotato production is about 0.4 to 0.5 million tons per year. A cooperator of SAAS, the Yilong Green Food Limited Corporation founded in 1997 was the first demonstration factory for sweetpotato whole nutrition flour in China. The total investment was 2.50 million Yuan (US\$0.30 million). It produces a total of 500 tons of whole nutrition flour and 1000 tons of compound sweetpotato powder annually. Its annual contribution to local farmers is estimated 3.40 million Yuan (US\$0.41 million). This product has been successfully used to make instant sweetpotato flour, sweetpotato steamed bread flour, sweetpotato fried cake flour and some other food products. The technology will be further extended in Sichuan Province and in the whole

China.

*The largest sweetpotato noodle processing county in Sichuan*

Since the mid-1980s, scientists from SAAS and CIP researched and developed technology for sweetpotato starch and noodle processing in Santai county. The farmers were trained in the demonstrating factories, and some were able to learn quickly. Yong-Chun Sweet Potato Company, which produces starch and noodle machines, and Guang You Special Roots Company, which produces noodles and manufactures processing machines, are some of the companies that use the technology from SAAS. They have been both well-supported by SAAS and CIP project scientists. These companies have progressed very well and have also greatly influenced many other potato and sweetpotato processing enterprises. In 2001, total noodle production in Santai county was 120,000 tons with a total sales value of 480 million Yuan (US\$58 million). The locally made machines for sweetpotato starch and noodles were sold in more than 20 provinces in China. The average income of a processing farm family was estimated to be three times more than the non-processing farmers. The annual income of a processing family was 4530 Yuan (US \$ 548), 85% of these income derived from sweetpotato processing.

*The town of sweetpotato noodles – Zhouli Town of Anyue County*

Anyue County ranks first in Sichuan province in terms of sweetpotato production. The average annual sweetpotato planting area in the county is over 30,000 hectares and total production is about 0.75 million tons. Under the guidance and help of SAAS and CIP, sweetpotato starch and noodle production has gradually shifted from traditional to modern scientific techniques, and towards larger scales of production. Specifically, scientists from SAAS and CIP have improved the sweetpotato processing technology and trained farmers and some enterprises in Zhouli Town of Anyue County. The major changes brought about by the new technology are quality improvement of starch and noodles and the doubling of income from production and sales. In 2000, the total noodle production of the town was 60,000 tons amounting to 190 million Yuan (about US \$ 24 million). This value is ten times more than the earnings ten years ago. Currently, 90 percent of the farmers are involved in noodle processing. A team of professional transportation groups and traders for wholesale has been organized while four sweetpotato starch and noodle specialized markets have been set up. The business is progressing very well. The noodles are sold to more than 20 provinces daily. Zhouli Noodle Industry Society, a special farmers' association which was organized in Zhouli Town in 1997, helps to promote the local industry and its products.

### *Potato and sweetpotato instant noodles*

In recent years, instant noodles has become more and more popular in Sichuan. This product originated from the sweetpotato noodle and refined starch that SAAS researched before. Currently, there are at least three large-scale enterprises producing instant potato and sweetpotato instant noodle with the annual output of more than 5000 tons. Meanwhile, under the guidance and technical support of SAAS, the new instant noodle technology known as the “Sheeting Method” has been successfully used. Instant noodle has become a very popular food in Sichuan and many provinces of China. Further research and popularization of this product by SAAS are currently ongoing.

### *Sweetpotato snack foods of vacuum frying sticks and chips*

In the course of disseminating the vacuum frying new technology and machines for potato and sweetpotato sticks and slices, the SAAS set up sample factories in the provinces of Sichuan province and some other provinces such as Guizhou, Chongqing, Guangdong, Guangxi and Tibet autonomous region. The products are very popular, especially among young people.

