

Improving sweetpotato flour quality and small-scale process efficiency through participatory action research with household enterprises in East Java, Indonesia

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Abstract Previous studies have determined the potential location for sweetpotato flour processing and also examined the processing procedure necessary to produce marketable and profitably flour. This paper reports the second technical trial in which conversion rate and flour quality (i.e., whiteness and coarseness) were further investigated by selecting for sweetpotato roots with high dry matter content and modifying processing procedure (i.e., use a press, one-day drying, and repeated washing). Conversion rates improved substantially with selected varieties and even whiteness was unexpectedly improved among the selected varieties. Food safety was also analyzed and found that TPC is within safety limit and, even though fungus and E. coli were off the limit, can easily be brought within the limits. Flour products, such as noodles, cakes, and cookies were also experimented with the trial flour and showed promise. Further technical trials were identified and will be conducted on-station prior to the next season of on-farm trial in which feasibility will be determined, along with a market study.

Key words: sweetpotato flour, dry matter content, processing, browning, conversion rate, marketability, profitability, flour products, participatory research.

Introduction

The potential of small-scale sweetpotato (SP) flour processing activities to provide social and economic benefits in East Java was reported in Peters and Wheatley (1997), which also reviews information on SP in East Javan food systems and previous SP flour research. This study also included SP flour product development trials with users, and identified the quality and price requirements of potential SP flour markets. Flour processing trials with users indicated that more technical research was needed to improve flour quality/marketability, especially whiteness, and enterprise profitability (especially the fresh root to flour conversion rate).

A subsequent participatory processing trial with a womens' association in Kenongo, near Malang, E. Java in September 1996 (Peters et al, submitted) investigated ways of improving flour whiteness and increasing the conversion rate. However, none of the treatments of this first trial produced flour of marketable quality or profitable (>25%) conversion rates.

This paper reports recent (1997) efforts to obtain flour of marketable quality and competitive price, research have focused on adjusting processing procedures to improve the color of the flour, and on selecting sweetpotato varieties with high dry matter content. Martin (1984) reported SP flour yields from fresh roots varied between 17-38%, depending on variety. The advantages of a participatory approach are reviewed in Peters and Wheatley, submitted.

Materials and Methods

Trial design

The objectives of the participatory flour processing trial reported here were to:

1. test the effectiveness of the processing modifications, suggested by the participating women based on 1996 results, to improve flour quality.
2. select SP varieties yielding the best root:flour conversion rates, and with good dry matter production per hectare.

3. evaluate the marketability and profitability of sweetpotato flour and its final products by conducting a consumer tasting preference workshop.

Flour processing procedures: three modifications to the procedures of Peters and Wheatley (submitted) were made, to improve flour whiteness to meet market needs:

1. Following suggestions of the participating women after the 1996 trial, root shreds were washed in clean water three times before drying, a practice also recommended by Martin (1985).
2. a stainless steel press was used to de-water moist shreds, to facilitate faster drying and to extract phenolic compounds involved in browning reactions.
3. Processing took place early in the morning, to take advantage of a full day for sun-drying of shreds. Drying was completed in one day.

The complete process for flour production used by the women was: manual root washing and peeling, shredding (using manual shredder) into water, washing three times in clean water, dewatering using a manual screw press, sun drying, milling in a local pin mill, and sifting (50 and 70 mesh) . To ensure rapid drying, the root washing and peeling began at 05.00h and shreds were placed on drying trays by 06:30-07.00h, to fully utilize the solar radiation. For the first three days of the trial, shreds were collected at 15.00h for milling; for the last three days they were collected at 14.00h, to prevent over-drying. The equipment used comprised: 6 hand held peelers, 2 shredding machines, 1 stainless steel press, 24 bamboo drying trays, 18 plastic buckets, a pin mill with a 50-mesh screen, and 50-mesh and 70-mesh sieves for sifting. The shredder was loaned by the Research Institute for Legume and Tuber crops (RILET), while the press was constructed by Research Institute for Rice (Sukamandi, W. Java).

Sweetpotato variety: roots from promising high dry matter content SP clones from a harvest of a SP selection trial in Malang, E Java were obtained, and used as the experimental material for the participatory processing trials reported here. The goal of this new trial was to improve flour quality and conversion rate by using the standard processing procedure outline above.

Six varieties were used, comprising four advanced clones: AB94001.8 denoted as K₁, AB94065.4 (K₃), AB94078.1 (K₄), and AB94079.1 (K₅) from the CIP SP breeding program, previously selected for high dry matter content (Table 1) and two local varieties normally grown for the fresh market (IR and Senduro). IR was the variety used in the previous 1996 trial (Peters and Wheatley, submitted).

