# NEW CASSAVA PRODUCTS OF FUTURE POTENTIAL IN INDIA

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**ABSTRACT**

The Green Revolution and increasing living standards of the people of India, especially in Kerala, have resulted in a gradual shift in the cassava utilization pattern. Despite the fact that India has the world's highest cassava yield, the crop's importance for food security is giving way to its role as an industrial raw material. A well-organized grain distribution system and shifts to more remunerative plantation and horticultural crops also reduced the importance of cassava as a subsistence food crop in traditional farming systems in Kerala. In order to overcome this and retain cassava in the cropping system, concentrated efforts are being made to promote value-addition and find alternative uses.

In the 1940s, cassava became an important raw material for the starch and sago industries established in Salem and Dharmapuri districts of Tamil Nadu. The cassava-based starch industry recorded a high rate of growth over the past five decades and has currently a turnover of 3000 million Indian rupees worth of starch and sago. The produce is marketed through a well-organized cooperative society, which is presently the largest agro-processing cooperative venture in South and East Asia. The sustainability of industrial growth of cassava depends to a large extent on diversification and value-addition, for increasing internal demand as well as export markets.

Three and a half decades of research on cassava utilization at CTCRI has led to the development of several technologies for value addition and *in situ* utilization. The potential markets for products, such as pregelatinized instant and convenience foods, extruded and fermented food products, feed products using by-product utilization for poultry, and value-addition through microbial enrichment, modified starch products like adhesives, sweeteners, cold water-soluble starch, commodity chemicals like citric acid, ethanol, biodegradable polymers incorporating cassava starch, biogas from starch factory wastes, etc. are discussed in this paper.

The future priorities and utilization strategies for cassava, comprising diversified products, setting up of rural agro-enterprises through the involvement of NGOs, by-product utilization as fish or poultry feed, biofertilizers from cassava starch factory waste and large commercial ventures like biodegradable plastics and alcohol are enumerated. The need for an effective technology transfer system to inform industrialists of the benefits of adopting root and tuber crop technologies is also highlighted.

## INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is believed to have been cultivated in India for more than a century. The ability of cassava to supply adequate calories at a lower cost encouraged its maximum use among low-income social groups. While the cultivation of cassava spread widely in Kerala as a food crop, it slowly became an industrial crop in the neighboring state of Tamil Nadu. Cassava cultivation in Kerala and the northeastern states has proved that rural food security can be met by local measures, which will help not only farm output but also promote rural employment. The production of a food surplus in response to guaranteed markets will provide additional income for producers, besides ensuring a continuous food supply in rural areas. This additional produce can also be

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processed into various food products to suit the taste and needs of the people in urban and rural areas. Demand for cassava for human consumption depends on income, relative prices and taste preferences. Some cross-section surveys have indicated a negative relationship between cassava consumption and income. In the low-income groups there is an increase in consumption of cassava with an increase in income, while in the middle and upper classes increases in income reduce the consumption of cassava.

Cassava was originally a food security crop to supplement the rice diet during periods of food scarcity, but gradually it has become a subsidiary food even in normal years. During periods of food scarcity cassava played a vital role in averting famine in Kerala. However, the success of the green revolution and increases in the living standards have changed the food consumption pattern of the people of India. This has led to a lower preference for cassava as a staple food. The low income generated from cassava when compared to high-value horticultural crops is another reason for the recently experienced shift in cropping system, placing cassava at the bottom of the cropping agenda in the cassava-growing state of Kerala. By contrast, cassava has emerged as a cash crop in Tamil Nadu, Andhra Pradesh and Maharashtra where it caters to the needs of the massive starch and sago industries in those states.

Approximately 300,000 tonnes of sago and starch are manufactured from cassava roots by nearly 1,100 factories in Tamil Nadu and 42 factories in Andhra Pradesh. Sago is consumed as a breakfast food, or is used for the preparation of wafers. It is also an ingredient in *payasam* (a sweet semi-solid food preparation served during feasts). West Bengal, Maharashtra, Gujarat, Rajasthan and Madhya Pradesh are the largest consumers of sago in India. In neighboring countries such as Nepal, Bangladesh and Sri Lanka, sago is also consumed in various preparations. A limited quantity of sago is exported to Middle-eastern countries where there are Indians who have migrated there to work. The cassava-based sago industry has experienced a phenomenal increase during the last few decades.

