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Technology Assessment of Small and Medium Cassava Starch Enterprises in North Vietnam

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Abstract

The cassava starch processing supply chain in Vietnam has rapidly changed over the past decade. The introduction of high yielding cassava varieties (KM 94, KM 60) with high starch content for industrial purposes has led to a complex situation, where both small and large scale producers have to tackle the burgeoning environmental issues. Three categories of small-sized wet starch extraction systems were identified in a cluster of root processing enterprises from the Red River Delta (Hoai Duc district, Ha Tay Province) where the hazards caused by liquid waste from cassava processing has been approved by all the stakeholders. The type A and B processors used cylindrical rasper with manual sieve (A) or a milk starch filtering machine (B); the type C processors used an equipment combining rasper and filtering machine. A methodology is proposed to assess the impact of these three technologies based on processing efficiency and volume of effluents. For each system, processing parameters such as dry matter, starch content, conversion rate, extraction efficiency and water consumption were studied. The amount of water used to produce one kg of dry starch, was 18, 14 and 22 l for systems A, B and C respectively. The quality of starch and by-products and a cost estimation were also determined. Despite the growing popularity of the use of system C throughout the villages, it required higher power consumption than systems A and B.

Key words: Vietnam, cassava, starch, rasper, water use, environment

Introduction

Global cassava (*Manihot esculenta* Crantz.) production has progressively increased since the 1960's and reached more than 229 m t in 2010 (FAOSTAT, 2010). In South-east Asia, the rapid economic recovery from the Doi Moi ensured good conditions for agricultural commodity chains to be strengthened. It was particularly significant for cassava in Thailand (Sorapipatana and Yoosin, 2011) and later on in Vietnam, where the yield of the crop increased dramatically in 1990's with the introduction of high yielding varieties for industrial purposes (Dieu, 2006). The share of commodity production utilized for starch boosted from 24% in 1998 to more than 50-70% in Vietnam in 2008 (Da, 2008). The Vietnam Ministry of Agriculture and Rural Development (MARD) reported in 2005 that small-scale processing accounted for over 70% of the total processing units with a production capacity of 0.5 to 10 t of dry starch per day. While it may appear that the economic conditions may support this processing scale for the next two decades in Vietnam (Fuglie et al., 2005), processors continue to face many difficulties. A case in point is the

Red River Delta, where cassava wet starch is mainly produced within a cluster of densely populated craft villages. The lack of space for these seasonal processing activities (October to April), combined with a continued expansion of production capacities, has resulted in a constraint on liquid waste management from processing (Da et al., 2012).

The general objective of this study was to assess cassava wet starch processing industries (SMEs) within a cluster of villages in Vietnam in a technological perspective. Specifically, it consisted of a diagnosis of three different starch manufacturing types, where production characteristics were measured and compared to quantify their impact on the environment.

Materials and Methods

The method of diagnosis applied in this study was influenced by a previous study carried out on a small scale in Colombia (Gottret et al., 1997). In this study, a diagnosis consisting of two complementary phases (qualitative and quantitative) was followed. The Participatory Rural Appraisal, the qualitative component of the study, distinguished three different extraction manufacturing systems (A, B and C) for producing cassava starch (Fig. 1) (Da et al., 2005).

Location and interviews

The study was carried out during 2005-2006 in Ha Tay province (Hoai Duc dictrict), within a cassava root processing cluster located 20 km from Hanoi. This province has the largest production of cassava wet starch in the Red River Delta and good potential for trading and processing cassava and cassava-based products (Dao The, 2004). Most small-scale processors were previously producers, while existing small-scale processors have been continually expanding their operations. Interviews were conducted in 9 hamlets, 14 hamlets and 10 hamlets respectively in Cat Que, Duong Lieu and Minh Khai villages. Interviews consisted of informal interviews (with local institutions, processors, mechanics and middlemen) and questionnaire requesting representatives to list and describe the types of cassava starch processing technologies within their hamlet.