Five kg fresh roots of each variety were processed by the standardized procedure each day for six days (i.e., six treatments and six replications), by six women in coordination with the researcher and an assistant. Thus, each woman processed a different variety each day. Roots damaged by weevils were replaced in a few cases.

Flour whiteness and quality testing.

Sweetpotato flour whiteness was determined at Research Institute for Rice using a Kett Whiteness Tester Model C-100. Results were compared with locally purchased wheat flour. Flour quality was evaluated by participating women on a scale based on their perception of flour color (i.e., whiteness), texture (i.e., coarseness), and suitability for making flour product. The scale ranged from 9 (high quality) to 3 (low quality).

Food safety inspection

Total Plate Count (TPC), total fungi/yeast counts and E. coli (fecal and total) counts were carried out at Institut Pertanian Bogor (Bogor Agricultural University, Bogor, Indonesia) using standard procedures of Fardiaz, (1989).

Results and Discussion

Sweetpotato variety selection trial

The four CIP advanced breeding clones were planted in Malang (RILET research station) in a second selection trial from May to September 1997, under irrigated conditions during the dry season. Data on yields and fresh root dry matter content was taken (Table 2). Both yields and DM content of the clones were lower than the 1996 selection trial, perhaps due to:

- The 1997 trial was conducted on station, while the 1996 trial was farmer managed.
- The planting material for the 1997 selection trial was not in good condition

- Seasonal fluctuations.

Only 50 plants of K₄ were harvested, a 16.7% loss, enough to reduce total yields. The IR yield data were derived from farmer interviews in 1996, the preceding year, and cannot provide a direct comparison with yields of the advanced clones due to seasonal variations.

Even though the DM contents of these selected varieties were higher, only K₁ yielded higher DM per hectare in 1997 (8.03 t/ha) than the local variety IR in 1996. Trials are planned for 1998 to directly compare the advanced clones with local varieties in Kenongo, using locally produced planting material for all clones.

Farmers seek to diversify their market options. To gain greater and faster acceptance, any new processing variety of SP should also be acceptable in the fresh market. Thus, a consumer taste preference test was organized to evaluate these varieties for fresh consumption. Twenty eight consumers from Kenongo tasted all four advanced breeding clones, evaluated each on a scale of 1 to 3 (3 = best). The result of this tasting (Table 2) indicated that K₁ was highly desirable for fresh root consumption, with a rating of 2.93. K₅ was not acceptable, with a rating of 1.43. The reactions to K₄ and K₃ were intermediate. Some fresh root market sales in E Java are for sauce factories, for which taste criteria are not relevant, providing modest market potential for high yielding but poor tasting materials.

Conversion rates

A high correlation was found between fresh root DM content and the root:flour conversion rate: 0.836 (P=.0001). On average, K₄ achieved the best conversion rate of 29.12%, but there was no significant difference between conversion rates of the 4 advanced breeding clones, which were all significantly higher than those of the local varieties, IR and Senduro (Table 3). After milling and sifting flour with a 50-mesh sifter, a coarse texture still remained. A second sifting (70-mesh) was administered. This reduced the conversion rates (Table 3) and increased the labor needs of the process. Further improvements to the milling and sifting steps are needed to permit an acceptable yield of fine flour, although the women considered that not all food products require the use of fine flour.

The moisture content of the SP flour ranged from 8.0 to 9.1%., well below the standards for wheat flour (13- 14%). Conversion rates, flour yields, and process economics, could be improved by drying closer to the standards. The correlation between number of hours of sun-drying and flour moisture content was low but significant (correlation = -.520, P = .0001), but all samples contained less than the permitted moisture content. There is potential to shorten drying times further in the future.

Flour whiteness and quality

The measures taken to improve flour whiteness (de- watering with manual press, sun-drying within one day, and washing the shreds three times with clean water) were applied to all varieties equally. The results from the 1996 SP breeding trial indicated that all CIP advanced breeding clones had white flesh color, in addition to containing high DM (Table 1). However, some differences in color between varieties were noted in this trial (Table 4). Local varieties IR and Senduro appeared to have the whitest flesh color. However, these did not produce the whitest flour: K₄, with yellow flesh color, yielded the whitest flour and the best flour quality (Table 4), especially from Days 1 and 2 of the trial (Figure 1). This indicates that variety can affect flour color, but that this is not necessarily related to flesh color of the fresh root: varietal variation in levels of critical enzymes and substrates involved in the browning reaction could also be important. Regardless of the variety, all the SP flour samples were less white than wheat flour, with a whiteness reading of 83.97, indicating that further technical research is needed to improve whiteness. However, the SP flour samples (especially from K₄) were rated more positively by the women than the objective whiteness reading would suggest.

