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# Carotenoid contents in fresh, dried and processed sweetpotato products

Authors:

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## Abstract

To understand the effect of drying and processing sweetpotato roots into high provitamin A content products, total carotenoids and  $\beta$ -carotene were colorimetrically determined in fresh storage roots of different flesh colors, dried chips, and sweetpotato processed products. Fresh roots were white, yellow, cream, orange and purple. The total carotenoids ranged from 0 to 10,000  $\mu\text{g}$   $\beta$ -carotene equiv./100 g of fresh storage root tissue. Flesh color for storage roots of high carotenoid content cultivars was consistently orange and was yellow or white for cultivars with low to very low carotenoid contents. The "b" values were high and consistent for flours from orange and cream-fleshed root cultivars and could easily be used to predict the total carotenoid and  $\beta$ -carotene contents of sweetpotato cultivars. Process of drying sweetpotato storage roots at 65°C for 12 h reduce the total extractable carotenoid contents by 30% and the storage of dried chips in ambient conditions for 11 months induced a loss of 10% in total carotenoids. Addition of orange-fleshed sweetpotato root flours in processing of buns, chapatis, and mandazis increased by 20 times the total carotenoid contents in the products suggesting the high suitability, affordability and sustainability of simple food processes and the sweetpotato crop in combating Vitamin A deficiency in the developing world.

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## Introduction

Vitamin A deficiency is a serious nutritional problem among many developing countries. Millions of people suffer from this affliction which leads to night blindness, xerophthalmia, and keratomalacia (Smith et al., 1996) and subclinical deficiency also reduces immune function to increase the risk of severe and fatal infections (Bates, 1995; Underwood, 1994).

Since the early 1990s, the main strategy for combating Vitamin A deficiency has been to distribute massive dose capsules (Kennedy and Oniango, 1993). However, a similar effect could be achieved by an equivalent consumption of  $\beta$ -carotene and Vitamin A-rich foodstuffs, as the safest and most appropriate long-term approach to control Vitamin A deficiency (Rahmathullah et al., 1990). It is known that foods such as dairy and meat products containing preformed Vitamin A are often too expensive for the majority of people in developing countries. Therefore, the availability of more potent and sustainable food sources of provitamin A carotenoids and improvement of production, shelf life, and consumer acceptance of these foods, can make a tremendous contribution to improved human health.

Sweetpotato (*Ipomoea batatas*) has a broad genetic base with tremendous variability in biochemical composition where the main storage root constituents of the dry matter are carbohydrates, specifically starch (Woolfe, 1992). In addition to high starch content, sweetpotato roots are known to be one of the major food sources of carotenoids along with apricot, carrot, and peach (Henkel, 1996; Woolfe, 1992). The colour intensity of the flesh roots differs from one cultivar to another, and varies from white to deep orange. The intensity of orange colour of flesh roots is attributed to carotenoid content (Ameny and Wilson, 1997). Carotenoids are widespread plant pigments belonging to the family of fat-soluble terpenoids and are used as natural colorants or act as Vitamin A precursors. When consumed, carotenoids are enzymatically broken down to retinol (Vitamin A) (Simon, 1997), but the Vitamin A activity of  $\beta$ -carotene is substantially greater than that of other carotenoids (Almeida et al., 1988).

Sweetpotato crop has been receiving increasing attention from agriculturalists and ecologists interested in developing world's sustainable production systems because it can grow on soils of limited fertility, is relatively drought tolerant, provides good ground cover, and is usually cultivated without fertilizer or pesticide (Ewell, 1990). In Africa, it is an important staple food source of calories and consumed by all age-groups but are particularly liked by young children who also are at risk of the Vitamin A deficiency. The varieties widely consumed are white or pale yellow in color and

contain very little amount of  $\beta$ -carotene (Takahata et al., 1993; Ameny and Wilson, 1997) while carotenoids of orange-fleshed sweetpotato storage roots are highly Vitamin A active and almost exclusively  $\beta$ -carotene (Purcell, 1962; Purcell and Walter, 1968; Simonne et al., 1993; and Takahata et al., 1993). In this way, consumption of orange-fleshed sweetpotato roots and their based foods would provide sustainable, cost-effective, and required Vitamin A intake and, therefore, their use as food source of carotenoids merits further attention.

