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POST HARVEST EQUIPMENTS IN TUBER CROPS- REVIEW

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Abstract–Mechanization is important in tuber crop post harvest unit operations to process the freshly harvested cassava and other tuber crops before getting spoilt. Cassava tubers are rich in its starch content and can also be used in the edible form. Post harvest equipments in tuber crops includes washers, both mechanical washers and manual washing, then peeling using a manually operated peeling knife and a mechanical peeler for major tuber crop, Cassava, abrasive peeler, then size reduction equipments, slices, chips and graters using cassava chipping machine, manually operated including hand, pedal operated and mechanically operated cassava chipping machine, strip cutter including cuber and sorter, grater pulverizor, dryer of manual method including sun drying, hand dryer, mechanical driers of solar drier, electrical drier, equipments in starch extraction including rasper, starch settling units of hydrocyclones and centrifuges for the starch industry. In this paper all the post harvest equipments developed both in India and abroad had been given to know all the equipments and machineries developed so far in the post harvest technology of tuber crops. This paper also clearly explains the necessity for all these equipments in tuber crop post harvest technology to minimize the post harvest technology losses, that is usually 10%.

INTRODUCTION

Cassava is one of the most important energy sources in the diet of the people in the tropics, that is storage roots provide 8% or more of the minimum calories requirements for more than 750 mi. tonnes people. It has also been under consideration as a starch or energy crop in developed countries such as Australia. National average yields vary widely, from 1.5t/h in Sudan to more that 32t/ha in Fiji. Most cassava is grown in areas where annual mean temperature is above 20 °C and rainfall exceeds 700mm/y. Much cassava is grown without irrigation in tropical areas with a pronounced dry period. Cassava is one of the crops included in a priority list by IBSNAT (International Benchmark Sites Network for Agro technology Transfer) an organization established to stimulate and co-ordinate research into cropping systems. CIAT survey results estimate that a 21% potential increases in economic yield is possible through improvements in quality, processing and product marketing. Surveys indicate that rapid post-harvest root deterioration and low root dry matter content are broadly recognized constraints that limits farmers income from cassava. The processing constraints that limits farmers income from cassava. The processing constraints include mechanization, pollution control and economic use of by products.

India had achieved self sufficiency in food during the past decade and the country must now turn its attention to post harvest practices in order to store and utilize the produce produced in times of need most effectively and efficiently. The post production phase of agriculture experienced heavy losses of the food item (5-50%). These losses are due to insufficient handling, storage, transport, processing and marketing infrastructure facilities. The extent of loss depends on the type of food products. ie.-5-15% in durables, 20-30% in semi perishables and 30-50% in perishables. These post harvest losses amounts to be 21,500 crores for durables 2,400 crores for semi

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perishables and 52,500 crores for perishables. The tropical tuber crops played a vital role in providing food security and rural employment in the tropical countries. They include cassava, sweet potato, yams, aroid species viz. *Colocasia esculenta*, *Xanthosoma sagittifolium, Amorphophallus paeonilfolius, Alocasia macrrohiza, Crytoperma chamissionis* are five minor tuber crops viz. *Coleus parviflorus, Pachyrrhizus erosus, Maranta arundinaceae, Psopocarpus tetragonolobus* and *Canna edulis*. Tuber crops, being perishable deteriorate rapidly after harvest and are often until for food or feed within a few days. About 20-30% of the total production is lost annually due to varied reasons both during harvest and post harvest phases. Losses appear at different stages namely during harvest, improper transport and handling, storage, distribution and use of inferior processing technologies causing both qualitative and quantitative losses. Post harvest handling is very important at the farm level as it influences the quality of the products produced from them. Cassava is grown in an area of 16.37m.ha globally with an annual output of 164.75m.tonnes of tubers. The major cassava producing countries are Nigeria, Congo, Brazil, Thailand and Indonesia. As far as productivity countries are Nigeria, Congo, Brazil, Thailand and Indonesia. As far as productivity is concerned, India ranks first in the world accounting to about 24.5t/ha. In India, cassava is mainly cultivated in Kerala, Tamil Nadu and Andhrapradesh producing 6m. tonnes. Cassava is the most widely cultivated tuber crops and 25% of the cassava produced are lost at the post harvest level. These losses may be due to external agents (insects and predators), physical factors (handling, transportation and storage condition) or physiological origin. The poor shelf life of tubers necessitates the immediate utilization after harvesting or processing into value added products. Tuber crops owing to the high starch content has vast applications in food, feed and industrial sectors. The major post harvest unit operations involved in food, feed or industrial products consists of washing, peeling, size reduction, starch extraction and drying.

Washing

Soil should be removed from cassava roots before processing. Washing is also done to reduce the cyanide content. Washing through moving water is the best method for soil removal. Bitter cassava cultivars should be intensely washed. Manual washing is done by small and cottage level processors, while mechanical root washers, having a capacity of 10-20t/h are used by medium scale factories. In the traditional method of manual washing the average capacity of each person in performing the task is 125kg/h in washing. Washing can be done using washing tanks or flowing water.

Mechanical Washers

It is a perforated cylindrical tank immersed in water. A spiral Brush is attached at the central axis of the tank, which propels the roots and they are subjected to vigorous scrubbing in order to remove all dirt. Jet of water is sprayed counter current to the flow of the roots giving an efficient washing.

Drum Washers

It consists of a rotary wooden or perforated drum with an interior pipe, which sprays water on the roots. It is about 3-4 m long and 1m diameter and mounted inside a concrete tank. Washing is done by the auction of water sprayed assisted by the abrasion of the roots both against one another and against the side of the cylinder drum and when they come out at the other end, they are clean and partially peeled. Dirty water and skin are periodically drained out through the small opening in the concrete tank.

In Philippines two root crop washers are used viz. Visca root washer and the PRCRTC root washer. The Visca root washers is mainly for sweet potato only, but can be used for cassava also. It is made from an empty oil drum equipped with a rotating wooden frame holding brushes. The oil drum is cut at an angle of 270^{o}C and the small portion is removed and is replaced by wire mesh semi circular net. The axis carrying the brushes is rotated inside the drum. Water is placed inside the oil drum portion. It is manually operated and has a capacity of 300kg fresh roots per hour (Tabinan *et al.,* 1985). The PRCRTC (Philippines Root Crop Research and Training Centre) had developed a washer that has a rotary drum and a water basin. It is also manually operated with a washing capacity of about 300-500kg/h.

Peeling: Traditional cassava is peeled by hand and the yield is about 200 kg cassava/day. CTCRI peeling knife has an average output of kg/h.

Peeling can be of three types, viz.,

1. Manual peeling can be inefficient and result in high losses.
2. Mechanical peeling by abrasion in a rotating drum with water added to flush loose peel.

3. Lye, roots immersed in solution of sodium hydroxide.
4. Steam, roots exposed to steam under pressure.
5. Combination of lye and steam peeling.