Processing equipment

Type A and B processors used both a cylindrical rasping machine and a manual sieve (type A) or a milk starch filtering machine (type B). The type C processors used an equipment combining a rasping device together with a filtering device, similar to a sweet potato starch

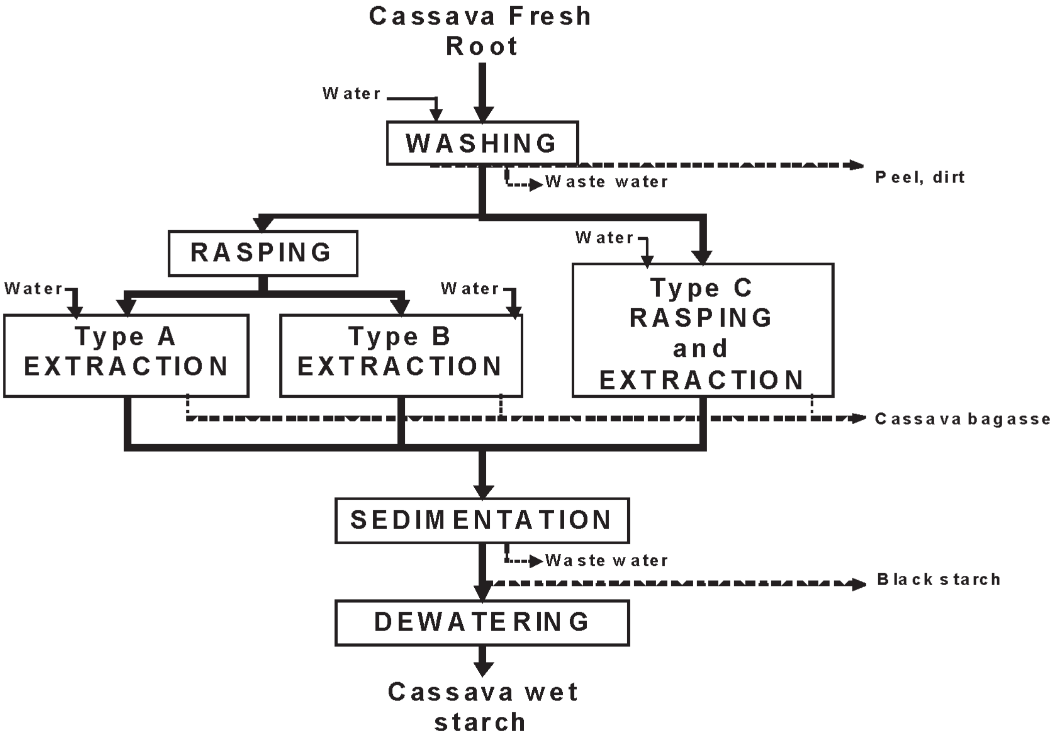


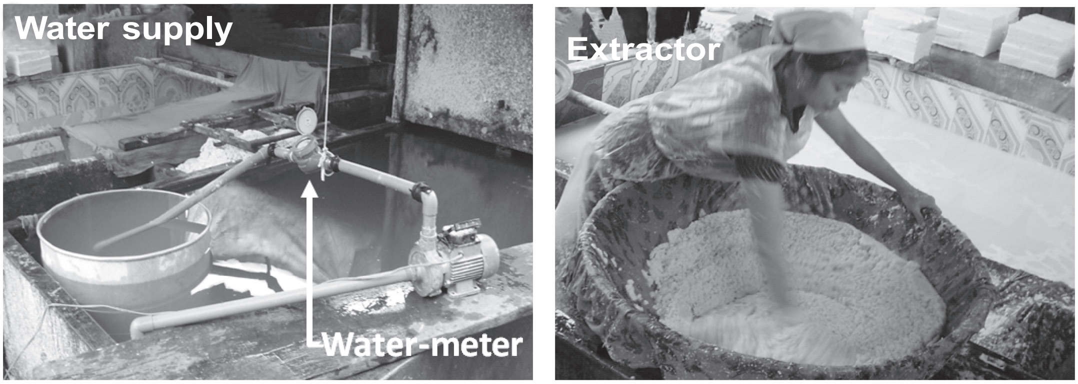
Fig. 1. Flow chart of the existing wet starch production systems *viz.*, Type A, B and C in Ha Tay province, Vietnam

extractor previously used at this scale in Vietnam (Nguyen Duy, 1994) (Fig.2).