Sweetpotato roots are highly perishable, and, in Africa, they are not generally stored for extended period after harvest (Karuri and Ojijo, 1994). The only kind of storage regularly practised is in-ground storage, by which farmers keep unharvested mature sweetpotatoes in the field until they are needed for consumption or local sale (Smit and Ocitti p'Obwoya, 1994). They are commonly consumed in fresh form, usually just boiled. In semi-arid areas with long dry season, in-ground storage is limited by attacks from sweetpotato weevils (*Cylas spp.*), and farmers have traditionally chipped or crushed sweetpotato roots and dried them in the sun as a method of preservation. The dried product is stored in traditional granaries, and is, all the year round, used in the preparation of traditional staple dishes. Sweetpotato roots of most farmers' varieties in the region have white or pale yellow colored flesh and are low in  $\beta$ -carotene content. The International Potato Center has been making effort to avail more nutritious sweetpotato varieties to the developing countries and high yielding orange-fleshed sweetpotatoes are being introduced to the African farmers (Gichuki et al., 1997). Chipping and drying for storage of orange-fleshed sweetpotato varieties can overcome the seasonality and provide important quantities of Vitamin A, a micronutrient which is critically short in the diets of many low-income households, especially during the dry season when any kind of fresh green vegetables has dried up. However, little is known about the effect of indigenous drying practice on the carotenoid content in sweetpotato roots.

Limited research has been conducted on sweetpotato drying and flour production. Flour was assayed by Walter et al. (1983) for amino acid content, nonprotein nitrogen, and available lysine. Protein efficiency ratio for protein of the flour ranged from 2.2 to 1.3, depending upon cultivar and dehydration treatment. Collins and Abdul (1982) tested the effect of sweetpotato flour (and puree) as an ingredient on quality of yeast-raised doughnuts. Several chemical and physical properties and six organoleptic attributes of the doughnuts were tested, but overall quality was not significantly lowered by addition of sweetpotato. Gakonyo (1993) and Omosa (1994) have shown that sweetpotato either in fresh grated, boiled and mashed, or flour form could, with high potential of success, partially replace wheat flour in processing of fried products such as "chapatis" (Indian-type flat bread), and "mandazis"

(doughnuts). Furthermore, Hagenimana and Owori (1996) reported that wheat flour is too expensive in a such manner that the cost of a 2-kg pack is equivalent to a 3-day salary of a casual worker in Lira Municipality, Uganda. Small-scale businesses of such fried processed sweetpotato products are beginning in Western Kenya and Lira (Uganda), and these products may constitute an important snack item and source of Vitamin A in these regions in the future. Therefore, in order to achieve the desirable colour, nutritional and acceptable products, an understanding of carotenoid stability during the processing is essential.

We are interested in increasing the use of rich  $\beta$ -carotene orange-fleshed sweetpotato when processing sweetpotato-based foods. The current study has been undertaken to identify the change in total carotenoid content after drying sweetpotato storage roots and processing indigenous foods when orange-fleshed sweetpotato roots are used as an ingredient.

## **Materials and Methods**

Fresh sweetpotato roots were obtained from the breeding collection of the International Potato Center (CIP), Regional Office in Nairobi, Kenya. Cultivars used were grown for 5 months at the university farm in Kabete, Nairobi. 32 cultivars were chosen respecting the flesh coloration range of the storage roots. They visually were white, yellow, orange, and purple (Table 1). Medium and large sweetpotato roots of each cultivar were maintained under ambient air conditions, washed, and used 2 days after harvest.

### ***Carotenoid determination***

Carotenoid content was determined as described by Imungi and Wabule (1990). Total carotenoids were extracted in acetone from 2-10 gram samples of fresh sweetpotato or sweetpotato-based products (flour, buns, chapatis, mandazis) until the extract was colorless. The acetone solution was transferred to a separatory funnel and the pigment was transferred into petroleum spirit (40-60°) and the acetone layer discarded. The petroleum spirit extract was brought to 100 ml and samples were withdrawn for determination of total carotenoids using a spectrophotometer to measure absorbance at 450 nm. Concentrations were determined by comparison with a standard curve developed using pure  $\beta$ -carotene from Sigma, St. Louis. Then, 25 ml of the petroleum spirit extract was concentrated using a rotary evaporator at 30°C, the residue dissolved in 1 ml of petroleum spirit, and the solution introduced onto a silica gel chromatographic column with  $\beta$ -caroten from Sigma as standard. Separation was run using petroleum spirit and the  $\beta$ -carotene fraction collected. Absorbance was read at 450 nm as above. For

comparison, carrots were purchased from a Nairobi market and their carotenoids extracted and analyzed using identical procedures.