The feasibility of peeling cassava (*Manihot esculenta*) by immersing the tubers in a lye solution was investigated. Response surface methodology was used to determine the effects of concentration and temperature of the solution and immersion time on peeling efficiency. Complete removal of the peel from the cassava was achieved with a lye concentration of 9-14%, temperature of 85-98 ^{o}C and an immersion time of 4-7min. Manual peeling of the roots is tedious and time consuming. Still it is practiced in small scale industries. Peeling is accomplished manually in small scale industries with the help of a special peeler knife having a broad based U shape. The peeling knife developed at CTCRI, has an average output of 113.5kg/h comparable to that of the traditional knife. The additional labour cost per tonne of tubers peeled by the improved knife (Rs.3/basket) of 55-60kg unpeeled tubers is about Rs.12/- only. Flesh loss with the improved knife is only 1.38% compared to the 5.70% flesh loss by the traditional knife. The cost of the additional tuber loss by the traditional knife or in other words the saving of tuber flesh by the improved knife is nearly Rs.106/- at the factory rate of Rs.145/-per bag (70 kg of tubers). The traditional knife costs Rs.5/- each and 2 or 3 knives are disposed by a labourer each week, with the minimum cost of operation being Rs.10/- The cost of the improved knife is estimated at Rs.15/- and its blades can be replaced or sharpened at the same interval with the cost of operation of Rs.1.50 per week (Balagopalan, 2000).

TNAU had developed a cassava peeler, that consists of a cylindrical rotor fitted with a number of cutting blades. It comprises of a rotor of 25cm diameter and 30cm length. The cutting blades that scrap off the tuber surface during its operation, have been fixed along the circumference of the rotor with a blade angle of 50. Performance of the machine was evaluated in terms of flesh loss and peeling efficiency for sized and unsized roots. For unsized roots, the flesh loss was 12.95% and peeling efficiency was 52.90% at 1150rpm, capacity was 362 kg/h and effectiveness of the machine was 0.457. For sized tubers at 1150 rpm, 3.67% flesh loss and 59.33% peeling efficiency and 549 kg/h capacities were achieved. The machine has a peeling efficiency of 83% and an average capacity of 950 kg/h. The cutting blades are fixed along the circumference of the rotor with a blade angle of 50. TNAU has developed a cassava peeler that consists of a cylindrical rotor fitted with a number of cutting blades. The peeling efficiency of the machine is 83% and it has an average production of 950 kg/h. The peeling machine developed consists of a partially immersed cylindrical perforated drum or a U trough with a series of paddles or a spiral brush attached to a central rotating shaft. As the roots are propelled forward the combined action of high pressure water gets and abrasion of the tubers against the wall and against each other removes most of the skin. A model power operated cassava peeler, developed at TNAU was evaluated at 5 different rotor speeds with size sorted and unsorted tubers. Peeling efficiency and capacity increases with the speed of the rotor. The optimum capacity of the peeler, the peeling efficiency and the effectiveness of peeling were 540 kg/h and 0.57 respect - ively. (Sheriff *et al.*, 1995)

Abrasive Peeler

It consists of a drum that is coated inside with coarse carborundum grit. Water is fed into the drum through the axis. Tubers are put inside the drum, peeled by rotating the drum manually. Peeling may take 2-15min.The peeling machine consists of a drum of expanded metal attached to the inside surface of a framework of small pipes. The drum is mounted eccentrically on a shaft inside surface of a framework of small pipes. The drum is mounted eccentrically on a shaft. Inside the drum, four abrasive cylinders of expanded metal are mounted and driven by a planetary gear arrangement to rotate at 4 times the rpm of the main drum. To operate, whole cassava tubers and some abrasives are loaded into the drum, that is rotated at 40rpm. Faster peeling of the tuber is achieved by the shaking motions of the drum and faster rotation of the abrasive cylinders. Peeling achieved at about 300 kg/h is so thorough that hand trimming is eliminated.

Peeling cum washing machine developed in Nigeria works in the principle of abrasion. (Nwokedi, 1984). The machine is an oval chamber that has holes cut along the walls and is lined with sharp wire gauze. Cassava roots are loaded in the chamber that is mounted on two mild sheet rods, 35cm in diameter, attached to either end. The rods allow the chamber to rotate clockwise. The left rod is connected to a 5hp electric motor by means of a V belt pulley. Thirty balls coated with wire gauze are added to the chamber. The machine is mounted at 33R. The angle permits through sharp edges of the chamber balls to carry out effective abrasive peeling. The roots are cleaned as they are being peeled the chamber passing through a water filled pan underneath it. The peeling efficiency is 80% when set for a particular specific size range. The machine's rate for unsized roots was 15 kg/h, for sized samples was as high as 500-1000 kg/25 min. This rate does not include the time spent in cutting the cassava roots into straight chunks about 80-100 mm or sorting the cut pieces.

Peeling efficiency index, measured as the ratio of peeled and unpeeled root was found to be 45% for unsized roots and for sized roots, it was 68%. Peeling capacity was 800-1000 kg in 25 minutes of operation for sized roots. In Indonesia, cassava roots are peeled manually. In Malaysia and Thailand roots are neither washed nor peeled before chipping (Mahurung, 1974). The peeler consists basically of a cylindrical knife assembly and a solid cylinder, both mounted parallel and 20 mm apart on an inclined frame (Odigboh, 1976)

Size reduction equipments: The bulkiness of cassava tubers pose a great problem in transportation these tubers from the farm to the market or factory sites. Chipping operation makes the bulky roots more manageable while the increased surface area of sliced roots allows faster drying. Moreover, the high perishability of the cassava tubers and the unfavourable market prices prevailing at the time of harvest can be overcome by primary processing of the tubers into chips, flour and starch. Size reduction can be of 3 types,

1) Slice for snack food products.
2) Chip for French fry cut.
3) Grate for starch extraction and for some traditional products.

There are various chipping machine, both hand operated and pedal operated. The output from manual chipping has been found to vary from 11 to 37 kg/h at a chip thickness of 2.7 to 12.5 mm. An improved cottage type cassava type cassava slicer is developed in Philippines (Hachero, 1957) and this can be used for sweet potatoes also. Both cylindrical and disc type power operated cassava graters along with the manual cassava graters are used in Ghana. (Lartey, 1990). The CTCRI hand operated chipping machine consists of two concentric mild steel drums with the annular space divided into compartments for feeding the tubers and the machine is supported on four legs. A rotating horizontal disc at the bottom of the drum carries the knives assembly. A pair of bevel gears is provided to operate the machine manually. The capacity of the machine is 120 kg/h for producing 6-9 mm thick chips manual chipping produces 24 kg/h for 12.5 mm thickness. Cost of the machine is Rs.6000/-

Breakage of chips will be about 2-5%. The pedal operated chipping machine is a modified version of the hand operated one with a provision of a pivoted pedal to transmit the power to the cutting disc through suitable belt and pulley drive mechanism. A trimming knife is also provided on the frame to remove the woody neck portion of the tubers before feeding into compartments Capacity varies from 83kg/h to 768 kg/h for chip thickness of 0.9 mm to 6.9 mm. The cost is Rs. 5376/- could be saved per year if the conventional hand chipping is replaced by this machine.