## **Prospects of sweetpotato processing in Sichuan**

Sweetpotato processing has reached an industrial scale and has contributed to the growth of the local economy during the past ten years. It has enabled many farmers to get out of poverty. Yet, the sweetpotato processing industry is still not big enough and only utilizes about 10% of the total sweetpotato output. There are still problems in sweetpotato processing that need to be studied, particularly on technology and product quality. There is also a need to develop new high value-added products. Research priorities include study of the physical and chemical characteristics of starch and distinct traditional food from sweetpotato. Research and development of sweetpotato processing should focus on the following concerns:

- 1) The physical and chemical characteristics of potato and sweetpotato starch and trial products’ application for the modified starches
- 2) Distinct traditional foods
- 3) Instant foods and snack foods
- 4) Further usage and research of the whole nutritional sweetpotato flour

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Table 1. Results of the analysis of the whole nutrition sweetpotato flour, 1995

Items	Sweetpotato Roots <sup>1</sup>	Sweetpotato flour (pure flour) <sup>2</sup>	Complex sweetpotato flour (instant flour) <sup>3</sup>
Soluble sugar (%)	4.95	39.50	
Moisture (%)	72.50	7.06	2.75
Protein (%)	1.50	5.56	13.40
Lipids (%)	0.17	0.85	8.87
Carbohydrate (%)			60.98
Coarse fiber (%)	0.62	1.58	2.90
Ash (%)	0.62	1.94	3.62
Calcium (%)	268.02	0.13	294.51
Phosphorus (%)	0.043	0.164	118.69
Iron (mg/kg)	17.98	74.5	11.66
β-carotene (mg/kg)	14.74	27.58	0.093
Vitamin B <sub>1</sub> (mg/100g)	0.132	0.498	0.853
Vitamin B <sub>2</sub> (mg/100g)	0.027	0.164	0.32
Vitamin C (mg/100g)	27.00	1.20	29.91
Vitamin B <sub>5</sub> (ug/g)	15.00	20.00	
Amino-acid (%)			9.07

Note: 1) comes from the new variety of fresh root bred by SAAS.

2) comes from the root of the same sweetpotato variety as <sup>1</sup>).

3) comes from the flour of <sup>2</sup>), and some other food auxiliary materials are added.