Two issues emerged from these results warranting further discussion. First, SP flour from the 1996 trial, using the local variety IR and similar processing procedures (peeled and shredded roots) produced flour with whiteness readings of 75.0 (using sulphite) and 74.1 (water soak only) (Peters and Wheatley, submitted). This is considerably higher than IR reading (69.9) from the 1997 trial. Fresh root characteristics could differ between years, and variable water quality could influence the

result. However, it is possible that the modifications introduced this year may have had a negative, not positive effect.

Washing, shorter drying times and pressing were the process modifications introduced in 1997. It is unlikely that repeated washing should adversely affect flour whiteness since Martin (1984) found that this improved the color. Faster sun-drying than in 1996 (<1 day compared to 1.5 days) can only improve quality. Therefore, a small additional trial was designed, using K₁, K₃, K₄, to determine the effects of pressing on flour whiteness and moisture content. The use of the press did not produce whiter flour or reduce the final moisture content for a given drying time (Table 5). Although statistical analysis was not possible, it would appear that pressing gives no advantage and may contribute to the whiteness problem. The flour from the non-press treatments also seemed to maintain whiteness during 3 weeks of storage better than that from the press treatments (Figure 2). This justifies further examination of the utility of the pressing step in the process.

All the trial roots were purchased (Senduro) or harvested (IR and advanced clones) on the same day. By the last day of the trial, roots had been stored for six days. K₄ and K₅ both tended to produce flour of decreasing whiteness with each succeeding day, while K₁ and K₃ were more stable (Figure 1): varietal effects may be important for stability of flour quality.

Food Safety

All TPC's were below the limit of 2×10^5 established as the Indonesian standard for cassava flour (SNI 7312020070). The total count of fungi/yeasts was below the standard limits of 1×10^4 for all samples (except for two of the K1 samples). No fecal E. coli were found. 50% of samples produced Total Coliform counts below 1×10^3 (Table 6). Considering that flour samples were produced using appropriate technology, under village conditions by rural women, these results are quite satisfactory. Counts could be reduced, if necessary, through implementation of more rigorous personal hygiene and use of hypochlorite to disinfect equipment and for washing fresh roots prior to processing (Ostertag and Wheatley, 1992).

Sweetpotato Flour Product Development

After the flour processing trial, a workshop was held to demonstrate products that can be developed from SP flour or wheat/SP composite flour. Fresh noodles (20% SP flour), cupcake (50%), and chocolate cookies (100% SP flour) were produced. Fresh noodles were made with fine flour from K₄ and K₅. Cupcakes and chocolate cookies were made with K₄ flour¹, both fine and coarse.

Twenty-four villagers participated in tasting the noodles, which were cooked into a dish. 13 people evaluated cupcakes and cookies. Participants were asked to score the six products—two types of flour for three products—on color, appearance, taste, and general acceptability of the product. The scores were on a scale of 1 to 3 (3 = good, 2 = fair, 1 = bad). Most products were well received. Noodles made from K₄ flour were rated higher than from K₅, especially in color and looks (Table 7). Cupcakes in general were rated higher than noodles, especially when made from the fine flour. However, the difference in rating between the fine and coarse flour was small, indicating that it is unnecessary to use fine flour for this purpose. For the chocolate cookies, consumers preferred coarse flour.

Profitability

There are two types of market for which these processing activities target: direct sales of SP flour to users, and marketing of final products. For the flour market, targeted clients include noodle factories, bakeries, and home industries. They consider that SP flour should be positioned about 25% cheaper than wheat flour (Peters and Wheatley, 1997). Imported items in Indonesia are increasing in price. Wheat flour currently (November 1997) costs Rp840 kg⁻¹ wholesale (US\$1.00 = Rp3,200, Nov. 1997). Therefore, the price of SP flour should not exceed Rp630 kg⁻¹. SP fresh root (IR) prices in Kenongo, on the other hand, fluctuate between Rp100 and Rp140 kg⁻¹. The material (i.e., root) costs for processing, and the gross profit from each kilo of SP flour depend on the conversion rates (Figure 3). At the best possible scenario (i.e., root price = Rp100 kg⁻¹, conversion rate = 30%, and price = Rp630), the raw material cost would be Rp330 kg⁻¹ of SP

flour, with a gross profit of Rp300 kg⁻¹ of flour. The worst possible scenario (i.e., root price = Rp140 kg⁻¹ and conversion rate = 22%), the raw material cost would be Rp636 kg⁻¹ of flour and there would be no profit. Conversion rate and root price are both critical determinants of profit margin. A minimum 28% conversion rate is needed.