Motorised cassava chipper consists of 2 concentric rows of cylinders of 10 and 17 cm diameter. The chipper with motor is installed on a brick masonry foundation with a sloping chute serving as outlet for chips. The capacity is 286 kg/h for producing 2.5 mm thick chip 655 kg/h for 5.3 mm and 1091 kg/h for 9.9 thick. A motorized cassava chipper was designed, fabricated and tested. The capacity of the chipper is 270kg/h. The cost of chipping was estimated as Rs.18/t.

A pedal operated cassava chipping machine (Khurup *et al.*, 1995) consists of a feeder assembly to accommodate tubers of varying shapes and sizes, a driving mechanism to transmit the power from the pedal to the disc carrying the blade assembly and the frame. The overall dimensions of the machine are 1170 mm × 930 mm × 950 mm and weight is 72kg. The capacity of the machine ranges from 83 kg/h to 768 kg/h as the chip thickness was changed from 0.9 mm to 10 mm. The maximum capacity of 768kg/h was observed at 6.9 mm chip thickness. The rate of manual chipping ranged from 10.7kg/h to 26.7kg/h as the average thickness of chips was varied from 2.7 mm to 9.8 mm. Cost of operation of the machine is Rs.18.80/h with a profit of Rs. 5376/ annum.

The Malaysian chipping machine consists of a rotating circular steel plate of 12 mm thick and 100 cm diameter to which 4 or 6 blades are attached. The capacity of this machine is 1000 kg/h when operated by manual feeding with two men. The blade consists of 1.15 mm steel plate that is corrugated at the cutting edge. The rotor is vertically mounted on the driving shaft and driven by a 3 hp electric motor with a belt drive mechanism at a required disc speed of 500 rpm. The machine produces strips about 6mm wide and 3.6 mm thick with a small percentage of fine particles.

In Malaysia, a mechanical cassava chipper with 4.5hp gasoline driven motor that will process 2t chips/h is used for the chipping operation (Malaysian Department of Agriculture, 1974). In the thai chipping machine, cutting blades are made up of a thin circular plate, cut and formed to produce cutting elements throughout the surface. The rotating notched disc is mounted on a wooden frame equipped with a hopper. The chips or shreds produced are irregular in shape. In Thailand the chipping machine used to make chips has a recovery rate of 40% (Poonsook Atthasampunna, 1990).

The Nigerian Chipping machine consists of an assembly of 3 knives held in slots of metallic cylinder. It is mounted horizontally about which a hopper is attached. Another cylinder of small diameter placed parallel with 2.5 mm gap and they are rotated in opposite direction with lesser speed (4:1). Roots are fed through the hopper to the gap between the cylinders and chips removed from the table by the knives are flung below through the gap and guided down by the bottom part of the hopper. This machine produces chips of 3 to 7.5 cm length and the turn out is 225 kg/h. Power sources is by 1hp electric motor.

The cassava chipping machine consists of mechanisms for slicing and dicing roots, in addition to the feeding, power and drive units. Performance at motor speeds between 360 and 400 rpm was rated satisfactory with the dimensions of the sliced product (chip) near the desired value of 25 mm. The best chip geometry was obtained at a motor speed of 400rpm with a throughput of 0.27kg/s(970kg/h) (Nigerian chipping machine)

The PRCRTC pedal operated root crop chipper consists of a cutter head assembly is cylindrical in form and has two kinds of blades, one for grating and other for chipping. Chipping blade produces longitudinal strips of chips. The machine can chip about 500 kg/h operated by a single man. A pedal operated cuber sorter of capacity 181 kg/h is developed by Visca. The cuber sorter has a wooden frame, blade assembly, power transmission system and the vibrating sorter. The wooden frame houses the blade assembly at the top while the vibrating sorter is located directly below the blade assembly. Power is transmitted to the blade assembly with the use of a rotating disc and a connecting rod. The disc in turn is rotated by a chain connected to pedal power. Then the root crop slabs are fed into the cuber sorter the reciprocating blades cut the slabs into cubes and together with a set of electors, discharge the cubes to the reciprocating sorter. The cuber sorter is operated by only one person. The average cubing output is 55 times faster than the manual cubing capacity of 3.27kg/h (Felix Amestoso and Augustin Dignos, 1991).

A strip cutter was also developed with a capacity of 86 kg/h. It is similar in construction with that of the cuber, sorter, the only difference is in the thickness and length of cuts. The slicer developed to produce cassava chips of various thickness and different orientation has a capacity of 72 kg/h. The only difference from that of a strip cutter is the absence of an ejecting mechanism and the multiple cubing blades in the blade assembly. The recovery rate of the slicer is 95% of the raw material.

The grater pulverizer developed by the Visca has a capacity of 50 kg/h. The cutting surface of the grater was provided with punctures arranged in straight lines along the axis of rotation and placed one inch apart. This grater functions as a pulverizer also.

In Myanmar, the peeled roots are cleaned and then sliced into 2 cm size chips by mounted blade machines (Thun Than, 1990). In Philippines pedal operated chipper/grater with a cylindrical cutter head assembly, housing two kinds of blades, one for chipping and one for grating is developed. The unit can chip 400-500 kg/h of fresh roots/h and grate 115-120kg roots/h at normal pedaling speeds (Tabianan *et al.*, 1985).

The cassava grater developed at Philippines consists of a stand, cover, blade, funnel like attachment and handle. The grater has a capacity of 12 kg of roots/h thus being 200% more efficient than the native graters. On the other hand, upto 76 kg of roots /h could be grated by increasing the gear ratio to 4:1 and the blade diameter to 31 cm. This machine can extract as much as 20% of the starch in the roots.

Vietnamese farmers prefer to use a simple chipping knife for size reduction of tuber crops.40-60% of the cassava production is processed into dried cassava chips. In south pacific countries, chips of *Xanthosoma sagittifolium* are made. Simple hand grater (kitchen type) stationary type power grater are used in Ghana (Cervinka, 1972). The tractor drawn cassava grater is used to permit the operation to be undertaken in the fields. The grater is mounted on the tractor 3 point hitch and the drum is driven from the PTO shaft. The length of the grating drum is 30R, the diameter 10" and the revolutions are 800-1200rpm. The capacity of the hopper is 120-140lb. This amount of cassava roots is processed in 1-2min.

In Ghana a locally manufactured chipper that can chip 1 to 1.5t chips/h and a grater of 1.5 to 2t/h is developed for cassava processing. The advantages are,

1) A cassava grader driven by tractor can work on different cassava farms.
2) The capacity of the grater is high.
3) The grater is of a simple design and easy to operate.