During the past 40 years, India achieved a remarkable increase in cassava yields due to the introduction of high-yielding varieties and improved management practices. Further increases in cassava production, consumption and income-generation are only possible by expanding the utilization avenues for various cassava-based diversified products. The Central Tuber Crops Research Institute (CTCRI) over the years has built up into a strong centre for crop utilization with a multidisciplinary approach to tackle the multifaceted problems in cassava utilization. Hence, research programs are oriented towards developing technologies for utilization at the home, farm and industrial fronts (Balagopalan, 1988; Balagopalan *et al*., 1988; 1990; Padmaja *et al*., 1990; Balagopalan and Ray, 1992). Besides CTCRI, several state agricultural universities and developmental agencies have also developed technologies for cassava utilization in India.

## HOME FRONT TECHNOLOGIES

### Food Products

***1. Pre-gelatinized cassava starch (yuca rava and yuca porridge)***

*Rava* is a wheat-based convenience food used for the preparation of various breakfast recipes like *uppuma* and *kesari*. Conventionally, wheat semolina is used for this purpose. The properties of wheat *rava* is based on its gluten-gliadin content which makes it swell to a small extent without breakdown. Attempts were therefore made to develop a simple economic process for the production of cassava-based *rava* as a substitute for wheat *rava*. The conditions for controlled gelatinization and swelling of starch for the preparation of *rava* were worked out. The process developed suits the cottage and small-scale industry programs. The process of making cassava *rava* has been transferred to village-level workers to promote rural employment and technology development.

The process for producing cassava *rava* consists of the following steps:

1. Partial gelatinization of cassava
2. Drying, and
3. Powdering.

By partial gelatinization, the granules swell to a small extent and give a granular form to the product. Care must be taken to avoid too much steaming or treatment in hot water as this can lead to too much swelling, resulting in a cohesive texture on powdering. It has been found that a steam treatment of less than 5 min at 5 psi of steam, or immersion in boiling water for less than 10 min is ideal for gelatinization The moisture content at this stage increases by 10-15% over the original moisture content in the cassava roots.

After draining the water, the chips are spread out on mats in the sun or placed in a mechanical dryer (drying temperature of 70°C). The moisture content is brought down to around 15%. At this stage, the chips are hard. The dried chips are then powdered in a hammer mill, taking care that the powder is not too fine nor too coarse. The maximum fraction should have a granule size between 0.5 and 3 mm, and should pass through sieves of 20-80 mesh. Sieving is carried out on the powdered product. The fraction passing through 80 mesh is too fine, but possesses a cohesive texture useful in the preparation of sweets, puddings, etc., i.e. products which require fast miscibility of starch in milk/water, etc. The fraction which is retained by a 20 mesh sieve may be re-powdered and sieved. The fraction which does not pass through 80 mesh but passes through 20 mesh has a granule size range of 0.5 to 3 mm, and is most suitable as a wheat semolina substitute. It can be used for the preparation of products such as *uppuma* and *kesari*. The process is shown in **Figure 1** and the properties of two cassava rava products are shown in **Table 1** in comparison with those of wheat semolina.

The fine grade pre-gelatinized cassava starch (*yuca* porridge) can be utilized to make an instant energy drink using hot milk or hot water. Two teaspoonfuls of porridge can be added to hot milk or water after adding sugar to taste, and served to infants and invalids as an energy drink. Addition of cardamom powder to *yuca* porridge will add flavor to the product.

***2. Papads***

Cassava *papad* is an important snack food item prepared from cassava flour. The preparation involves gelatinization of the flour with a minimum quantity of water, spreading out the paste on a mat or some similar surface to dry in the sun. After drying it is stored in polythene bags. The *papad* is consumed by deep-frying in oil, especially coconut oil. The final product undergoes 2-3 times expansion on frying. It is crisp and can be consumed as a side dish. The preparation of papad is shown in **Figure 2**.