### ***Chipping and drying***

A 5-kg sample of medium and large sweetpotato roots of each cultivar were washed, left overnight to get their surface dried, hand peeled, and cut into sizable chips. The initial weight was recorded and dried at 65°C in a forced-air oven until the moisture of 6-8%. Dried chips were stored in opaque paper bags and a sample taken after 3, 6, and 11 months of storage under ambient air conditions to check the change in total carotenoid contents. The process of producing dried sweetpotato chips and flour is shown in Figure 1.

### ***Sweetpotato flour Hunter L\*a\*b value determination***

Color and color difference meter used was a Minolta Chroma Meter CR-200B. Calibration was done before each measurement using the calibration plate provided with the Yxy values as 93.1, 0.3139 and 0.3213 respectively. During the calibration, the plate was wrapped with a plastic film which was also used during analysis of the sweetpotato storage root flour samples. Flour samples were carefully mixed using a spatula and then, in triplicate, 10 g sample taken for readings.

### ***Dry matter determination***

For the fresh material, three medium-sized roots were washed and chop into small cubes, and for each processed product, 3 pieces were hand cut into small pieces. Dry matter content was determined by drying triplicate 20-g samples at 70°C for 72 h in a forced-air oven.

### ***Baking procedure***

The wheat flour used was that for bun- or bread-making in Nairobi, Kenya. The flour brand found in different shops was milled by Unga Millers Ltd., Nakuru, Kenya. Sweetpotato flour, fresh raw hand-grated, or peeled roots maintained in boiling water for 30 min and then hand-mashed into a puree (cooked and mashed), wheat flour, baking dry yeast (Saf-levure, S.I. Lesaffre 59703 Marcq, France) reactivated in warm solution of 20% sugar in water, and sugar were mixed together and a quarter of total water added. The dough was kneaded using an electric mixer at the slow speed, and cooking oil slowly added. The mixer continued at this speed for some time. The remaining water was slowly added to the mixture and mixing continued for 10 min until an elastic dough was formed. The dough was cut into equal pieces which give a normal bun weight of 45-50 g after baking, moulded, and then left in ambient

conditions for rising. The raised dough was then baked in a kitchen oven for 25-30 min. A control was processed using only wheat flour. The buns were packed in plastic bags and then taken the following day to the laboratory for carotenoids analysis.

### ***Chapati processing***

Chapatis (flat indian-type bread) were made from the following recipe: 1.0 kg of cooked and mashed or raw and hand grated roots, 1.0 kg of wheat flour from UNGA Ltd., Nakuru, Kenya, and when sweetpotato flour was being used the ratio was 3:7 sweetpotato flour to wheat flour, 1 teaspoon (about 1.7 g) of salt (Salt Manufacturers Kenya Ltd., Mombasa, Kenya), 3 teaspoons (about 5 mL) of baking powder (Kapa Oil Refineries Ltd., Nairobi, Kenya), 1/4 cup (about 100 mL) of corn oil (Elianto Co., Nairobi, Kenya), and 2 cups (about 450-480 mL) of water.

Sweetpotato and dry ingredients were mixed together. Water was added and the mixture hand-kneaded to make a soft, smooth dough. The resulting dough was divided into approximately equal portions and formed into balls. These were rolled into circular shapes of about 12 cm in diameter and about 3 mm in thickness using a floured pastry board, and grilled on a hot and oily griddle iron for about 1 minute each (about 30 sec for each side). A control was processed using only wheat flour. Carotenoids were extracted from the end-product samples and determined in triplicate as described above. Analysis of variance was processed using the MSTAT-C program (MSTAT-C, 1991).

### ***Mandazi processing***

Mandazis (doughnuts) were made from the following recipe: 1.5 kg of cooked and mashed or raw and grated sweetpotato roots, 1.5 kg of wheat flour from UNGA Ltd., Nakuru, Kenya, and when sweetpotato flour was being used the ratio was 3:7 sweetpotato flour to wheat flour, 250 g of sugar, 2 tablespoons (about 10 mL) of baking powder, 5 tablespoons (about 25 mL) of "Elianto" corn oil, and 2 1/4 cups (about 500-600 mL) of water. Dry ingredients were mixed together and a well was made in the centre where the oil was placed and mixed. Sweetpotato was added and then water was added slowly and gradually. The mixture was hand-kneaded until a soft dough was formed. The dough was left to relax for 10-15 min and was then rolled on a floured pastry board to the thickness of 1.25 mm as reported by Oyunga (1994). It was then cut into approximately equal pieces that were deep-fried until brown. A control was processed using only wheat flour. The carotenoid content of samples was determined in triplicate from a 5 mandazi samples as described above. Data were analysed using the MSTAT-C program (MSTAT-C, 1991).