A vast array of chipping, grating and slicing machines have been developed for root and tuber crops from manually operated chippers. (Output of 1.200 kg/h the continuous process equipment used in large starch extraction plants, capable of processing 200 t/day. Yam chips are produced in a similar way to potato chips. Processed cassava is one of the staple foods in Africa. As cassava production is rapidly increasing and needs immediate (within 48h) processing to prevent deterioration, the introduction of a cassava mash pulverizer is required. A rotary drum pulverizer for cassava mash was able to handle over 125 kg of mash per hour to produce a quality and refined powdery dough. The efficiency of the machine is 98% at a capacity of 307.3kg/h. Recommendations are made to improve the applicability of the machine to developing areas.

Energy requirement in mechanical chipping of tapioca says that the cutting energy per unit area for cassava was observed to be minimum at about 37.5 of the knife bevel angle. The studies on the effect of knife velocity indicated that the cutting energy per unit area was minimum at a velocity between 2.25 and 2.75 m/ s and optimum shear angle was reported to be 83.The manually operated machine has a capacity of 68 kg/h for unsoaked tuber and over 10 kg/h for soaked tubers. The power driven unit has a capacity of about 1000 kg/h with minimum amount of sub standard chips. Operating speed based on capacity rating and quality of chips is 250-300 rpm.

The chipping machine consists of the chipping mechanism, a feed tray and an optional collection box for the chips. The chipping mechanism, a feed tray and an optional collection box for the chips. The chipping mechanism is a plain GI sheet, G16 cut into a circular plate, 35cm diameter and pressed to form alternate 4 mm deep concentric grooves. Two rows of alternate punches 1cm apart are made on each groove along 8 equidistant radial lines. The grooved plate is fixed into a wooden or steel plate support to that the crank handle or a pulley is attached. The power driven unit is provided with a 0.37kw(0.5hp) electric motor. Chipping reduces fermenting and drying time by more than 50% (Jeon and Halos, 1991).

A variety of mechanical cassava grater, powered either by electric motors or small internal combustion engines, are used in Nigeria. This paper describes a mathematical model that simulates optimum cassava grating systems according to the processing capacity and power source of the cottage industry. A computer program written in a basic language computes the most appropriate size of grater, compares the costs of various grating systems (fixed cost, variable cost and timeliness cost) and selects the least cost grating system. The model was tested on selected cassava cottage processing industries with capacities of upto 10ha crop area in Bida, Nigeria. The cost of grating generally decreased as the crop area increased from 1 to 10ha.

A motorized cassava chipper was designed, fabricated and tested. The capacity of the chipper is 270kg/h. The chip recovery was assessed at 92% for 1mm chips at 295 rev/min. The cost of chipping was estimated as Rs.18/t (Balasubramanian *et al.,* 1993). In Zaria, a simple man powered cassava root grinder is used to make cassava chips (Lee, 1974). Two low cost cutting mechanism (a manual press and a disc cutter) were designed to produce rectangular cassava bars, the optimum geometric figure found. The disc cutter produces the bars at a rate of 240kg/h that operated by a bicycle pedal mechanism or 500kg/h when motor driven (Rao, 1974). There are two ways to grind cassava with a motorized machine (costly advanced technology) and by hand. An easily constructed intermediate method was designed made from bicycle parts plywood iron water pipe and old hacksaw blades.

Cubing of root crops was attempted by Orias, 1984 using three designs, a shearing lever, a dice puncher and a press. The shearing lever cuts roots cross sectionally before cutting them into squares, while the dice puncture and press cutter have blades arranged in grids for cutting cubes from pre cut slabs. Guards and Truong, 1986 reported another cuber using a steel shaft machine in that ten circular flanges served as slicing blades spaced at ½" intervals and flat bars serving as dicing blades arranged as spokes of a wheel rotating perpendicularly with the slicing blades. The device used precut slabs as the starting material for slicing, followed by dicing.

Slicer

Using the basic operation of the Visayas state college of agriculture(VISCA) developed strip cutter, a slicer was designed. The main difference is the absence of an ejecting mechanism and the multiple cubing blades in the blade assembly. The gravity feed for roots to be sliced was adopted because only the blade assembly was changed. The capacity of the slicer at normal pedaling speed of 60rpm is 72kg/h with a recovery of about 95% of the raw material.

Grater Pulverizer

Existing graters use metal sheets punctured all ever their surfaces to serve as the cutting surface. Due to clogging the cutting becomes less effective during sustained operation and makes the cutting surface more difficult to clean. To overcome this, the cutting surface of the grater was provided with provided with punctures arranged in straight lines along the axis of rotation and placed one inch apart . The hopper assembly together with the clearance adjuster mechanism was made to open for easier cleaning after operation. The grater could produce grater 150kg/h using a 0.5hp motor.

Drying:

Fresh tubers cannot be stored for a longer time without spoilage. To overcome this the roots need to be processed into some form of dried product with longer storage life. The most common thing is to convert the tubers into dried chips. There are many types of driers available.

Sun drying

Sliced tubers of cassava are dried in the open air under sunlight by spreading in a single layer on cemented floor, bamboo mat, rock surface or sometimes even on bare earth. The chips should be turned periodically during the drying period until the moisture content reaches 13- 15%. Drying takes about 2-5days depending upon the weather condition.

Cassava chips are spread out on wood framed trays with a base of chicken wire or fine mosquito screens. The trays are placed at an angle of 25-30 by supporting them on a bamboo frame of posts. The drying rate is enhanced by stirring the chips by means of hand pushed wooden rake. The tray size is 170x90x5cm, the loading rate is 10-16kg/m^2 and the drying time for the process was10-12h.

Hand drying method

Cassava is cut into four halves, hung on a rope and dried for 2 to days. The factors such as chip size, shape and loading rate influence the drying. By combination sun drying with either solar heated air drying or the use of mechanical dryers, dependence on the weather is reduced.

Solar drier

It consists of a solar collector(m^2) constructed on a concrete base and 20cm thick bed of fine stones, a centrifugal fan(1.5hp,0.38m^3/min air flow) and a drying bin of 2m^2 floor area. The centrifugal fan draws air through the solar collector and passes it through a 30 cm diameter duct into the plenum chamber of the drying bin. The loading rate is 125kg/m^2 and drying can be completed in 45h.

Electrical drier

It consists of a centrifugal blower with ducts, insulated heater box and drying chamber. The drying chamber is equipped with a perforated GI sheet floor. The drying temperature is 65-70 ^oC in 8-10h to 500 kg chips in 20-24 h from 65-70% mc to 12-14%. The overall cost of the system is Rs.30,000. 300kg batch size is optimum for one batch per day. CTCRI has developed an electrically operated dryer that has a holding capacity of 1m^3 and is suitable for drying upto 500 kg of fresh chips. Moisture content can be brought down from 65-74% to 12.2-13.8% within 24h of drying.