Figure 1. Traditional processing of sweet potato starch

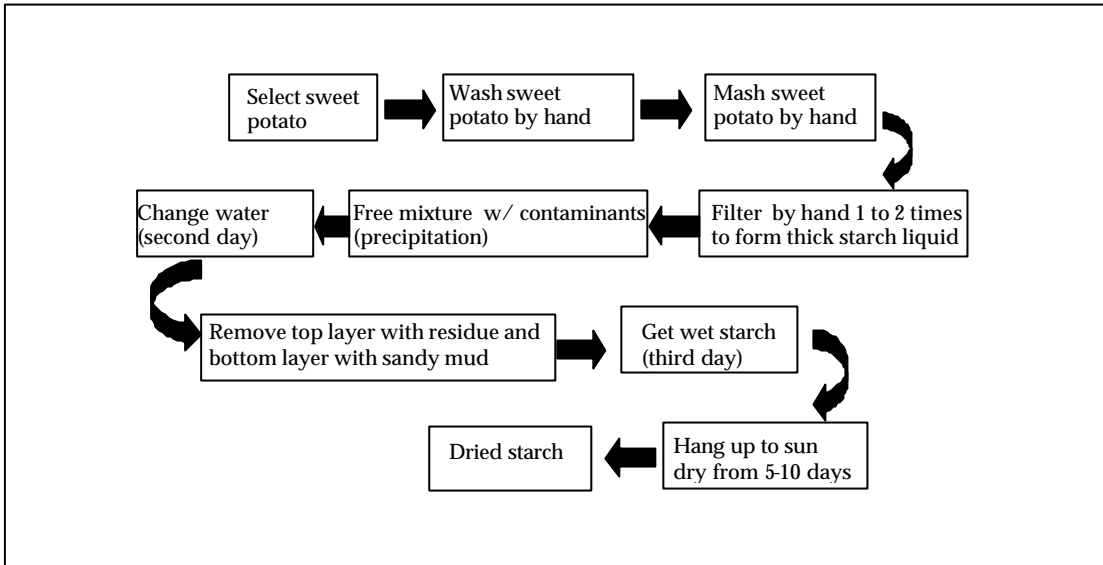


Figure 2. Starch processing using the developed technology

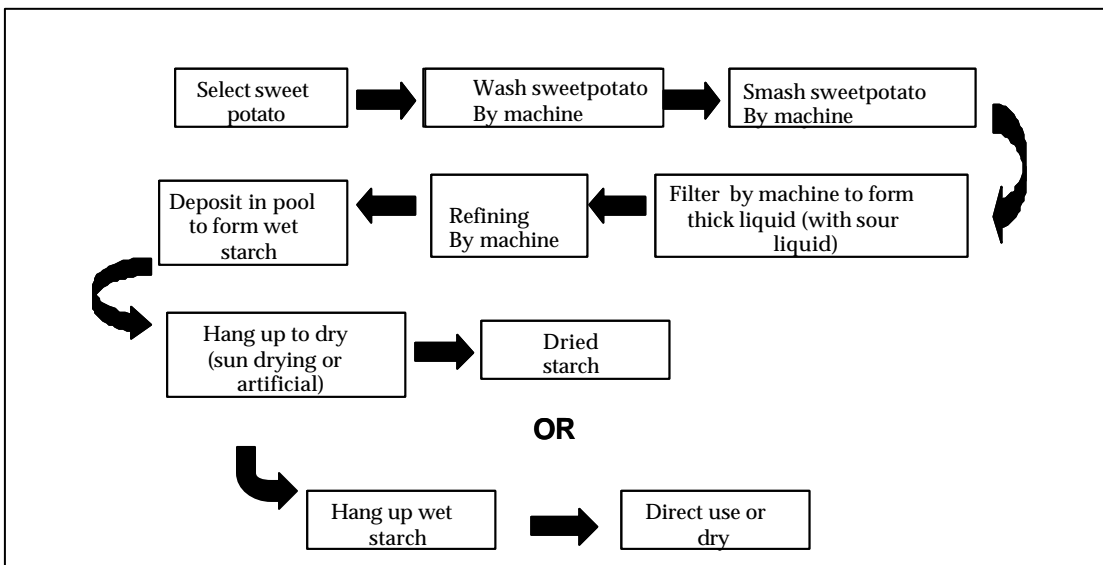


Figure 3. The traditional method of processing sweet potato noodles