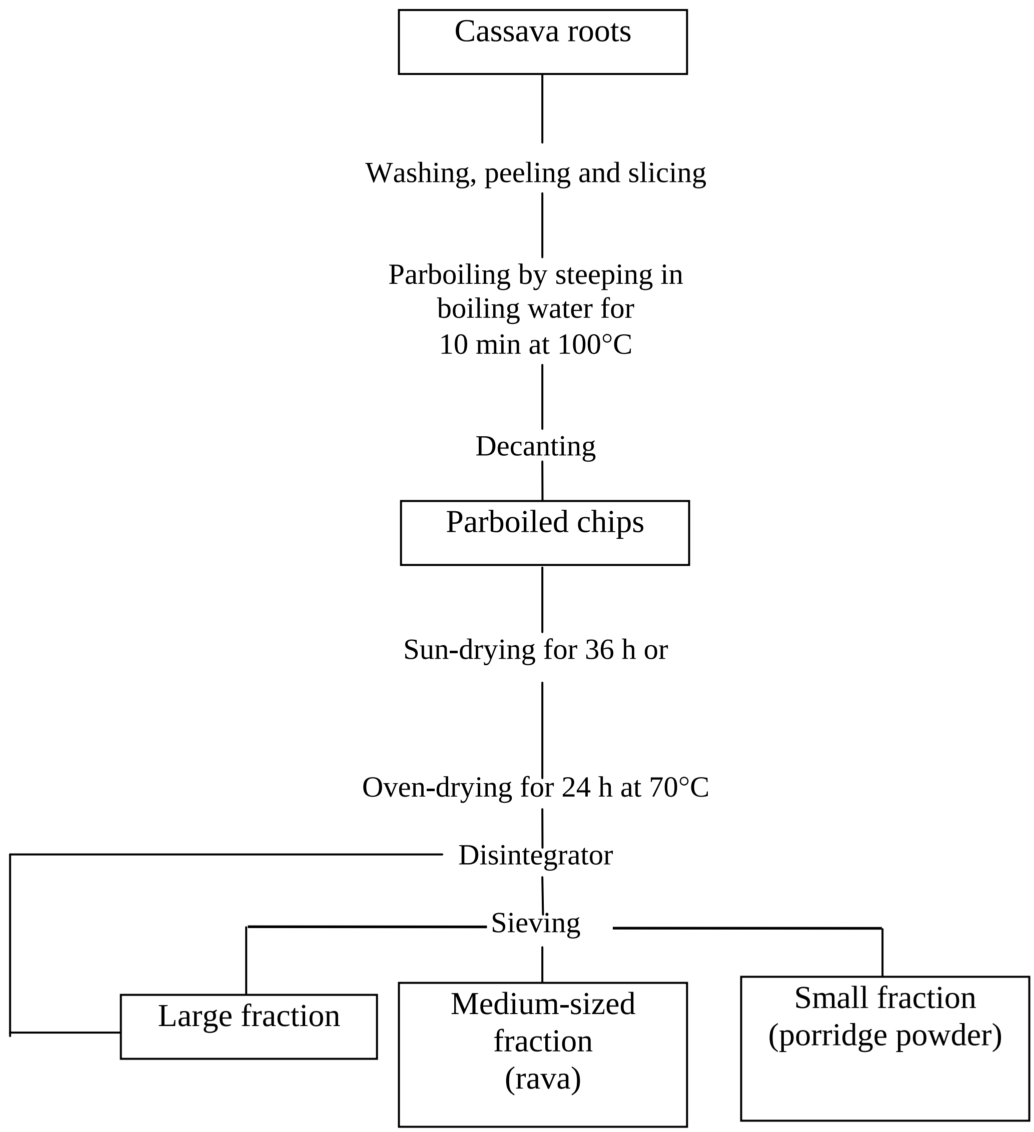


*Figure 1. Flow chart for the preparation of yuca rava and porridge.*

**Table 1. Properties of cassava rava in comparison with wheat semolina.**

| | Wheat semolina | Medium-sized cassava rava | Small size cassava rava |
|---|---|---|---|
| 1. Granule size | 0.1- 0.5 mm | 0.5 to 3 mm | 0.5 to 1.5 mm |
| 2. Reducing value (ferricyanide) | 2.8-3.5 | Nil | 1.5-2.5 |
| 3. Congo red staining | Fast | Slow | Fast |
| 4. Swelling in water | 2 times original volume | Negligible increase | 1½ times original volume |
| 5. Stickiness | High | Low | Low |
| 6. Taste and flavor | Acceptable | Acceptable | Acceptable |
| 7. HCN content | na | 55 ppm | 55 ppm |