Washers used in this study consisted of batch operated hexagonal iron cages. An electrical engine (4 kW) transmitted the power for the rotation of the cage (40 rpm) through a central axle fixed to the edge of the equipment. Inlets placed above the bars of the cages were supplying and spraying water onto the roots. Each cage was equipped with one batch used to load and unload the roots onto a cement-floor for short term storage before being rasped. The water supplied for washing stage was unfiltered water directly drawn from wells.

The cylindrical rasper used by type A and B processors consisted of a support structure, a chute-like hopper, a chassis, a transmission shaft and a cylindrical rotor made of "Xa Cu" wood and covered with fine wires. The rotor movement was provided by an electrical motor (15 kW). Type C processors used a batch processing for rasping stage, where one chute-like hopper was used to feed the rasping chamber with peeled roots. The rasper consisted of support structure, transmission shaft, three fixed baffles (on the upper part of the chamber) and a double-layered disk. The upper layer (rasping surface) was made in "Xa Cu" wood and it was covered with fine wires. The disk rotated at 2500 rpm. The wooden layer was fixed to the iron layer above and the whole double-layered disk was fixed to the main axle of the combined

Type A



Type B

Type C

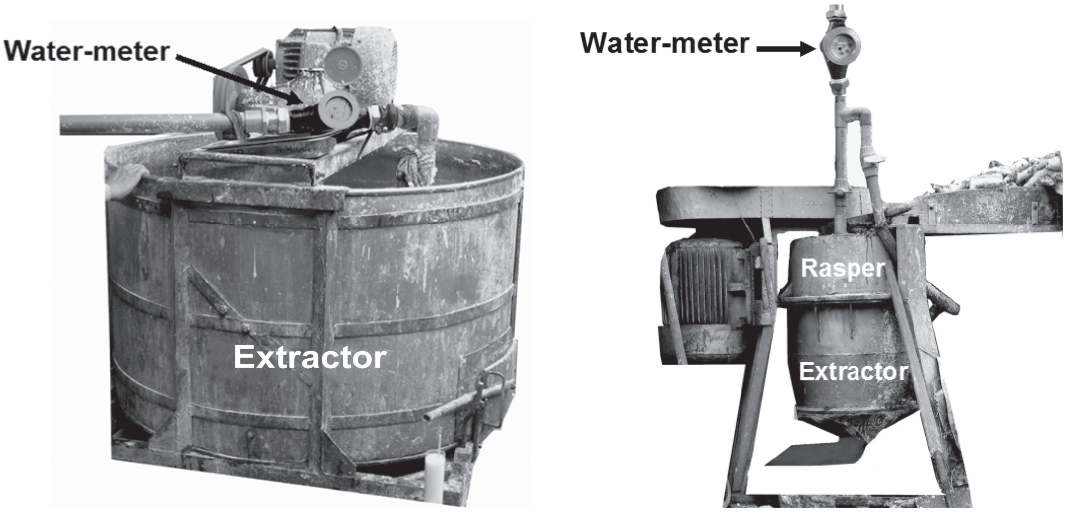


Fig. 2. Different wet starch production systems with arrangements for water consumption at extraction stage for the Types A and B and at rasping and extraction stages for Type C

machine. One pipe inlet was placed on the upper edge of the rasping chamber to spray water onto the peeled roots.