Solar cabinet drier

It consists of a rectangular cabinet preferably insulated and covered with a roof of glass. Holes are present in the base and upper part of the cabinet. Perforated drying trays are positioned within the cabinet. The insolation passes through the roof and is absorbed on the blackened interior surfaces that are then heated and warm the air within the cabinet. The warmed air rises by natural convection and passes out of the upper holes. Fresh air in the mean time enters through the base holes. The length of the cabinet should be 3 times the width to minimize the shading effect of the sides.

Biomass energy assisted drying

The system consists of a double cylinder drying bin with one tonne holding capacity, an agricultural waste fired furnace and blower and cyclone ash separator. The roof of the drying shed is designed to serve as the solar collector to tap supplemental heat. Cassava chips can be dried in 20h from 67-69% to 12-13% mc.

Visca Natural Convection dryer

The main feature of this drier is the heat exchanger that is made of a used oil drum placed directly below the drying compartment. It is directly connected to the furnace and the chips are loaded. In the drying chamber there are two 10 layer screen trays and each can load 5kg of chips. This type of drying is practiced in Philippines.

Batch driers that can be constructed simply and cheaply can be powered by locally available sources of fuel (eg. coal, diesel, plant byproducts etc) the drying temperature should not exceed the gelatinization point of the starch contained in the roots, about 50-60R°c. For cassava artificial drying results in a final product with a higher cyanide content than a naturally dried one. In Philippines, drying cassava chips in a forced air dryer at 47R°c and 60R°c for 6h showed removal of 25-30% of the bound cyanide compared to 10-15% decrease brought about by faster drying at 80R°c and 100R°c. In Uganda both solar and sun drying of cassava chips are practiced. The natural convection drier produced clean, mold free cassava chips in 2.5-3 drying days. In Uganda a drying study was conducted in a wood fired deep bed drier. This dryer dries cassava chips from 64.5% to 10.83% mc(wb) in 34h, sun drying took 150h to dry chips from 59.63% to 10.83% mc(wb).

When a comparative study of solar and open sun drying of cassava chips in Uganda was made, the studies revealed that both the wire mesh and reed mesh tray driers performed well in the drying of cassava chips in good weather and at loading rates upto 20-25kg/m^2. The performance of the natural convection drier produced clean, mold free cassava chips in 2.5- 3drying days (Wilfred Odogola, 1963). In India, the sliced chips are usually sun dried on cement floors, bamboo mats, rock surfaces etc. The recovery of dried chips is usually 38-40% of the weight of fresh roots. In India, sweet potato flour is produced by dehydration, can also be produced by spray drying and cabinet drying of the peeled sliced roots.

CTCRI had developed an electrical dryer with a holding capacity of 1m^3 that is suitable for drying upto 500 kg of fresh chips. It is possible to reduce the mc of 65-74% to 12.2-13.8% by drying for 24h. In Kenya, precooked ready to use cassava flakes were produced using a single drum drier. By this process, the mc of the raw tuber was reduced 12 fold, weight reduction was 4 fold. Final product moisture could be reduced by raising the steam pressure or increasing the retention time of the product on the drum surface. The drum dried products stored well at a moisture content of 5% or less at 25R°c. The product can be consumed after dehydration with warm water/milk and salt to taste. Dehydration of sweet potato roots is a traditional practice. The roots are cut into pieces and spread out in the sun to dry.

In Indonesia, fresh roots are soaked in 8 to 10% of salt solution for about 1hour before cutting into slices and sun dried. In Indonesia a prototype drier suitable for village cooperatives was designed. It consisted of a cabin 5m long, 2.4m wide and 2.4m high with movable trays, a vapour compression system, a heat pump, ducts and an instrumentation and control system. High quality dried cassava chips can be obtained with the drying period reduced to 40h depending on the size of the chip. In China, many thousands of tonnes of sweet potato are dried every year in the form of chips by traditional sun drying. In Taiwan, pressing of sweet potato chips to extract a high percentage of juice before drying to save fuel is recommended. A solar drier for potatoes that could be adapted for use with sweet potato has been developed at Inter - national Potato Centre, Lima, Peru. Cooked, shredded potatoes are placed on a shaded screen oriented towards the wind and the moisture is reduced by about 45% in 18hours. Reorientation to direct sunlight, indirectly with solar heated air or in a combined direct and indirect mode. In Kualampur dehydration of tapioca is done by mechanical and artificial heat dryers (Toh., 1973).

In Germany manioc was dried under natural conditions and solar drying was considered the best manioc is dried in the drier with air flowing through and across the layer, taking with the requirements of drying under practical conditions, particularly solar drying. Optimum drying air and manioc parameters were determined (Germany). In the Atlantic coast of Columbia a through circulation solar heated air drier is used for drying cassava chips. This includes a bottom ventilated drying bin, centrifugal fan and solar collector (Rupert Best *et al.,* 1984).

In Columbia solar drying units have been set up for drying cassava. Drying cassava chips were so faster with wire baskets, placed at 30 cm from the ground, facilitating air circulation. Drying so even faster if the foil is painted black, the basket so placed in a vertical position and RH is lower that 75%. The experiments proved that the best drying rate was attained with rect - angular pieces 5 cm long and $1cm^2$ across. A through circulation solar heated air dryer developed at CIAT, Colombia consists of a solar collector with an area of $10m^2$ set up on a concrete base and 20 cm thick bed of fine stones, a centrifugal fan of 0-38 m^3/min air flow and a drying bin of 2 m^2 floor area. The centrifugal fan draws air through the solar collector and passes it through a 30cm diameter duct into the plenum chamber of the drying bin. The system can dry 125kg/m^2 in 45h. The solar collector gives an average increase of only 1 to 3R°c in air temperature corres - ponding to reduction of 4.4 to 9.6% in RH. In Columbia drying units have been set up f or drying cassava. A passive crop drier (pit drier) for maize and cassava was developed that uses a drum furnace as a heat exchanger that is placed in a pit under the drying bed. A study was conducted to improve the passive crop drier (Purwadaria, 1993).

In Columbia solar drying units have been set up for drying cassava. Drying cassava chips were so faster with wire baskets, placed at 30cm from the ground, facilitating air circulation. Drying so even faster if the face is painted black, the basket so placed in a vertical position and RH is lower that 75%. The experiments proved that the best drying rate was attained with rectangular places 5cm long and $1cm^2$ across. A through circulation solar heated air dryer developed at CIAT, Columbia consists of a solar collector with an area of $10m^2$ set up on a concrete base and 20cm thick bed of fine stones, a centrifugal fan of 0-38 m^3/min airflow and a drying bin of 2 m^2 floor area. The centrifugal fan draws air through the solar collector and passes it through a 30cm diameter duct into the plenum chamber of the drying bin. The system can dry 125 kg/m^2 in 45h. The solar collector gives an average increase of only 1 to 30 in air temperature corresponding to reduction of 4.40 to 9.80% in RH. In Columbia drying units have been set up for drying cassava.