## Results and Discussion

### *1. Carotenoids and dry weight in fresh sweetpotato roots*

Total carotenoids and  $\beta$ -carotene contents in 32 sweetpotato storage root cultivars were determined (Figure 1). Table 1 shows the flesh colours of cultivars used in the study. Cultivars had different flesh colours ranging from white, yellow, cream, orange and purple. The total carotenoids ranged from 0 to 10,000 $\mu$ g  $\beta$ -carotene equivalents per 100 g of fresh storage root tissue (Figure 1), and the  $\beta$ -carotene contents were highly correlated to total carotenoid contents, and almost in the same range of values (Table 2).  $\beta$ -carotene contents of orange-fleshed sweetpotato storage roots were even higher than that of carrots found on the Nairobi markets (results not shown here). Our results are in agreement with previous report from Takahata et al. (1993) that sweetpotato carotenoids would be almost exclusively  $\beta$ -carotene.

Flesh color of storage roots for high content carotenoid cultivars was consistently orange (CIP400014, CIP420009, CIP420010, CIP420027, CIP42004 and SPK004), roots with cream flesh colour had medium carotenoid contents (CIP187004.1, CIP440377, CIP440186, and CIP197004.2), while carotenoid contents in yellow, white, and purple-fleshed storage roots was low to very low (Table 2). The low level of carotenoids, and consequently,  $\beta$ -carotene contents in yellow-fleshed storage roots was surprising because one considering only the colour would expect the carotenoid level of yellow-fleshed cultivars to be between that of orange-fleshed and white-fleshed storage roots. The variation in total carotenoids and  $\beta$ -carotene within roots of the same cultivar was high especially for orange-fleshed ones (Figure 1).

There was no correlation between flesh colour and the dry weight of the roots (Table 2). The dry weight of orange-fleshed storage roots was generally low to medium (from 20.4 to 27.8%), except SPK004 which had the high dry weight of 32.3% and was among cultivars with high carotenoid content. Purple flesh-colored storage roots had generally medium to low dry weight (30.2-20.3%), however, CIP420031 had the high dry weight of 34.3%. Dry weight was variable among cream, yellow and white-fleshed storage roots, but was generally high (Table 2). CIP187004.2 had the highest dry weight of 34.5% while CIP440154 had the lowest (18.8%).

### *2. Carotenoids and Hunter colour values of sweetpotato flours*

Analysis of the Hunter colour values showed there was a significant difference in the "L" (white) values for sweetpotato flours from different cultivars (Table 2). The white

fleshed cultivars did not have the high "L" values indicating the high level of browning occurring during the sweetpotato chip drying and flour processing. Hagenimana et al. (1992) reported that the discoloration or darkening may be attributed to the reaction between polyphenoloxidase and o-dihydroxy-phenols or to a Maillard type reaction between reducing sugars and aminoacids in sweetpotato roots. Also, both enzymatic and non enzymatic oxidation of flesh root pigments with concurrent colour lost have been reported in dehydrated food (Edwards and Lee, 1986). Interesting was the high correlation between the high "L" value of the flours and the purple flesh colour of the roots (Table 2). Cultivars CIP420031, CIP420053, CIP400002, and CIP420047 had the purple flesh colour and high "L" value suggesting the high content of anthocyanins. Bassa and Francis (1987) used the L values to predict the pigment changes in anthocyanin contents from beverage, and anthocyanins from sweetpotatoes were found to be more stable and effective than commercial food colorants.

The "a" (red) values of the sweetpotato flours were different for all the cultivars. There was a good correlation ( $r=0.737$ ) between the "a" values of the flours from orange and cream-fleshed cultivars and total carotenoids from the fresh roots, suggesting a prediction of total carotenoids and consequently B-carotene in a given orange or cream-fleshed cultivars by just reading the "a" value of its flour.

