Sweetpotato starch in China: current status and future prospects.

Christopher C. Wheatley and Song Bofu[1]

International Potato Center (CIP)

Abstract

Over 10% of the annual production of 100 million tons of sweetpotatoes in China is processed into starch, mostly in small scale enterprises using manual or simple mechanized equipment. The starch is used mainly for noodle production, but food and other industrial uses are developing in some regions of the country. Export of both starch and noodles to East Asia is growing, especially in Shandong Province.

This paper reports the detailed results of research on small scale starch producing enterprises in Sichuan Province, and market research with starch users, highlighting the need to improve product quality in order to take advantage of market opportunities in food and other industries. At household level, sweetpotato processing for starch is also closely linked to pig production, through use of residues for feed. This integrated system, which generates income from both starch/noodles and livestock, requires improvement in efficiency and profitability is it is to remain sustainable into the 21st century. The research priorities for both sweetpotato varietal improvement and process improvement are discussed.

Introduction

The sweetpotato is an important crop to small farmers in many provinces of China. In previous decades it represented food security; now it offers income generation possibilities, though processing and use of roots and vines for animal feed. China produces of 100 millions tons of

sweetpotatoes each year, 40% of this in only two provinces: Sichuan and Shandong. In Sichuan, sweetpotato is a major crop in the poor, hill region where per capita incomes average only $35-40/yr, and out-migration is widespread (Peters, 1996). Efforts to enhance the income generation potential of this crop will have significant social benefits, and fit well with the official objective of poverty alleviation. Opportunities exist for more efficient use of sweetpotatoes for livestock production, and for expanded processing of the roots for starch, especially at small and medium enterprise scales. This paper will attempt to summarize the current situation of sweetpotatoes in Sichuan, while contrasting this with Shandong, as well as highlighting opportunities for research to enhance the prospects for this crop to benefit the rural poor. Special emphasis is placed on starch processing and marketing, but the links to animal production in this intensive system will also be stressed.

Current status in China and Sichuan

China dominates sweetpotato production in Asia and globally. With stable annual production of >100 million tons, China represents over 80% of world sweetpotato production (Scott, 1992). Indeed, the production of Sichuan province alone, 20 million tons, exceeds that of all the non-Chinese developing world (Jiang et al, 1993). Sweetpotato production rose from 77 million tons in 1960 to 131.5 million tons in 1978. Thereafter, as rice production increased and fresh consumption of sweetpotatoes declined, production declined to under 110 million tons by 1981. It has remained within a range of 110-100 million ton/y ever since. Although production of sweetpotatoes declined somewhat, it did not collapse: sweetpotatoes became instead a major component of pig production systems across China (Table 1; and Li et al., 1992) . Per capita consumption of pork rose by over 100% during the 1980's, reaching 18.1kg/capita in 1990 (World Bank, 1993). The bulk of pig production was, and still is, small scale, using farm-produced feed resources (Li et al. 1992, Jiang et al. 1994). Sweetpotatoes fit well into the pig production cycle, especially since roots can be stored for five or more months over winter. In some areas of China roots are also sliced and dried

[1] Processing Specialist, CIP-Bogor, PO Box 929, Bogor, 16309, Indonesia and Country Liaison

before storage. Sweetpotato vines are also used as a source of protein and vitamins (CIAD et al., 1995).

In addition to feed use of roots, during the last 20 years a significant industry based on extraction of starch has developed in several regions of China (Li et al., 1992) and especially in Shandong and Sichuan provinces (Tang et al., 1990a,b; Zhang, 1995). The starch is used mainly for the production of traditional noodles. Both starch and noodle enterprises are predominantly small scale, family or village units. In Shandong, starch processing may account for over 30% of total sweetpotato production (Table 1), or some 0.9 million tons/yr of dry starch. Sweetpotato starch production in China may exceed 2 million tons/yr. Since much of this production is small-scale, and is processed and consumed locally, there are few accurate statistics.