In Malayman, the drying characteristics of cassava chips using the autolytic method of cyanide analysis observed decreased cyanide ranging from 49 to 93% for 31 cultivars, by drying whole at 70-80R°c for 48h. In Malayman, the drying characteristics of cassava chips were studied using artificial heat. Variables studied were air temperatures (55, 66 and 77R°C) air velocity (31, 61 & 8m/min) and bed depth (5, 8 and 10 cm) under most conditions, the drying process was found to be diffusional in nature, phase II being slower that phase I. Towards the end of drying internal resistance to water movement rather than external factors controlled the rate.

In order to improve the quality of sweet potato flakes, Chang and Chan, 1987 used response surface methodology to find out the optimal preheating condition of sweet potato strips. If sweet potato strips were preheated at 78 °C for about 35 min before steaming at 100 °C for 20 min bulk density of the flakes was increased and dispersability of rehydrated sweet potato pastes was improved. Cassava chips are generally of higher quality that pellets, and both the size and shape of the chips are very practical with regard to the time required for sun drying. Thin slices (2 mm) spread over black painted floors can be dried on sunny days within 8h or less, roughly chipped cassava takes several days to dry with detrimental results on quality and economic considerations.

In USA, a vertical type of natural drier consisting of parallel wire panels was the most efficient. The vertical position of the layer and adequate product geometry permits the air to move through the product creating turbulence. Horizontal elevated mesh trays ate loss efficient than the vertical drier but more so than conventional system of drying cassava on concrete floors. In USA, solar dehydration of sweet potato chips are done that takes in 12 to 15 h. Osmosal process of dehydration gives good quality sweet potato slices. To produce dehydrated flakes, thicker slices (13 mm) are blanched in steam for about 30 min and then pureed.

A sun drier for cassava (and other) chips exists at the vaini (one of the south pacific country) research station but it is little used. In W. Africa, a variety of late yam with small tubers and white flesh. *Dioscorea cayenensis rotundata* are used for the manufacture of dried chips intended for the preparation of a special paste. Yam flour is most popular in W. Africa. Tubers are peeled, sliced into pieces and dried in the sun for several days and then pulverized by pounding in a mortar and then sieved and thus yam flour will be made. Yam chips are produced in a similar way to potato chips. Peeled tubers are sliced and kept in the sun for several days to make chips. In Benin, the yams are peeled and immersed whole in the water then brought gradually upto a measured maximum temperature measured in heart of the chips is 59 °C. Pre blanching is done before drying. The chips are dried under the sun for 6-8days. In a process developed at CFTRI Mysore corms are peeled, cut into thick slices, washed, soaked overnight in Water and then washed again immersed in 0.25% potassium bisulphate solution for 3h.

The slices are then blanched in hot water, sun dried and tunnel dried at 57 to 60 °C ground sieved and then packed (Ghosh *et al.*, 1988). For edible aroids' the process developed at CFTRI, Mysore corms are peeled, cut into thick slices, washed, soaked overnight in water and then washed again immersed in 0.25% potassium bisulphate solution for 3 h. The slices are then blanched in hot water sun dried and tunnel dried at 57 to 60 °C ground, sieved and then packed. Tapioca chips dipped in sodium hypo chloride (0.5%) for 3 minutes then washed with fresh water and dried up at 70 °C may have 90-100days shelf life. In Nigeria, 1996 drying is done on open trays on platforms, tray placed under shade, unprotected concrete slabs by the road throughout the day of solar dryers. Under natural conditions drying of cassava chips in solar dryers is the most promising method.

A new Philippines designed root crop dryer is described, root drying heat is supplied by combustion of Waste derived fuel. From 50 to 60kg coconut husk is burned over 7-8h to dry a 100kg batch of fresh root chips. Alternate rotation of trays promotes uniform drying. Cassava chips were dried in a wood fired deep bed crop dryer with a maximum capacity for one tonne of fresh cassava chips. The deep bed dryer dries cassava chips from 64.57% to 10.83% mc(wb) (Augustine Dzisi and Joseph wirth, 1970). An air dehumidifying system comprising a heat pump and a solid moisture absorbed was designed and experiments to determine the drying rate of various crops using this system were carried out. It was found that the RH of ventilated air could be reduced from 85% to 15%. Coefficient of drying rate were established for crops including radishes, sweet potatoes and mushrooms and the moisture content of buck wheat was reduced from 21.9% to 9.9% in the first 30min. (Taharazako Morito Wei, 1990).

The effect of air dry bulb temperature air RH, air velocity and sample thickness on the thin layer air drying of sweet potato slices was investigated. The drying rate curves consisted of 2 approximately linear falling rate periods and contained no constant rate period. Several mathematical models were fitted to the drying rates of sweet potato slices under a range of drying conditions. It was found that the modified page equation best described the thin layer air drying of sweet potato slices down to a moisture content of 10%db (Diamante *et al.*, 1991).

Various shapes and sizes of roots are cut manually and dried on different media. Chip drying time could be greatly shortened by using a black drying floor or perforated shelf drier. Drying time is greatly influenced by chip shape and size slices and strips produced by the Malaysian cutting machine were optimum for drying efficiency. Small chips in the form of slices and strips with a moisture content of 12-14% were found best for pelleting process.

A study on the application of a heat pump as a heat source for drying cassava chips was carried out and a prototype drier suitable for village cooperative was designed. It consists of a cabin 5 m long, 2.4 m wide and 2.4 m high movable trays a vapour compression system heat pump ducting instrumentation and a control system. High quality dried cassava chips were obtained with a drying period reduced to 40h depending on the size of the chip (Suwona, 1991).

The raw materials for gruel making were made from sweet potato flour traditionally in chambers and using solar energy (Guatamala) All the cassava samples under observation were considered dry then the moisture content was below 15% as recommended by CIAT, 1991 & the total cyanogens content had been reduced by atleast 80%. Drying cassava chips in a forced air dryer at 47 °C and 60 °C showed removal of 25-30% of the bound cyanide compared to 10-15% decrease brought about by faster drying at 80 °C and 100 °C (Cooke, 1983 and Maduawa and Adewale, 1980) using the autolytic method of cyanide analysis observed decreased cyanide ranging from 49 to 95% for 31 cultivars by drying whole at 70-80 °C for 48h. Cooke, 1983 noted that losses during dehydration determined by the enzymatic method were smaller than those analysed by the autolytic or distillation methods CTCRI dryer capacity 500 kg of chips within 18h.

In Thailand it was found that black concrete surfaces were more efficient than ordinary concrete, but more uniformly dried and better looking chips were obtained then using trays with bamboo netting or chicken wire. Artificial drying (thermetically controlled hot plate) is more reliable than sun drying but requires a higher initial investment. Drying time was influenced by chip shape and six regression equations for calculating length of time for different drying techniques are available from the authors (Than and Lohani, 1978).