Currently, most women in Kenongo process cassava *keripik* : a fermented, sun-dried flour dough is boiled, rinsed, dried, sliced and re-dried over a ten day period: one person makes 30 kg of *keripik* using 125 kg of cassava roots (conversion rate = 24%). The prices of cassava roots fluctuate between Rp80-100 kg⁻¹. The *Keripik* is sold for Rp1,000 kg⁻¹, giving Rp20,000 (assuming a root price of Rp80 kg⁻¹) of gross profit for ten days of labor (Table 8). SP flour processing, on the other hand, is less time-consuming. Each woman can process 30 kg of fresh roots a day, including 3h for manual peeling of the fresh roots. Processing must be finished at the latest by 9 am in order to fully utilize the sun to dry the shreds in one day. Thirty kilo is the daily limit for one woman, unless a more advanced peeling technique is devised. At 22% of conversion and Rp140 of root price, a woman processing 30 kg SP roots will suffer a loss. However, with 30% conversion and a Rp100 fresh root price it would be possible to gross Rp2,670/day (Table 8). The SP flour must achieve at least a 28% conversion rate with a root price of Rp100 kg⁻¹ in order to exceed the current income generated from cassava chips.

The potential market for final products, such as cookies, cupcakes, and cake is local bakeries, the local marketplace, and even bakeries in Malang town nearby. The quality of these products depends on where they are targeted: Malang bakeries offer higher prices but demand better quality products (i.e., expensive raw material in cookies and cakes). Local village markets have lower prices and poor quality products. A local home industry in Kenongo makes simple cup cakes (with

wheat flour) which sell for Rp100/unit, with material costs of Rp50/unit. By replacing 50% of wheat flour with SP flour, the cost of each cup cake could decrease by 20% (Rp10) (assumes Rp1,000 kg⁻¹ of wheat price and Rp500 of raw material to make sweet potato flour). If a household sells 100 cupcakes a day, the gross profit would be Rp6,000, of which Rp1,000 would be extra profit from replacing wheat flour with SP flour. In comparison, agricultural labor rates in Kenongo are Rp 3,000/day, when available.

Conclusions

This processing trial has shown that production of SP flour, a new product for E Java, is possible at village level, using simple, low cost equipment. Village women have proved both able processors and keen researchers in the quest for procedures to improve product quality and reduce processing costs. Based on the results presented here, and the feedback obtained from the Kenongo womens' association, small scale pilot production and marketing of SP flour will be attempted from 1998, to assess the feasibility of SP flour enterprises. This will involve SP production trials of the new clones, a final series of processing trials and marketing research using the flour produced.

In addition to high dry matter content and better conversion rates, the new K advanced clones were rated easy to peel. They also gave whiter, finer flour (Table 9). K₁ and K₄ show the greatest potential, based on conversion rate, yield of flour/ha, whiteness, and the women's own rating. Using these two new clones, SP flour marketability and profitability is much improved over the results of 1996 (Peters et al., submitted). However, varietal selection needs to continue through more seasons.

New variety selection trials with K₁, K₄, K₅² and some additional promising clones are now in progress in Kenongo. After evaluation, the best clones will be multiplied in Kenongo to be ready for the next participatory processing trial in Kenongo (May 1998).

Before the next series of processing trials in Kenongo, controlled experiments will be conducted to address the remaining technical issues identified in this trial: effects of variety, pressing, washing, use of sodium bisulphite, water pH and flour storage conditions on flour whiteness; and the effect of milling and sifting procedures on conversion rates and flour texture.

The interdisciplinary approach used in this research, in which socio-economic pre-feasibility studies are combined with participatory processing action research, varietal selection trials, feedback to on-station trials for specific technical process research and for laboratory analysis of samples generated in the field, may be relevant to other crops, countries and small enterprise situations. Small scale rural enterprise production of SP flour is of relevance to rural people and research projects in E Africa, China, the Philippines and Vietnam.

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¹ K₄ flour was used for all experiments because it appeared to be the whitest flour and has the highest conversion rate during the trial.

² K₅ is still under consideration for the following reasons: 1) the plants harvested, which determined the yield, during the last selection trial were few, so it is possible that the planting material might have been damaged, and 2) K₅ produces a great quantity of leaves and vines which is highly desirable for Vietnam and China. The value of vine and leaves may more than compensate the lower DM and flour per hectare.