The production of sweetpotato starch is primarily a small-scale, household or medium-scale, village cooperative enterprise activity. For example, in Sichuan province, over 75% of starch production comes from small scale enterprises (Tang et al, 1990b). These family enterprises commonly also transform the starch into noodles, for sale to provincial and national markets. In other regions of China, lager scale enterprises exist, but the level of technology is similar to that of Sichuan. However, some enterprises targeting the export market, produce refined starch, which is obtained after separation through finer mesh screens, centrifugal dewatering and mechanical drying. This commands a higher price (Zhang 1995).

In Sichuan province, where CIP has worked with the provincial Academy of Agricultural Sciences (SAAS) for over 6 years, significant progress in upgrading the technology level of small scale enterprises has been achieved. Manual processing of the roots has been largely replaced by small- and medium-scale mechanized equipment (root washers, grinders/ raspers, horizontal and drum separators, and inclined channel sedimentation). Sweetpotato noodle production has benefited from

---

Scientist, CIP-Beijing, PR China, respectively.

the introduction of small scale single screw extruders which have allowed increases in productivity and output (CIP 1995a, Tang et al, 1991).

Sweetpotato starch production in China has faced problems of slow sedimentation and poor separation of starch from some impurities which produce off-colors in the final product. A traditional fermentation process involving the addition of liquid fermentate from peas or beans (called sour liquid) at the separation stage, speeds sedimentation and enhances separation and final product quality (Timmins and Marter, 1992). Sour liquid contains lactic acid bacteria. Sour liquid is used even in enterprises with mechanized equipment.

During November 1994, a participative appraisal of three small-scale starch extraction enterprises (Table 2) was carried out in Santai county, Sichuan (Wheatley et al., in press). Data on the technical operation of the process, through direct measurement and observation of normal operations, was complemented by relevant information on the food system in which each enterprise operated. The appraisal showed that all enterprises were profitable with high returns on investment, despite low utilization of installed capacity (Table 3), due to problems in raw material supply: in 1994 drought lowered sweetpotato production in Sichuan, and reduced the length of the processing season. The dry starch yield (15% moisture content, approx.) ranged from 11 to 18%, depending on both process and variety (Table 3). Improvements to process efficiency, especially at the separation stage, would increase profitability (since more starch would be produced per unit of roots processed). Use of higher starch varieties (such as Mianfen 1) by farmers should be encouraged by the processing industry, and adequate price incentives should be given, as justified by process economics: At Guanqiao enterprise, where two varieties were compared, Mianfen 1 gave a higher yield of dry starch and greater profits, allowing the enterprise to pay farmers a higher unit price for roots of this variety. The low labor costs, as a proportion of total costs, in the two mechanized enterprises is encouraging. Future increases in labor costs, inevitable as the economy develops, should have a small effect on overall enterprise profitability.

Sweetpotato noodles are a traditional food product in East Asia, where they are consumed during celebrations and festivals, especially the spring festival or Chinese new year (February). This peak in demand coincides well with the production season of sweetpotato starch and noodles (Figure 1, cropping and processing calendar for Sichuan). Sweetpotato is harvested October-November, the starch is extracted November-December and noodles are produced December-February of the following year.

Traditionally, noodles are made by mixing starch with water, working the mixture into a dough, and pressing manually through a container with basal holes. The wet noodles fall directly into boiling water, and are swiftly transferred to a cold water, where they are held for a time before sun drying (Tang et al. 1990b, Timmins and Marter, 1992). The use of an extruder obviates the need for submersion in boiling and then cold water, since the heat and friction of the apparatus gelatinize the starch sufficiently, and the cold ambient temperatures are adequate for cooling the moist noodles afterwards.

Noodles are frequently produced by the same household or village enterprises that extract the starch. In the cold winter months, moist starch can be stored for weeks without damage. The use of extruders has allowed small enterprises to expand production and profits, and to overcome the shortages of skilled labor as migration to cities proceeds. Appraisals of 5 traditional, manual noodle enterprises and 5 enterprises using extruders were conducted in 1994, and clearly showed the advantages of the extruders (CIP, 1995a). Households which have invested in the extruder, often through a local government loan program, have two advantages over traditional processing households: greater profit per unit of noodles produced and a higher production volume of noodles (Table 4). These result in a significantly greater enterprise profit in those households with extruders. The capital investment is not excessive and, according to users, can be paid off in one processing season.