In experiment at the Asian Institute of Technology (Thailand) cassava chips of various shapes and sizes (circular, rectangular, cubical and slices and Malaysian cutters were sun dried to –14% mc on cement floors black concrete floors or air dried in perforated (Mar-July) and wet season (Sep-Oct) although drying it was considered impracticable at present because of high cost. Drying time was greatly reduced in the other types the black concrete floor and perforated shelf driers, the later giving uniform drying at low costs while eliminating the need for frequent turning or chips but was impracticable on a large scale. Hence black concrete floor was suggested as a compromise between drying efficiency and practiced feasibility. Drying efficiency was best with slices or strips and smaller thinner slices or strips are recommended to improve the efficiency of sun drying. There was no difference in drying efficiency between seasons heat transfer by convection in wet season appeared to compensate for the heat transfer by the conduction in the hot season (Thanh Muttamara, Lohani, 1978)

Cassava tubers (sliced) are usually dried in the open air under sunlight by spreading in a single layer on cement floors, bamboo mats, rock surfaces or sometimes on bare earth. Chips dry better on rocks because they dry white in colour and take less time. Depending upon the weather conditions, it takes 2-5 days to dry the cassava chips. Contamination by air borne dust, dirt and debris cannot be entirely avoided during sun drying, especially on windy days. Sun drying is carried out by many methods, exclusively on cement drying floors in Malaysia and Thailand. The overall heat efficiency during sun drying of cassava chips was estimated to be 11- 14% Main cost of sun drying was labour costs.

The possibility of using artificial heat drying, a combination of artificial and sun drying and a mechanical dewatering and artificial heat drying is practiced. The results of the implements conducted in Thailand indicate that the most adequate chips are those in the form of strips and slices (0.52, 0.1-0.2cm thick respectively and that the total drying period required to obtain an optimal mc(approx. 14%) is 4.5,10,12 & 14h for the artificial method, black concrete, tray drier and plain concrete respectively. It was found that the drying systems did not affect the pellet quality. In Thailand, sand and waste products are added to the chips to minimize the drying time and to make the process economically viable. The drying period for chips is very short and the moisture content is rarely reduced below 19%. The influence of the size of the cassava chips on the duration is also an important variable. The use of black body or solar reflecting paint offers the possibility is drying in a shorter time.

A study was made of the parameters affecting the drying and pelletizing of cassava chips in order to obtain a product with constant optimal quality under condition typical of rural areas in Thailand and similar agro economic regions of south east asia. Various shapes and sizes of roots were cut manually and dried on different media. It was found that chip drying time could be greatly shortened by using a black drying floor or perforated shelf drier. Drying time is greatly influenced by chip shape and size slices.

Chips produced by the Malaysian cutting machine were optimum for drying efficiency noticeable differences were found in drying efficiency due to season (Mahmud Cong. Thanh. 1977).

Equipments in starch extraction

The input of raw materials to starch factories can be from 24 to 1500 tons per day in the smaller countries and Europe to nearly double the figure in the USA. Milling can be done to extract the starch from the tuber mills are of the hammer type rotating between 1000 and 1500 rpm. They may be equipped with upto 6 sets of hammers arranged radially on a rotor, with a semi circular perforated plate as an anvil. Generally two mills are placed in series to obtain a high starch yield, the mill having an anvil plate of larger perforation than the second. Perforations can vary between 5 and 5 mm in diameter. This is overpowered for the duty, robust in construction and is inclined to fragment the starch granules.

Generally raspers are used for extracting starch from the tubers. Rasping is an operation that is done to disrupt the cellular structure of the plant material to release the starch from its fibrous matrix. The conventional rasper consists of a wooden drum with steel shaft and cast iron ends. The metal sheet having protrusions facing outside is fixed around the drum. This drum rotates inside a housing and the rasped material passes through the metallic sheet of specified thickness of holes to the sump below. There are two types of rasping namely primary rasping and secondary rasping.

The raspers are in some ways similar to hammer mills the vital difference being that the hammers are replaced with a multitude of fine saw blades. These are set in a rotor revolving at about 1000 rpm. The action of the blades in freeing the starch is more efficient than that of the hammer mills fibre strands remain larger and are more easily sieved out. Starch granules are also less liable to impact damage.In larger factories, it is usual to mince roots to a standard size before milling. This reduces the peak horse power demands at the mill or rasp due to large roots.

CTCRI had developed a rasper that has a hopper, a mild steel rotating drum with saw toothed blades, a motor of 2hp and a chute for collecting the rasped material. The dimensions of the rasping drum is 250 mm diameter and 300 m length. Thirty numbers of blades with 25 teeth each are fixed along the circumference of the drum to crush the tubers in presence of water. The overall dimensions of the machine are length water supply. The average output of the prototype is 218.3 kg per hour. The average of water required for rasping is 338.4l/h with a tuber to water ratio of 1:1.55.

Use of hydrocyclones and centrifuges for the starch industry for extraction or had become common. TNAU had designed and fabricated a centrifugal separator that is driven by a 3hp motor. This has a capacity of extracting about 20 kg of starch per hour. An inexpensive portable cassava root rasper, driven by a 0.25hp electric motor to handle 100-110 kg roots per hour for small scale industry is used in Philippines. In Malaysia the starch extraction is mainly by two systems one using sedimentation and the other uses centrifugal separation. In peninsular Malaysia the bulk of the starch is produced by traditional sedimentation techniques but recently centrifugal separator is and refiners are adopted. The starch recovery rate averages around 17% with a range of 13-22% than sedimentation techniques are used and 20-30% with partial centrifugal methods. The residue or refuse produced during screening accounts for about 20% of the fresh weight (Chan *et al.,* 1983) sweet potato starch extraction in Korea is by the tank precipitation method and dry the starch water with natural solar heat. Only a few factories have modern facilities with centrifugal machines and instant driers rotary system with water injection and then separating the extracted starch from the fibre and other root components. Separation may be through centrifugal action, sedimentation in tanks or in a system of channels. Small sized cassava chips can be successfully milled in a normal wheat flour roller mill with very high conversion rates (90% or more) Small scale hammer mills generally give lower conversion rates.

Larger water powered raspers can be used where running water is available. The water wheel is rotated by a flywheel and driving belts to a pulley on the shaft of the rasping drum. The drum 20-30 cm in diameter, is either attached to a primitive wooden construction or fitted into a rasping table. The operator, seated at the table, presses the roots against the drum and the shelf before it drops into the trough.