The extractor for system A (Fig.2) consisted of a circular basket where the pulp was manually stirred with water before being sifted through a cotton filter cloth (50 mesh). The extractor for system B consisted of a stirring device (a shaft with two paddles) placed in an aluminum tank (Fig.2) flanked by two baffles. The stirring movement (up to 250 rpm) was provided by an electrical motor (4.5 kW). Extractor B was equipped with a cotton filter cloth (70 mesh). The extracting stage for system C occurred in a stirring chamber placed under the rasping chamber (Fig.2). The movement of the shaft together with the two paddles used for both rasping and separation was provided by an electrical motor (15 kW). Extractor C was equipped with a cotton filter cloth (70 mesh) and a 10 mesh screen. The extraction stage required the use/ filtering through of water previously drawn from the ground and decanted in a concrete tank filled with sand.

For all the three systems, intermediate tanks lined with ceramic tiles were used between separation stage and main settling of starch milk. Then, two consecutive sieves (70 and 10 mesh for the upper and lower layers respectively) fixed on wooden frames were used before sedimentation in settling tanks. After discharging the waste water from the settling tank, a thick liquid fraction remained on the surface of wet starch. This yellowish green tint fraction, locally called “black starch”, was collected and transferred into appropriate concrete tanks for settling before being incorporated into the daily food ration for pigs. The absorption stage occurred after the collection of “black starch”. Wet starch in settling tank was covered with a cloth layer over which coal residues were placed in order to facilitate the absorption of excess water, enabling wet starch to be cut into blocks. These blocks were stacked up on clay bricks before being sold.

For the whole process, centrifugal pumps were used. System A required one pump to draw ground water, systems B and C required two additional pumps: one to pump filtered water up to the extractor and one to convey starch milk from the intermediate tank into the main settling tank.

Follow-up of the manufacturing processes during production

Three batches of high yielding cassava varieties were collected from one bulk delivery (a truck with a capacity of 12 t) and the roots were divided by the three types of processing units corresponding to the three extraction systems (A, B and C). These trials were repeated with the same households at least thrice at different dates during the processing season. The manufacturing process for producing wet starch was characterized using the following indicators:

i) The calculation of mass balance by weighing each stage of operation including the fresh roots at truck delivery stage, the peeled roots before rasping, the cassava bagasse after extraction stage, the “black starch”, the wet starch; by measuring water consumption for the washing stage with water-meters set-up on the water inlet of the washing machine; by measuring water consumption for extraction stage with water meters (Fig. 2): for system A, a derivative system was set-up to quantify the manual supply of water. The calculation of mass balance was completed by estimating the remaining solid compounds in waste water. Aliquots were sampled in plastic bottle (0.5 l) at regular intervals (5 min) from the outlets of sedimentation tanks.

ii) The calculation of the actual time of manufacturing for the three types of processors (measured with stopwatches) as well as the required labour (data collected from surveys of the three processing types).

iii) Parallel to the first set of trials, the following data were collected daily from type A, B and C households within the three villages: the quantity of fresh roots (kg) at truck delivery, the quantity of wet starch produced (kg), the purchasing prices of fresh roots and the selling prices of wet starch or by-products from processing (cassava bagasse, black starch). These two indicators were calculated using the data from interviews with processors. Electrical power consumption at the washing stage, rasping and extraction stages were estimated based on the monthly electricity bills and the number of days of production.

Data was reported and analysed in detailed flow sheets in order to compare the mass balances between the different processing types. Statistically significant differences between sample means were determined using the Student's t-test and Anova test for multiple comparison at 95% confidence level.

Composition analysis

Three aliquots of fresh roots were randomly collected from one truck delivery (up to 4 kg per sample). A similar sampling was carried out for the following products during the manufacturing process: washed roots, peels, pulp, cassava bagasse, wet starch and black starch.

Moisture content was determined after drying 50 g of sample at 60°C for 24 h (Gibert et al., 2009). Starch content in the solid samples was measured using an enzymatic colorimetric method (Gibert et al., 2009). The moisture content of starch samples was determined in triplicate by drying 10 g of sample at 105°C for 24 h. The conversion rate (R) or starch extraction yield was calculated as kg of dry starch released per kg of cassava fresh root.