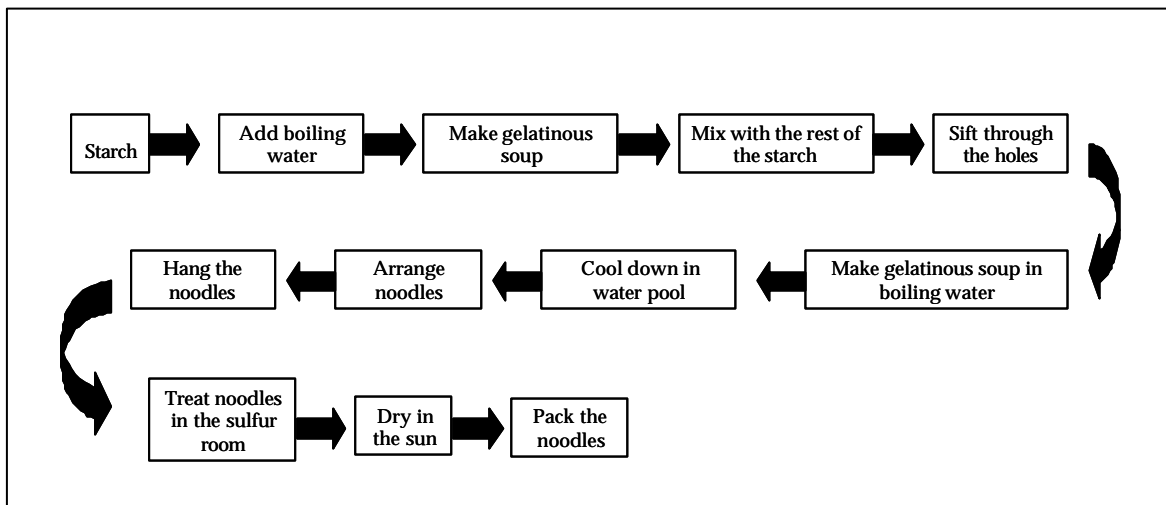


Figure 4. Mechanized processing of sweetpotato noodles

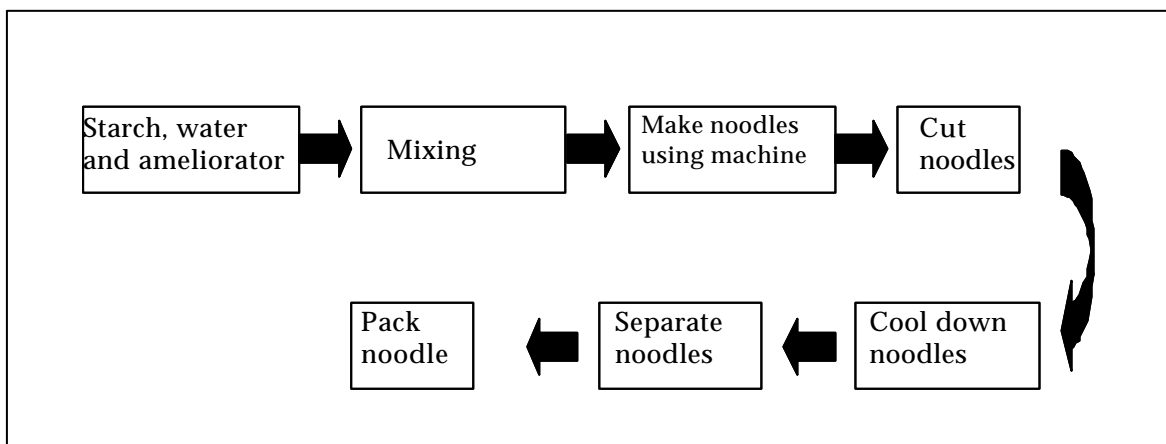


Figure 5. The vacuum frying technology

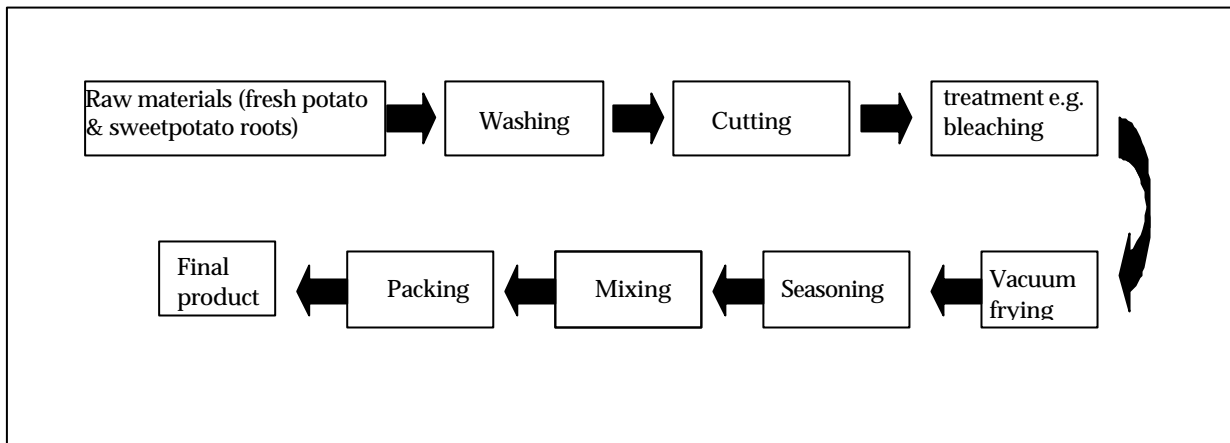


Figure 6. The sweetpotato whole nutrition flour processing technology