Engine driven raspers are used then the production rises to 10 tonnes of fresh roots a day. The machine has a rotor of 50 cm in diameter with the number of groves milled longitudinally to fit the rasping blades. The number of saw teeth on the blades varies from 10 to 12 per cm according to the need. The blades are spaced 6-7mm apart on the rotor. The rotor is fitted into a housing in such a way that the rasping surface forms part of the back wall of the receptacle for the roots. The power required to drive rasper of this kind is 20-30hp.

In the secondary rasper the identification of the saw blades should be somewhat finer about 10 per cm (25 to 27 teeth per inch) as compared with about 8-10 per cm (19 to 26 teeth per inch) for the primary rasper. The overall rasping effect is raised for over 90% by the secondary rasper. In a rasper used in larger factories the housing is equipped with adjustable breasts with sharp steel edges for the control of rasping fineness. A machine for peeling and crushing cassava roots that weighs 1200 kg is used. Average input is 800 kg/h of fresh roots, average output is 550-600 kg/h. The machine requires 4 people for operation. It can process roots of 10-40 cm length and 5-12 cm thickness. The roots are trimmed off at the ends and then introduced vertically between a toothed disks that split them off in 4 long pieces. These pieces are put by hand into the next part of the machine there they are squeezed between 2 revolving rollers to strip the skin from the pulp. The upper roller presses the pulp against the lower roller, that is a straight sided Cylindrical grid. (Herblot, 1978)

About 14-20% starch is extracted on a small scale from cassava roots in the Philippines. Rudimentary equipment for this process is described including a motor driven peeler a thin root pulverizer (grater) a copper screen wood on concrete settling tanks and aluminium sheet driers. A flash drier is preferable since the starch is pulverized at the same time. (Kuizon, 1958).

Rapid removal of the fruit water and is soluble and replacing this with pure water should be done to prevent the deterioration of the pulp. This stage includes sedimentation washing of the starch in tanks or on settling tables sitting and in some of the medium and larger factories centrifuging. The removal of water is done by draining, centrifuging and drying.

There are methods available to separate starch granules from the slurry after the screening step that include, Conventional sedimentation 1) Use of starch tables 2) Use of centrifuge and 3) Use of hydrocyclones

Application of centrifuges for the rapid separation of starch was reported and thoroughly reviewed the various dewatering techniques of cassava starch milk and explained about the various centrifuges used in the modern extraction Hydrocyclones have been recently suggested as a practical alternative in solid liquid separations involving biological materials and suspensions and it can compete well with centrifugation and filtration. The cost of the hydro - cyclone developed was Rs. 5775/- and the operational cost of the hydrocyclone to concentrate $1m^3$ of starch milk was found to be Rs. 1.50/-Sedimentation method is the most common method used for starch granule separation process. Rapid separation of starch can be achieved through the use of centrifuges. The advantages of using starch tables are shorter time of contact with fruit water and purer quality of starch. Use of hydrocyclone is the recent development and it is inexpensive.

There are machines for fibre washing also. In principle and appearance the machine resembles a centrifugal pump but the impeller blades are hollow. The liquor contact faces the inside curves of the impeller blades are surfaced with perforated plate, thus due to the rapid changes of direction of the slurry as it slides across the plates, centrifugal forces are generated that force starch slurry to pass through the plates and coarse fibre to proceed to the blade tips. The latter is collected in a chamber surrounding the impeller and is discharged through a flange at the base, the former escapes from the sides of the blades and is kept separate passing out via another flange. The above machine is used in the potato starch industry.

The machines used to dewater product is the screw press. There are two types,taper press and the parallel press. Reductions in moisture content of 20% are common by taper press. Nozzle type separators are employed in the refining stages of plants producing all commercial starches. A simple nozzle machine may be used for starch concentration. Dilute starch slurries may be concentrated upto rates of 70 m^3 per hour unit to obtain concentrations upto 270 g/l of starch and losses in the effluent of as little as 1-2 g/l.

The nozzle machines can be fitted with water washing facilities also. This machines forms the basis of starch refining plants and they are normally installed in series of three or four with the wash water arranged to flow in counter current to the starch. Typical flows through machines are upto $55m^3/h$ of starch slurry containing 60% starch with wash water rates upto 15 m^3/h. Peeler centrifuges operate on a horizontal axis. The machine consists of rotating drum mounted on a horizontal axis. Machines with rotor diameters upto 1500 and 1600mm normally have the bearing mounted on one side of the rotor. Larger machines with rotors upto 2500mm have bearings mounted on either side of the drum to give greater mechanical rigidity. Local conditions, local preferences, local raw materials and the available capital, influence the design and operation of the plant.

Conical screen centrifuge consists of a rotating cone fitted with a fine perforated plate screen and mounted on a horizontal axis. The feed of material is to the back of the cone where it is picked up on acceleration vanes and spread over the conical screen. By the action of centrifugal force the retained solids slide over the screen and fall away over the outer edge. The liquid and fine solids are drained away through the screens. Wash water may be introduced on to the solids on the screen by means of spray nozzles. A typical rotor diameter would be 500- 600 mm and speed of rotation 1450 rpm.

Starch extraction from disintegrated manioc can be made by fitting slotted plates to the centrifuge having a width of 125-250 micron. Capacities range from 2t/h of manioc or 3t/h of potato on two machines to 8t/h of manioc or 12t/h of potato on five machines. In both cases the extracted pulp leaving the extractor would have a moisture content of 85-90% with a negligible starch content. Fine fibres that pass forward with the starch in the first extraction process can be removed by using rotating screens with a fine perforated plate fitted with an aperture size of 80- 115 micron.

CONCLUSION

Effective post harvest management practices, should be adopted to reduce the post harvest losses. By this atleast 50% of the post harvest losses can be prevented using appropriate post harvest technology equipment and practices. This will help in getting additional income and employment. Use of time saving energy efficient implements at post harvest level will increase the availability of tubers year round. The measures implements to be used should be made possible at the farm site itself to prevent the losses in handling and storage. Portable equipment's have to be developed. The equipment's that are to be developed should be globally competitive and serve small scale starch processing sectors of the country.

Tuber crops are the most efficient converters of solar energy. Cassava produces 250x10^3 kcal/h and sweet potato 240 x10^3kcal/ha as compared to 170 x10^3kcal/h for 310 x10^3kcal/ha for wheat and 200 x10^3kcal/h for maize. hence if proper measures are taken to prevent the wastage and improve the quality of the product, tuber crops can surely meet the demands of the ever growing population.

Since value addition is given more importance nowadays the quality of the commodity produced is important that leads to the production of highly nutritious diversified products. Hence proper care and attention has to be given right from the production of tuber crops to consumption. Further mechanization can be brought to implement the use of cassava in the diversified food industry. The consumption pattern of tuber crops should be taken into account so that small equipment's for pappad and wafer making can also be developed. Cassava should be procured within relatively short distances from the processing plant to allow processing within 24h after harvesting and also to avoid excessive transport cost. If the tubers are left unprocessed for any length of time enzyme action occurs in the cassava root and reduces the quality and yield of the starch.

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