The "b" (yellow) values were different for all the cultivars. They were high and consistent for flours from orange and cream-fleshed root cultivars (Table 2), and low but erratic for yellow, white and purple-fleshed root cultivars. The correlation between the "b" values for the sweetpotato flours and the total carotenoids from orange and cream-fleshed root cultivars was high ( $r=0.770$ ). The flour "b" colour value seems to be the best measure for correlation between color value of orange and cream-fleshed root flours and the concentration of total carotenoids and  $\beta$ -carotene in fresh storage roots. The "b" values can easily be used by breeders from developing countries, where laboratory means are scarce, to predict the total carotenoid and  $\beta$ -carotene contents in different sweetpotato cultivars. Figure 2 shows how the "b" values can be used to evaluate  $\beta$ -carotene content in fresh sweetpotato storage roots.

### ***3. Effect of drying and length of storage on total carotenoid contents***

Process of drying sweetpotato storage roots at 65°C for 12 hours reduce the total carotenoid contents by 30%, and the storage of dried chips for 11 months induced a decrease in total carotenoids contents of about 11% (Table 3). The effect of drying



on total carotenoid contents was different among sweetpotato cultivars, and the reduction in total carotenoids was generally low in high dry weight content cultivars.

The storage of sweetpotato dried chips reduced the total carotenoid contents in dried chips from 70 to 59% after 11 months, and the variation was dependent on cultivar. The general trend is that the storage induced a loss in total carotenoids for all varieties. Our results are in disagreement with Collins and Gurkin (1990) who previously reported that a 6-week storage increased the  $\beta$ -carotene content by 20.7% in sweetpotato flour.

Observations from our preliminary work on drying sweetpotato storage roots indicated that the chipping followed by drying gave the best colored flour product than when fresh roots are grated and then dried. Both enzymatic and non enzymatic oxidations of carotenoids (Edwards and Lee, 1986) and other browning phenomena (Hagenimana et al., 1992) concurrently occur in the whole mass of grated and dehydrated sweetpotato storage roots, while those phenomena are restricted to the chip surfaces in chipped sweetpotato roots.

The best way of keeping carotenoids in sweetpotato storage roots would be to chip, dry, and store sweetpotato dried product, and then make flour from dried chips when it is needed.

#### **4. Total carotenoids in processed sweetpotato products**

Table 4 shows the total carotenoid content changes when sweetpotato roots from the cultivar CIP420027 are used as one of the ingredients in processing chapatis, mandazis, and buns. Roots were either boiled and mashed into a puree, fresh grated, or processed into flour. Boiling of roots from cultivar CIP420027 induced the loss of 20% total carotenoid contents, while drying into chips reduced the amount of total carotenoids by 30% compared to the initial total carotenoid amount of fresh storage roots. Carotenoids were reported to be heat-stable and not sensitive to pH changes (Sian and Ishak, 1991), and the color changes that occur in processes of blanching, cooking or heat sterilization were attributed to the isomerization of trans-carotenoids to the less intensely colored cis-form (Sian and Ishak, 1991). Probably, the loss of coloration observed on sweetpotato dried chips and flours in the current study can be attributed to the same effect.

Addition of orange-fleshed sweetpotato storage roots in buns, chapatis, and mandazis tremendously increased the contents of total carotenoids and consequently B-carotene in the products (Table 4). Flour was the best form of using sweetpotato to increase total carotenoid and B-carotene contents of bun, chapati

and mandazi products. Adding sweetpotato flour in bun processing induced an increase in total carotenoids of the product by 2000%, 1000% by adding boiled and mashed, and 700% by adding raw and grated. In chapati products, addition of raw and grated sweetpotato storage roots come after flour (2000%) in increasing the total carotenoids of the product by 1300%, and the last was boiled and mashed form of sweetpotato which increased the total carotenoids by 990%. In mandazis, boiled and mashed come immediately after sweetpotato flour (1900%) and increased the total carotenoid content by 1480% and then raw and grated sweetpotato form which increased the total carotenoid content of the product by 1360%. The high agronomic performance and good consumer and farmer acceptability of orange-fleshed sweetpotato cultivars (Gichuki et al., 1997) combined with their high carotenoid content and of high stability after drying, cooking and frying treatments as shown in the current study, make the crop highly suitable in combating Vitamin A.