na: not available

***Source:*** *Balagopalan and Anantharaman, 1995.*

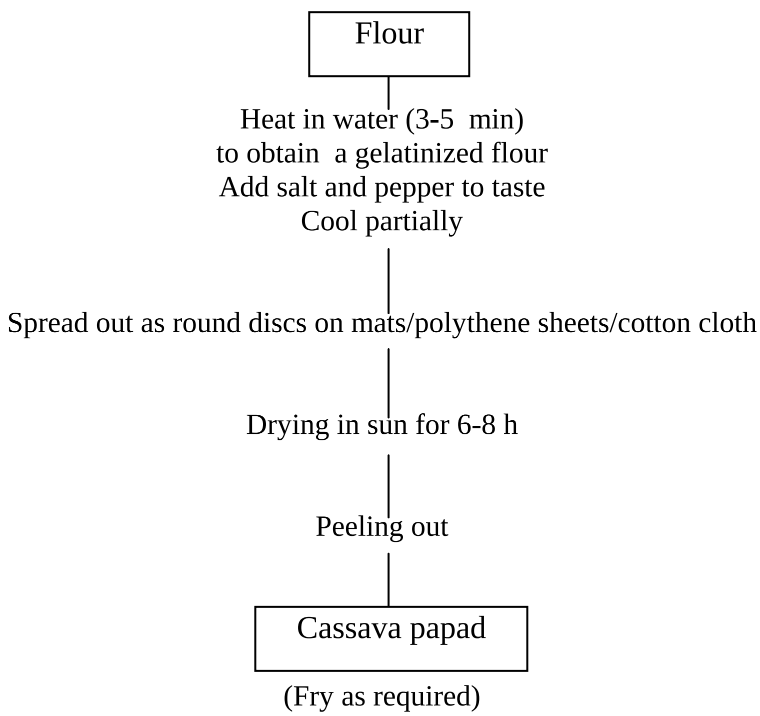


*Figure 2. Flow chart for making papads.*

The *papads* lose their crispness if stored in the presence of moisture; hence, the fried product has to be stored in air-tight containers.

***3. Sago wafers***

Sago wafer is an important product made at a cottage level in many parts of Tamil Nadu. The wafers are deep-fried in oil and consumed as a side-dish. Preparation involves spreading sago pearls in round aluminium trays. The trays are then introduced into steam boilers and steamed for 20 min. Gelatinization takes place, making the pearls adhere together and giving them a round shape. The trays are then sun-dried and resulting wafers are peeled off. Natural food colors and salt are added.

***4. Wafers***

Wafers made from cassava starch are similar to sago wafers. In this case a starch cake containing approximately 40% moisture is used instead of sago. Wafers can be made into different shapes and sizes, such as round, square, floral patterns, etc. The product on frying expands three to fourfold.

***5. Fried chips***

Fried chips are made by deep frying thin french fries made from cassava. The roots are washed thoroughly and the peel and rind removed. The roots are then sliced as thinly as possible. The quality of the chips depends very much on the thickness of the slices and the age of the crop. Chips made from the roots of varieties having high sugar content turn brown on frying. Similarly, roots from varieties harvested early or late do not give chips of good quality. Chips from varieties having high dry matter content also become very hard. Hence, for the production of good quality chips, roots of correct maturity with relatively lower dry matter should be used. In addition, the roots may be subjected to some blanching. The slices may be dipped in sodium chloride or sodium bisulfite solution for 5-10 min, and then removed. They are then washed with water and surface-dried on filter paper or cloth. The chips are fried in oil (preferably coconut oil which has been heated to nearly boiling temperature and to which a salt solution has been added). Usually, the frying takes 5-10 min. The fried chips are removed from the oil and drained before packing them in polythene bags. The bags are sealed tightly to prevent the entry of moisture and air.

Compared to potato chips, cassava chips have a harder texture, but a major advantage is that the chips do not become leathery like potato chips within a few minutes of exposure but maintain their crispness. There is vast potential for cassava chips, in view of the increased preference by consumers for convenience foods and ready-to-eat items. The shelf life of chips may be further increased by vacuum-sealing or using an inert gas during packing.

## FARM FRONT TECHNOLOGIES

### Poultry and Animal Feeds from Cassava

***1. Microbial technology for enriching protein in cassava***

The possibility of utilizing cassava starch factory waste (a by-product from the starch industries) as a broiler feed was investigated. Cassava fibrous waste contains approximately 56% unextracted starch, which therefore is an ideal substrate for microbial growth. Dumping wastes in the factory premises leads to foul smell, resulting in air pollution, and this has led to a lot of complaints in recent years. In order to help the starch factories from the threat of being closed down, effective by-product utilization seems to be a promising option. Studies conducted at CTCRI have shown that cassava waste can be converted to a broiler feed. The process consists of mixing the waste with cassava flour and steaming after partial moistening to increase the digestibility of the hemicelluloses and lignin. This flour-waste mix is dried and then mixed with other ingredients like peanut meal, fish meal and a mineral-vitamin premix to form a composite broiler feed. Feeding studies conducted with this feed showed that broiler performance was satisfactory, and that the birds reached a weight of 1.9 to 2.0 kg within eight weeks. The proportion of peanut meal in the feed mix can be reduced by enriching the waste-flour mix with microbial proteins through the use of a safe fungi such as *Trichoderma pseudokoningii.*