The change from manual to extruder-based technology has changed some of the process conditions, which could affect noodle quality. Noodles from the two processes were therefore compared (Table 5). The use of an extruder, with both heat and pressure in excess of the traditional process, probably results in a greater degree of starch gelatinization than in manually produced noodles. Extruded noodles had a greater tensile strength than those produced manually, and this was reflected in taste panel results, which rated extruded noodles as harder in texture. Other parameters showed no differences due to process, although there was substantial variation in noodle color, from white through yellow to brown, reflecting the variable quality of the starch raw material). Samples of noodles were given to market traders in Chengdu, who offered similar prices for the two types. Small family noodle production enterprises market their noodles locally and nationally. One small family enterprise visited in Sichuan maintained a sales agent in Shanghai.

Starch is the prime component of interest for food industrial uses of the crop. Sweetpotato starch characteristics have been reviewed by Tian et al., 1991, while Garcia, 1993 has studied the effects of variety and environment on root starch properties. Sweetpotato starch does not have the high viscosity values on pasting that characterize potato starch. Maximum viscosity is rather similar to cassava starch, but higher than maize starch. Gelatinization temperatures tend to be higher than for cassava and maize.

However, Garcia 1993 found significant variation in physical and functional starch properties across the limited number of varieties studied, which suggests that, as for cassava, there is potential to select varieties with specific starch properties for particular end uses. In addition, the same two workers found that both location and season affected starch properties, although some varieties showed more stability in this respect than others. Additionally, the extraction process can also affect the functional properties of the resulting starch, for example, in Sichuan starch of variety Xushou 18 extracted manually had viscosity at 95ºC 40-50% higher than starch obtained using

mechanized equipment. Starch sedimented using the sour liquid method involving mild fermentation had the lowest viscosity values (Lin, personal communication). All these results suggest that, while starch quality parameters may be subject to sources of variation, this also makes possible the selection of an optimal combination of variety, location and process for obtaining the desired starch quality for specific industrial uses. The commercial starch samples cited in Table 6 show highly variable levels of impurities, which will also affect functional properties as well as restrict potential industrial applications.

Prospects for market diversification

Sweetpotato starch is produced in many provinces of China, and in E Asia, but utilization is predominantly for traditional noodles. Some factories in China use the starch for production of derived products (e.g. maltose, in Jhejiang Province). The situation of the crop and its utilization potential varies greatly between provinces in China, for example between Shandong and Sichuan (Table 7). In Shandong, sweetpotato production is highly commercial, with a large proportion of roots being processed into starch. Medium-scale starch processing enterprises oriented towards E Asian export markets are expanding (Zhang, 1995). Maize production in Shandong is also high, reducing the importance of sweetpotatoes in livestock feeding systems and making sweetpotato starch more expensive than maize starch. In Sichuan, yields are lower but the production area is nearly double that of Shandong, resulting in a similar total production volume for the two provinces. Starch production is less important in Sichuan at present, despite the fact that maize starch is more expensive due to supply deficits (CIAD and SAAS, 1995). Located far from potential export markets, Sichuan's noodles are marketed provincially or, at most, nationally.

Sichuan is China's most populous province (110 million people). Although poorer than the national average (Table 8), Sichuan's economy is developing fast, including the food and feed industries. A market survey (CIAD and SAAS, 1995) assessed the potential demand for sweetpotato starch in both food and non-food industries. The results were surprising: companies complained of severe,

chronic shortages of maize starch (the major starch used), sufficient to restrict production to levels below demand for these products. Indeed, the actual supply of maize starch into the industrial sectors surveyed totaled only 100,000 MT, while starch demand was estimated by industry at over 200,000 MT. This large shortfall in starch supply was due to (a) insufficient maize production in Sichuan itself (b) competition from the feed industry for raw materials and (c) difficulties experienced in importing starch, or maize, from other provinces (CIAD and SAAS, 1995). This latter was due both to congested transport infrastructure and the simple unavailability of maize elsewhere in China, as the richer coastal provinces bought up available supplies for themselves.

This situation represents an opportunity for sweetpotato starch to fill a supply gap. Sweetpotato starch in Sichuan has consistently been below maize starch in price (Table 9), while sweetpotato starch extraction at small scale is more profitable at current prices than maize starch extraction in large scale facilities (Table 10), even after taking into account the income from maize starch by-products.