## **Conclusion**

The study provided information on the range of total carotenoid and  $\beta$ -carotene contents in 32 sweetpotato storage root cultivars and described a useful method involving the drying and reading of sweetpotato storage root flour Hunter "b" values for estimation of  $\beta$ -carotene in sweetpotato cultivars. It showed the effect of drying and storage of dried material for 11 months on total carotenoid contents. Finally, a demonstration of how, through simple food processes, sweetpotato storage roots can improve the provitamin A content in foods, was made.

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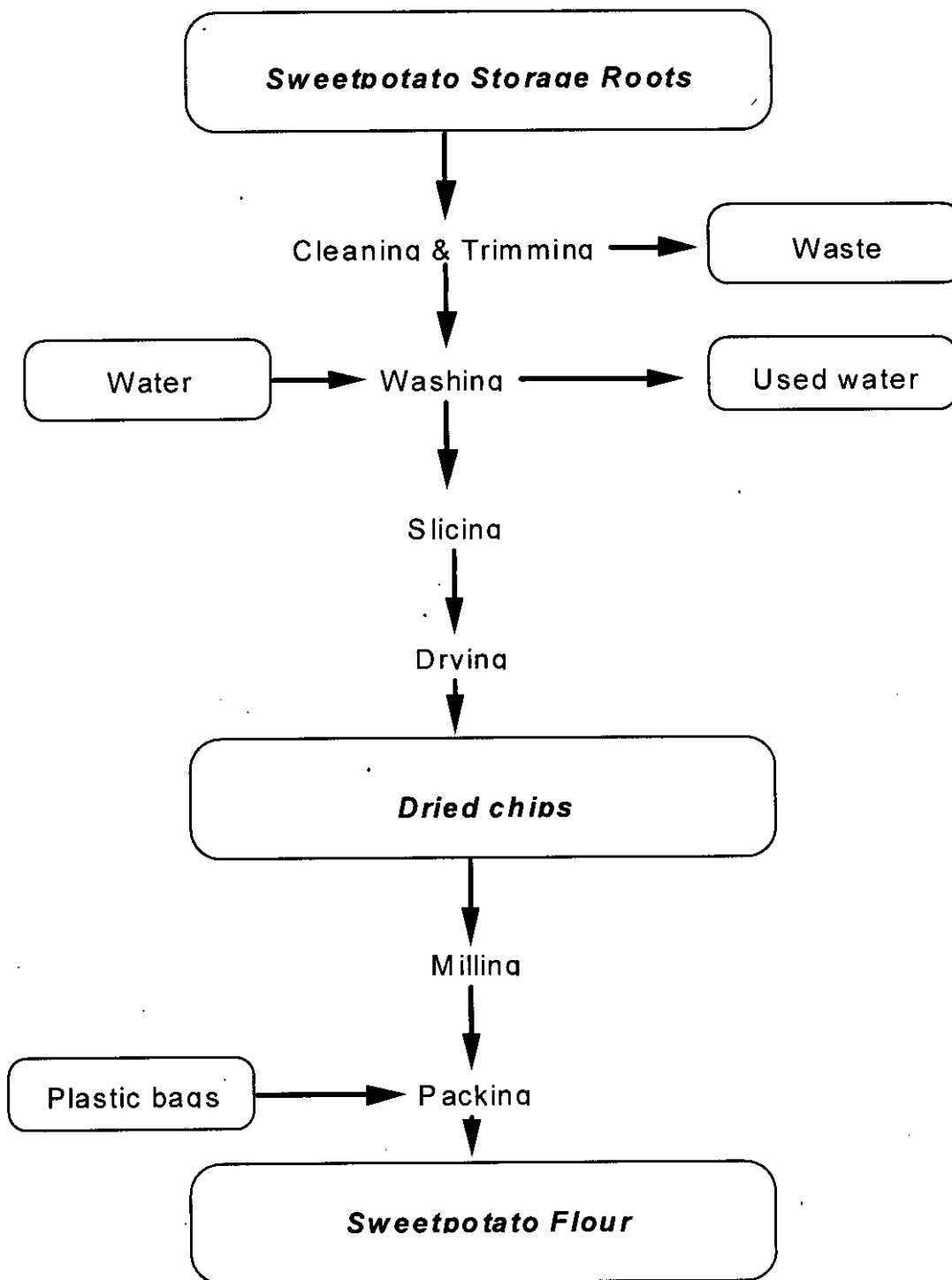


Fig. 1. Process of producing dried sweetpotato slices and flour