***2. Ensiling technology***

The poor postharvest storage life of cassava roots necessitates rapid processing into some stable product. Sun-dried cassava chips are susceptible to attack by a number of insect pests, making an economical and eco-friendly storage practically impossible. In order to ensure the supply of animal feed all year round, the possibility of ensiling cassava was investigated (Padmaja, 2000).

It was found that whole cassava chips mixed with rice straw can be ensiled to obtain stable quality silage with good feed value for cattle (**Table 2**). Cassava silage substituted at levels of 28% in a concentrate feed was found to increase the daily milk yield by 700 ml to 1000 ml . This low-cost technology can promote *in situ* cassava utilization as animal feed.

## COTTAGE INDUSTRIES

### Cassava Starch

Cassava roots are washed by hand and peeled with hand knives. These are then manually rasped to a pulp on a stationary grater, which is simply a tin or mild steel plate perforated by nails so as to leave projecting burrs on one side. The pulp is collected on a piece of fabric fastened by its corners to four poles, and washed vigorously with water by hand. Finally, the fiber is squeezed out while the starch milk collects in a bucket. When starch granules settle out, the supernatant water is decanted, and the moist starch is crumbled and dried on a tray or on a bamboo mat. In some places, the starch milk is squeezed through a closely woven thick fabric to trap the starch granules, or the fabric is hung overnight to remove gravitational water. Finally, the product is sun-dried. This simple process is used by many people in the rural areas of the tropics.

### Cassava Starch Based Adhesives

Adhesives can be made from cassava starch using simple low-cost technologies. These include gums made by gelatinizing starch by heat treatment without any additives as well as those made by extraneous addition of different kinds of materials.

**Table 2. Biochemical analysis of a cassava: rice straw silage. (cassava variety H 1687)**

| Components | Initial (0 day) | Final (72 days) |
|---|---|---|
| *Proximate principles* | | |
| Crude protein (N x 6.25), % | 4.66 | 3.62 |
| Ether extractives, % | 0.38 | 0.27 |
| Ash, % | 4.07 | 3.81 |
| Crude fiber, % | 7.60 | 6.83 |
| Carbohydrate, % | 83.45 | 85.37 |
| *Amino acids (g/16 g N)* | | |
| Aspartic acid | 3.45 | 3.51 |
| Threonine | 1.74 | 1.77 |
| Serine | 1.77 | 1.55 |
| Glutamic acid | 9.63 | 10.21 |
| Glycine | 2.40 | 2.65 |
| Alanine | 3.04 | 3.48 |
| Valine | 2.47 | 2.72 |
| Isoleucine | 1.64 | 1.58 |
| Leucine | 2.79 | 2.57 |
| Tyrosine | 1.59 | 1.76 |
| Phenyl alanine | 1.83 | 1.50 |
| Histidine | 4.72 | 4.80 |
| Arginine | 3.48 | 1.95 |
| Proline | < 1.6 | < 1.6 |
| Total lysine | 1.55 | 1.76 |
| Cystine | 1.23 | 1.41 |
| Methionine | 0.73 | 0.70 |

***Source:*** *Padmaja, 2000.*

***1. Gums without additives***

The simplest liquid starch pastes are made by cooking starch with water, with preservatives being added later. These are useful in bill pasting, bag making and in tobacco products. These gums have extensive demand, and the quality and color of the starch are not very crucial. However, they lose their fluidity after a day or two. In spite of these defects, they are in high demand because of their low cost.

The starch is cooked in stainless steel or wooden vats with excess water until all the starch has gelatinized. The consistency of the paste is gauged by the appearance and flowability of the gum. It should flow freely and pour out in a long, continuous stream. On cooling, the product becomes more viscous. Copper sulfate is added to resist microbial infestation. Cassava starch is preferred in view of its excellent cohesiveness, clarity and bland flavor. However, it cannot be stored for more than two days as the pastiness is lost, and it becomes too thick to handle.