Sweetpotato starch was however rated poorly by industry as regards product quality. The starch contains excessive levels of moisture and ash (but not of protein or lipids, Table 11), and may not be sufficiently white in color. Another aspect of quality important for some, but not all, uses relates to the functional properties of the starch, compared to those desired for particular end uses. The problem of impurities can be addressed through process improvements (better and faster separation, use of sour liquid method, improved drying). Refined sweetpotato starch is produced in Shandong province, using equipment similar to that employed in Sichuan, but with additional purification and drying steps added. Starch functional properties are dependent on variety, environment and the extraction process and can also be altered by subsequent enzymatic or chemical modification.

Many industrial enterprises in Sichuan have their own maize starch extraction units. They are uniformly unwilling to invest in similar facilities for sweetpotato starch: the seasonal nature of the sweetpotato harvest limits the processing period to about 45 days/year (Figure 1). Such low levels of capacity utilization make investment in large scale facilities uneconomic. Small- to medium-scale starch extraction, with much lower capital investment costs, does not suffer the same drawback: such enterprises are highly profitable even with such restricted processing seasons (Wheatley et al., in press). Diversified industrial use of sweetpotato starch in Sichuan represents an attractive opportunity for small scale enterprises to exploit, given the supply problems of maize starch and the lack of interest of the large-scale industrial sector.

An inter-disciplinary research strategy for impact.

Given the importance of sweetpotatoes in Sichuan, especially to small farmers and processors in areas targeted for poverty alleviation efforts, CIP has assigned high priority to achieving impact in this province of China. An integrated program of research on (a) crop production, especially varietal enhancement and selection (b) post-harvest processing and marketing of starch and noodles, and (c) more efficient feed use of sweetpotato roots and vines, has been designed and is now being implemented. Research collaboration is centered on the Sichuan Academy of Agricultural Sciences, but includes other organizations in China involved in both research (e.g. Xuzhou National SP research Center) and development (e.g. Center for Integrated Agricultural Development, CIAD, Beijing).

Sweetpotato starch process and market research

Market research, in collaboration with Wageningen Agricultural University, Netherlands, is underway to determine the potential for expansion in the use of sweetpotato starch for both noodles and for other industrial uses, building on the SAAS/CIAD study of 1995. Specifically, the hypothesis that sweetpotato starch quality, reflecting both purity and functional properties, is limiting the more

diverse utilization of the starch in Sichuan will be tested. Consumer research on noodles will determine the potential for demand expansion as incomes and urbanization increase, and will also examine the effect of starch and noodle quality improvement on consumer demand.

For starch the key issue is product quality, both as regards level of impurities and the functional properties of the product itself. Research at SAAS, Sichuan has, to date, focused on the efficiency of starch processing (equipment capacity, use of labor, starch yield) without great attention to product quality or efficiency in the use of other inputs (water, electricity). Research to reduce the level of impurities such as ash, protein and fiber to meet the specifications of industrial users of starch in Sichuan is now in progress. This should involve both more effective separation and additional purification steps. Faster drying of starch is also needed, given the climatic limitations of Sichuan. Efficient mechanical dryers, as used in Shandong are one option. Functional properties of starch and flour can be manipulated by processing (e.g. milling/sifting, Suismono, 1995) as well as by varietal selection. The effects of process conditions on starch functional properties is being studied, in collaboration with the University of Hong Kong. Chemical or enzymatic modification of sweetpotato starch to produce some of the desired functional properties is also possible.

The small-scale sweetpotato extraction process in China suffers from problems of slow sedimentation and poor separation of starch from impurities. Use of the sour liquid (lactic fermentation) method to speed sedimentation and produce a purer, whiter product is a traditional practice which has only recently been studied (Timmins and Marter, 1992). A better understanding of this process, permitting standardization, could provide another option for enhancing starch quality.