Results and Discussion

Distribution of processors within the processing cluster

The distribution of the three types of rasping-extraction technologies (A, B, C) within three villages organized in cluster showed differences in technological adoption by processors, with the highest concentration of type B processors in Duong Lieu commune (Table 1).

However, type C in Duong Lieu and Minh Khai communes included both wet cassava and canna starch producers, where canna noodles from starch has been produced for reasons of profitability. It should be noted that most of the processors within all the three villages were also pig raisers. They used "black starch" from processing to feed their own pigs and sold fibrous residues to be incorporated into the production of animal feed. It was particularly evident in Cat Que commune, which had the largest number of pigs of the three villages (24,000 in Cat Que versus 6,400 and 3,000 in Duong Lieu and Minh Khai respectively) and the largest number of manual processors (Table 1). Additionally, in recent times, Duong Lieu has been exporting extraction technologies (locally developed from the 1980's) to surrounding provinces, usually agricultural areas of hilly regions, where cassava cultivation for industrial purposes has been developed significantly since the introduction of high yielding varieties. Finally, in the next season, it was reported that most type A processors were in the process of being changed to type B or type C processors. This is a predictable phenomenon considering the growing constraints on space and labour (Da, 2009).

Table 1. Distribution pattern of the three types of wet starch production system in the surveyed villages

Name of villages	Number of households producing wet starch	Households according to the extraction system (%)		
		Type A	Type B	Type C
Duong Lieu	514	2	75	23
Cat Que	184	58	37	5
Minh Khai	35	0	71	29

Quality of raw materials

Both local and high yielding root varieties showed little differences in dry matter content (39% and 41% on wet basis respectively) and starch content (27% and 28% respectively). Even if these values confirm data from Hoang Kim et al. (2001), they were largely influenced by the time between harvest and processing (Sriroth et al., 1999). Cassava roots were cultivated in the mountainous regions before being collected and subsequently transported by truck (over a distance of 200 km) to the cluster, where they were processed within two to four days after harvest with great risks of perishables resulting in a loss of starch content. Thus, the processors not only depend on the raw materials supply, but also on the availability of the varieties (local or high yielding varieties).

Mass balance and water consumption

The mass balance for the cassava manufacturing process did not show significant differences of conversion rates (R) between the three extraction systems A, B and C (Table 2). The whole R average of 25.8% was higher than in other locations at similar scales, where 17% in Colombia and Ivory Coast or 20% in Brazil were reported (Da,

Table 2. Mass balance for the three types of wet starch production systems in Cat Que village

Parameters	Unit	Type A	Type B	Type C
Weight of fresh roots	[t]	1.13 ± 0.1	1.12 ± 0.0	2.19 ± 0.1
R (conversion rate)	[%]	25.4 ± 1.5	25.0 ± 1.1	27.0 ± 1.7
E[a)]	[%]	64.6 ± 2.7	63.7 ± 3.2	66.3 ± 1.8
F[b)]	[%]	21.8 ± 1.8	20.6 ± 0.4	14.1 ± 1.0
BS[c)]	[%]	3.1 ± 0.8	3.6 ± 1.5	3.3 ± 1.1
TS[d)]	[%]	8	10	15
W_{tot}[e)]	[l]	18.1 ± 0.5	14.2 ± 0.9	21.8 ± 1.5

All values are means of triplicates. [a)]kg dry starch per 100 kg dry peeled roots; [b)]kg dry cassava bagasse per 100 kg dry peeled roots; [c)]kg dry black starch per 100 kg dry peeled roots; [d)]kg total solids carried by waste water from settling tanks per 100 kg dry peeled roots; [e)] total water used in litre per kg dry starch