***2. Gums prepared using different chemicals***

Various chemicals may be added during the preparation of the gums. These include inorganic salts like calcium and magnesium chlorides, borax, urea, glycerol, carboxy methyl cellulose and carboxy methyl starch. The chemicals assist in increasing viscosity and flowability, and in humidity control. They are added by stirring while the starch is being gelatinized to prevent lump formation. The gums are useful in various applications like lamination of paper, wallpaper printing, for water-resistant formulations of pasting labels and other stationery applications.

**Starchy Flour Extracted by Microbial Techniques**

In order to facilitate the enzymatic cleavage of cell walls of cassava roots for starch separation, a simple low-cost technology using a mixed inoculum of micro-organisms was developed. This stable, self-sustaining, mixed-culture inoculum in the form of a mother liquor contains the following component micro-organisms: *Lactobacillus cellobiosus, Streptococcus lactis, Corynebacterium sp.* and *Pichia membranaefaciens.*

The mother liquor from an earlier lot, used to provide the mixed-culture inoculum, is kept in the refrigerator for subsequent fermentation. Half of the stored mother liquor is replaced with a fresh lot at intervals of 20 to 25 days. After a series of 25 to 30 sets of sequential fermentation, the inoculum is rejuvenated.

Peeled and washed cassava roots are sliced into 7-10 cm long cylindrical pieces and stacked in tubs. Water is added to immerse the root pieces completely with a surface column of 10-15 cm overhead. This requires about 100 liters of water for 100 kg of root pieces. While pouring the water, steeped liquor from an earlier fermentation supplying the mixed-culture inoculum is also added at 2% by volume of water with frequent stirring. The tub is then covered with a muslin cloth and incubated under ambient temperature (30-32°C) for up to 48 hours.

The root pieces are softened within 48 h making them easy to crush by hand. The extent of softening of the fermented roots is evidenced quantitatively from compressive strength tests which show 4.98 to 11.71 times reduction in comparison to their original compressive strength.

The pectinolytic and cellulolytic enzymes produced by the microbes in this process disintegrate the cell wall, thereby liberating the starch granules almost completely and enhancing the yield of starchy flour by 16-31%, depending on the variety of roots fermented . To produce sweet flour, the fermented pieces are mashed, sieved, allowed to settle in excess water (1:5), and then dried. The yield of sweet flour ranges between 17-23 kg per 100 kg of fresh roots (Mathew George *et al*., 1995).

## LARGE-SCALE INDUSTRIES

### Cassava Starch

Cassava is the raw material for large-scale starch extraction in Tamil Nadu, and currently around 1,100 factories are engaged in the manufacture of starch on a commercial scale. Two high-tech starch factories that have been established recently in the Erode and Namakkal districts in Tamil Nadu use a fully mechanized process for starch manufacture. The processing time from roots to dry starch is only 12 min. The high quality of the starch produced has brightened the prospects of cassava starch exports from India. Modernization of the age-old equipment used for starch extraction in traditional starch factories, brightened the color of starch/sago, and improved waste disposal by way of conversion to feed, fertilizers, biogas, etc.; this can help the starch manufacturer to increase product turnover through augmented internal demand and export opportunities.

### Sago

Sago is a processed food starch marketed as small globules or pearls, manufactured in India from cassava starch. For the manufacture of sago, wet starch is dried in the sun to a moisture content of 40-45%. This is made into small globules by shaking in power-driven globulators. In small units, globulation is done with 10-15 kg starch. The globules vary considerably in size and are sieved through standard meshes. The next step is partial gelatinization which is carried out on shallow iron pans with oil. These are then heated over fire. The granules are stirred continuously for 15 min, and then dried in the sun or oven.

### Sweeteners

#### *1. Liquid glucose and dextrose*

Cassava starch is a raw material for the production of liquid glucose and dextrose. Hydrolysis of starch to glucose is achieved mostly using hydrochloric acid. After neutralization with soda ash, the hydrolyzate is filtered, decolorized and concentrated in a triple effect evaporator. Finally, the decolorized syrup is vacuum-concentrated to obtain a product containing 43% dextrose, which is used by many confectionery industries in India.

Crystalline dextrose is obtained by further vacuum-concentration to 70-88% and crystallization in cylindrical crystallizers using the seeding technique.