Sweetpotato starch and pig production

Sweetpotato starch is not an isolated economic activity: the households that produce starch engage in many other activities depending on the crops and livestock produced. Sweetpotatoes are

closely associated with pig production, which in turn can represent between 20-30% of annual income for many households in Sichuan (CIAD et al., 1995). Before sweetpotato starch can be recommended as an income generating activity, it must be compared, from social and economic perspectives, with the income that can be gained from pig production using the same raw material. In fact the situation is more complex, because:

1. pigs are also needed for manure over and above income

2. pigs can also be fed on the fibrous residue from starch processing. Many specialized starch households are also major pig producers, using the residue as their basic feed resource over winter.

3. Raw starch digestibility of sweetpotato starch is low, necessitating cooking of roots before feeding them to pigs. Reducing this additional cost would be a major step forward for sweetpotato as a feed: possibilities includes varietal development (better raw starch digestibility) and post-harvest interventions (processing and storage conditions).

Fresh root production and quality

From a processor's viewpoint, raw material supply means the quality, price and availability of the fresh roots. Fresh root quality is important for two reasons: it's influence on final product quality and it's effect on process efficiency (i.e. on the economics of processing). The latter is crucial for sweetpotatoes where conversion of fresh roots to starch tends to be below that of cassava. The development of varieties (or crop production practices) which favor high fresh root dry matter and starch contents are critical, and have been pursued for some time in E and SE Asia (CIP, 1995). For starch production, the amount of extractable starch is relevant to process efficiency: some varieties appear to have starch which is easier to extract than others (CIP, 1995a): the reasons for this varietal variation are now under study at the Asian Institute of Technology (AIT) in Bangkok. For feed use, the energy value of the roots is crucial, especially the digestibility of the starch. Low levels of trypsin inhibitors are also advisable. Zhang and Collins (1995) showed that these are heritable characteristics that can be manipulated by conventional plant breeding.

The lower the price of sweetpotato roots, the more competitive they become for processing, but the less attractive they are for production by farmers. Improvements in fresh root yield and, more importantly, in dry matter or starch yield per hectare, are crucial in permitting a reduction in unit production costs while allowing both farmers and processors to profit from the crop. An analysis of production and utilization economics of two sweetpotato varieties shows that both parties can potentially benefit from high starch varieties with a lower fresh root yield but higher farm gate price (Table 12) than traditional varieties. Prices of Mianfen 1 in 1994 were not sufficient to compensate farmers for lower yield, suggesting that processors were not aware of the scale of benefits deriving from use of this variety, since it is in their interest to encourage production of Mianfen 1.

The starch functional properties of Chinese sweetpotato varieties, from local and introduced germplasm and from some advanced clones, will be studied in collaboration between the Xuzhou Center and Hong Kong University, in an attempt to identify starch sources for industrial use, or for production of higher quality noodles. The digestibility of sweetpotato starch for animal feed will also be studied across a range of clones, as will the effects of environment, simple processing and fresh root storage. These studies will feed into the on-going varietal development effort in Sichuan and China.

Integration with rural development for poverty alleviation.

It is important that tangible benefits result from the above mentioned research projects. Strong ties are therefore developing between SAAS and development projects in Sichuan, especially in areas targeted for poverty alleviation. In one such county, Yilong (400km from Chengdu in the hill region) a UNDP poverty alleviation project is working in an area, typical of many, in which agricultural systems are based a backbone of sweetpotato and pig production. Besides efforts to improve the efficiency with which sweetpotatoes are used for pigfeed in these small scale systems, the project is also studying the potential for introducing starch processing, and possibly noodle and other derived processes as well. The research to improve starch quality in small-scale enterprises is

being implemented in collaboration with several starch enterprises in Santai County. Through this type of effort it is hoped that research results appropriate to the situation of the target beneficiaries will be obtained, from which real benefits will flow.

References

Buck, J.L. (1937). Land utilization in China. Nanjing, University of Nanjing.

CIAD, SAAS and SAHVRI (1996) Social and economic assessment of the small scale sweetpotato based pig production system in Suining Municipality, Sichuan Province. Center for Integrated Agricultural Development (CIAD), Sichuan Academy of Agricultural Sciences (SAAS) and Sichuan Animal Husbandry and Veterinary Research Institute (SAHVRI); CIAD, Beijing Agricultural University, Beijing, China. 54pp

CIAD and SAAS (1996) Potential for market diversification of sweetpotato starch and flour in Sichuan Province. Center for Integrated Agricultural Development (CIAD) and Sichuan Academy of Agricultural Sciences (SAAS), Beijing Agricultural University, Beijing, China 28pp

CIP (1995) Vines to roots: sweetpotato breeding for impact. CIP, Lima, Peru. 46p.