2008). Thus, the starch content of the final product was reported to reach 90, 95 and 98 % in the three countries respectively. In our study, the starch content was in the range 96.8-97.2%, which was lower than the Grade 1 starch from Thai quality standards. The composition of the cassava bagasse revealed that the starch content was significantly higher for types A and B than for type C, with 54.0% (±2.8), 58.7% (±3.2) and 41.2% (±3.2) respectively, which may be due to the higher efficiency of the rasping disc (system C) than the cylindrical rasper (systems A and B). The follow-up also helped to estimate the added value of "black starch" (BS in Table 2) for pig raising. Black starch contained 61% of starch, 10% of proteins and 7% of fat. Finally, the loss of total solid in waste water was similar to other locations at this scale (Da et al., 2008), but the highest loss was obtained with system C (Table 2).

For A, B and C, water consumption was relatively lower than at similar scale (Rojas et al., 1996) but higher than at large scale where only 12 l were required (Sriroth et al., 2000). The higher water consumption for system C (Table 2) versus system A and B, may be explained by the use of water for both rasping and extraction stages (Da et al., 2010).

Production capacities and labour

The washing capacities (including loading, washing and unloading stages) observed (Table 3) were higher than root-washing machine from Columbia or from Ivory Coast (Da et al., 2012), but lower than large scale factories (Sriroth et al., 2000), where capacity of washing could reach 15 to 20 t of roots per hour. Even if these mechanical washers partially removed the outer skin of the roots (up to 3% of the fresh root weight) compared to large scale washers, they were still used within all villages to reduce labour, which was considered to be the most critical factor of the process at this scale (Westby, 2002). The main bottlenecks in capacities occurred at both rasping and extraction stages (Table 3). Rasping capacities under the use of the cylindrical rotor (systems A and B) requiring three labourers, were slightly lower than for similar scales in Columbia, where Rivier et al. (2001) mentioned 1.7 t of fresh roots per hour.

For a few years, households have been upgrading from system A to system B, and subsequently to system C with the objective of reducing labour (Da et al., 2005), which is consistent with data (Table 3). The manual extraction for system A required two labourers, while system B required only one. Lastly, system C required two labourers for a process including the rasping and separation stages. The subsequent stages following extraction were relatively similar for all the three systems: Sedimentation in settling tanks and draining off lasted between 8 to 15 h. The total manufacturing time for processing 1 t of roots for systems A, B and C was 17, 13 and 11 h, respectively. At large scales, capacities have increased dramatically by investing in separators and centrifuges instead of settling and dewatering systems. But, Sriroth et al. (2000) noted that these systems represented a minimum of 28% of the total electrical consumption. At small scales, other authors mentioned settling tables (Balagopalan et al., 2000) or settling canals (Rivier et al., 2001). But, the lack of space (density up to 3000 inhabitants per km^2) combined with the shortage

Table 3. Capacities of the wet starch production systems in Cat Que village

Stage	Processing capacities (t per h)		
	Type A	Type B	Type C
Washing	1.1	1.1	1.1
Rasping	1.1	1.1	0.9
Extraction	0.3	0.4	

of labour force restricted the households from expanding their processing activities.

Costs of roots and wet starch

The purchase price of raw material paid by the processors was in the range of US$ 31 to 45 per ton of fresh roots (by truck delivery). To control starch content in the roots, processors usually cut and taste a piece of cassava root flesh prior to processing. The standard density method (Bainbridge et al., 1996) generally used at small scale and large scale (Sriroth et al., 2000) would benefit processors to purchase roots on the standard starch content criteria. The processing season lasted from 120 to 180 days. The selling price of wet starch (55% dry matter) fluctuated from US$ 97 to 123 per ton.

Conclusion

This study presents a technical diagnosis in a cluster of cassava starch processing villages in Vietnam. It allowed quantifying the main differences between three extraction systems previously identified in a PRA qualitative study. The type C equipment which allows rasping and extraction stages to occur simultaneously, revealed higher extraction efficiency and higher capacities than the other systems used either locally or at similar scale elsewhere. Finally, type C requires higher water and electricity consumption, resulting in more considerations of environmental management issues by processors in the long term.

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