#### *2. Fructose syrup*

Fructose syrup has gained importance in view of the fluctuating prices of sugars and the potential harmful effects of synthetic sweeteners. Glucose is isomerized to fructose using commercial glucose isomerase enzyme at 62°C in glass-lined tanks for 6 h at pH 8.0 . The fructose solution is decolorized and vacuum-concentrated to obtain a syrup containing 45% fructose, 50% glucose and 5% oligosaccharides. Though the technology is readily available, the Indian industry has yet to come forward to exploit it fully (Balagopalan *et al*., 1988).

#### *3. Maltose*

Maltose is obtained commercially from starch by enzyme treatment. There are three types of commercial maltose syrups, i.e., high maltose syrup, extremely high maltose syrup and high conversion syrups. The process for maltose manufacture involves two steps, i.e., liquefaction of starch by heat and a thermolabile α-amylase, and saccharification using microbial β-amylase. The maltose syrup is used in brewing, baking, soft drink manufacture, canning and confectionery industries (Moorthy and Balagopalan, 1996).

### *4. Modified starches*

Cassava starch is modified by chemical or physical means to improve its functionality for industrial applications. The commercially converted starches are acid modified, oxidized and dextrinized starches. The undesirable properties of cassava starch, such as high breakdown in viscosity and cohesiveness of starch paste, can be modified through physical and chemical treatments. The physical treatments include heat, moisture, steam pressure and irradiation with γ-rays. For example, the gelatinization temperature is enhanced and viscosity is lowered but stabilized with steam pressure treatment. This starch has properties resembling fats, and hence can find use as fat-mimicking substances. The various chemical treatments which are used to modify starch include oxidation, esterification and cross-linking. Oxidation with hypochlorite gives a starch of lower viscosity suitable for the paper industry. It is expected that the paper industry is poised for tremendous growth in India. Esterification/etherification can lead to complete transformation in starch properties. The viscosities can be either lowered or enhanced and stabilized, and the pasting temperature can be altered. In fact, starch which gelatinizes in cold water, but does not gelatinize in boiling water, can be prepared by achieving the proper degree of substitution. Modified starch can find use in canned foods, frozen foods and as dusting powders in food and other industries. Cross-linking can stabilize viscosity and also provide various types of starch for food and industrial applications. Cross-linking agents include phosphate, epichlorhydrin and thionyl chloride.

CTCRI has developed laboratory-scale technologies for all these products, which can be scaled up for future applications. These products have wide applications in paper, textile and food industries. In addition, products like itaconic acid (Potty *et al*., 1982), lactic acid and citric acid can be produced from starch.

### *5. Biodegradable plastics*

Annual production of plastics in India is about 1.26 million tonnes against a corresponding demand of around 1.83 million tonnes, about 32% of the requirements being met by imports. Agricultural and packaging sectors account for about 50% of the plastics consumed in India. Use of plastics now has accelerated to such an extent that the disposal of used products has become increasingly difficult. The global shortage and mounting price of petroleum have also led to severe competition between fuel for energy and feedstock for petrochemicals. In the search of alternative feedstocks for polymers, starch, a natural polymer as well as a renewable raw material, has captured the interest of academic and industrial researchers across the globe pursuing environmentally degradable polymers for easier disposal.

The process for producing starch-based plastics involves mixing and blending starch with suitable synthetic polymers i.e., low-density polypropylene (LDPE) and linear low-density polypropylene (LLDPE), as stabilizing agents, and suitable amounts of appropriate coupling, gelatinizing and plasticizing agents. Compounding of the blend prior to extrusion film blowing was adopted to attain proper melt mixing. Successful extrusion film blowing was possible with formulations containing up to 40% cassava starch and appropriate amounts of suitable gelatinizing, plasticizing and coupling agents.

The properties of these films relating to strength, stability and physico-chemical properties were studied to determine their limitations and potentials for different end-uses. Films from starch-based plastics can be blown as thin (39-96 µm), as those from LDPE or LLDPE. Films containing starch above 20% exhibited relatively higher vapor transmission rates. Starch-based plastic films showed hygroscopicity in proportion to their starch contents.

These starch-based plastic films were found to possess adequate mechanical strength and flexibility to make them suitable for various potential agricultural applications. The tensile strength of these plastic films containing 10, 25 and 40% starch was found to be 12.56, 17.34 and 10.67 Mpa, respectively. The elongation at break values for these films varied from 211% to 122% as the starch content varied from 10% to 40%. In comparison, the tensile strength and elongation values of the LDPE control films were 10.97 MPa and 384%, respectively. The storage stability of these films, with regard to changes in tensile strength and elongation, was almost equivalent to that of the ordinary polyethylene films, the granular form of the material being more stable than the film form.