CIP (1995a) Program report for 1993-1994. CIP, Lima, Peru 192p

Garcia H., A.M. (1993) Physico-chemical characterization of sweetpotato starch. M.Sc. Thesis, North Carolina State University, USA.

Jiang, L; Rozelle, S. and Huang, J. (1993). Production, technology and post-harvest processing of sweetpotatoes in Sichuan Province. Unpublished report of CIP subproject 6211. pp 63

Jiang, L.; Rozelle, S. and Huang, J. (1994). Sweetpotato economy of Zhejiang, Jiangsu and Sichuan Provinces: a report to CIP. Unpublished. 60pp

Li W.G.; Wu, X.; Cai, H. and Du, R. (1991) Sweetpotato in China In: Scott, G.J. Wiersema, S. And Ferguson, P.I. Eds. Product Development for Root and Tuber Crops. Volume 1. Asia. Proceedings of the International Workshop April 22-May 1, 1991, ViSCA, Baybay, Leyte, Philippines. CIP, Lima, Peru, pp 41-50

Marter, A.D. and Timmins, W. H.. (1992) Small scale processing of sweetpotato in Sichuan Province, PR China. J Trop Sci, 32: 241-250

Peters, D. H. (1996) Research proposal: sweetpotato processing for poverty alleviation and rural stability; a case study of Yilong County in Sichuan, China. unpublished CIP document, May 1996.

Scott, G.J. (1992) Transforming traditional food crops: product development for roots and tubers. In: Scott, G.J. Wiersema, S. and Ferguson, P.I. Eds. Product Development for Root and Tuber Crops. Volume 1. Asia. Proceedings of the International Workshop April 22-May 1, 1991, ViSCA, Baybay, Leyte, Philippines. CIP, Lima, Peru, pp 3-20

Suismono, (1995) Study of sweetpotato flour processing and its utilization in a moist extruded product. MSc thesis, Institut Pertanian Bogor (IPB) Bogor, Indonesia. 137pp

Tang, Z. et al. (1990a) Sweetpotato utilization and processing in China. Chengdu, Sichuan Academy of Agricultural Sciences.

Tang, Z.; Lin, L.; Li, R.; Wan, Y. and Fu, M. (1990b) Sweetpotato utilization and processing in Sichuan (CIP working paper No. 89-15) In: Potato and sweetpotato research in China 1986-1989, CIP region VIII, Beijing, China pp 89-104.

Tian, S.J.; Rickard, J.E. and Blanshard, J.M.V. (1991) Physicochemical properties of sweet potato starch J Sci Food Agric 57:459-491

Timmins, W. H. And Marter, A. D. (1992) Aspects of sweetpotato processing in Sichuan Province, People's Republic of China. In: Scott, G., Wiersema, S. And Ferguson, P. (Eds.). Product Development for root and tuber crops. Volume ŁAsia. Proceedings of an International Workshop, held April 22-May 1 at Visayas State College of Agriculture, (ViSCA), Baybay, Leyte, Philippines. CIP, Lima, Peru. pp217-228

Wheatley, C.C. Lin, L.; Sun, G and Song B.F.(in press). Improving small scale sweetpotato starch enterprises in Sichuan, China, through process and raw material innovations. Tropical Science (in press).

Woolfe, J. (1992) Sweetpotatoes: an untapped food resource. Cambridge University Press, Cambridge, England. 643p.

World Bank (1993) China: animal feed sector study. Report 10922-CHA, World Bank, Washington D.C.

Zhang, D. and Collins,W. W. (1995) Estimation of genetic varience of starch digestibility in sweetpotato HortScience 30 (2) 348-349.

Zhang, L.M. (1995) the present situation of sweetpotato production and processing in Shandong Province, China. Paper presented at SAPPRAD workshop on Sweetpotato Processing, Jinan, November 20-24, 1995. Shandong, China. 7p