The suitability of these films for potential areas of application in the field of agriculture and single-use disposable packaging was assessed through outdoor weathering and soil burial; this showed a drastic reduction in mechanical strength and elongation values resulting in brittleness and disintegration. Deterioration of strength and of flexibility were progressively greater with an increase in starch content of the film, and the duration of environmental exposure. More rapid biodegradation (in 2-6 months) of these films could also be achieved by incorporating a suitable catalytic agent into the film composition. Films of the latter type would be much more suited for making nursery bags. Relatively easier disintegration and absorption of starch-based biodegradable plastics by the soil after a specific time interval would make this an ecologically satisfactory mode of disposal of plastic waste.

Synthetic polymers filled, grafted or blended with starch, either in its native form or modified, have been reported to impart biodegradability to the fabricated plastic goods. Incorporation of low-cost starch into synthetic polymers also provides a potential method for expanding their applications as well as improving the economics for making the plastics. Their superior utility has been deployed in specific applications such as short-service lifetime agricultural mulch, single-use disposable packaging and for controlled release of agro-chemicals, such as pesticides, pheromones, growth regulators and fertilizers.

### *6. Cassava alcohol*

Although the income elasticity of cassava is considered to be low, and in terms of ethanol production, crops like sugarcane enjoy a better competitive position at present, in the future cassava can also become an alternate raw material for ethanol production in India. CTCRI has perfected and patented the process for alcohol production from cassava. The process essentially consists in liquefaction, saccharification/neutralization and fermentation with yeast for 48-72 h at pH 4-4.5, followed by distillation to recover the alcohol (Vijayagopal and Balagopalan, 1978)

## FUTURE THRUST AREAS FOR CASSAVA UTILIZATION

### Extruded Food Products

Extrusion processing has become an increasingly popular procedure in food industries for the development of many successful products, including snacks and baby foods. Though extruded ready-to-eat food products based on cassava are common in many southeastern European countries, in the Indian market cassava-based extruded snack foods are not available. Once technology for extrusion cooking is standardized, ready-to-eat extruded snack foods will be readily available in the metropolitan areas and cities in India. Marketability of such products is foreseen to be possible without much effort.

### Rural Processing Units

In order to ensure rural employment and adequate remunerative prices for the producers or growers, the concept of cassava-based rural processing units has to be implemented. Many food items can be made out of cassava with little technological inputs. Wafers, chips, *papads*, dried chips for animal feed, *rava*, porridge powders, etc. are ideal food items for village-based food industries. Similarly, the technology developed for the production of gums, adhesives, cold soluble starches, etc. may also promote rural industrial growth in Kerala, Tamil Nadu, Andhra Pradesh and the northeastern provinces. The target markets for such products are urban and semi-urban areas.

### Cassava-based Large-scale Industrial Units

Novel products made out of cassava, such as biodegradable plastics, ethyl alcohol and modified starches, are ideally suited as ancillary industries in the sago and starch belts of Salem in Tamil Nadu and Samalkot in Andhra Pradesh, to cater to the needs of a wide spectrum of end-users.

Environmental pollution as a result of the extensive use of plastics is a serious concern of the government in India. CTCRI technology to produce biodegradable polymers incorporating cassava starch has given new hope to the country in tackling the problem effectively. The biodegradable nature of this polymer can to a certain extent control the pollution hazard. This patented technology has been purchased by four companies within the country. Besides the application filed for an Indian patent, a European patent has also been awarded for this product and process.

The scope of cassava alcohol in the potable alcohol sector has not been explored fully. High quality ethyl alcohol produced from cassava, besides serving as potable alcohol can also be channelled into the energy sector. CTCRI which owns a patent for this process has transferred this technology to two commercial firms.

The patent for the production of cold water soluble starches from cassava is under active consideration by the patent authorities and two or three firms have shown interest in the technology; in the near future this will also be transferred to industry. The target groups for these products are in the urban and semi-urban areas. Likewise, many modified starches find application in the paper, textile and food industries.

Cassava starch when subjected to hydrolysis with amylolytic enzymes and acids at low concentration can yield a variety of sweeteners, such as liquid glucose, dextrose, maltose and other saccharides, which have wide applications in the growing confectionery and pharmaceutical industries in India.

**REFERENCES**

Balagopalan, C. 1990. Utilisation of cassava in India: Research and developmental needs. *In:* R.H. Howeler (Ed.). Proc. 8th Symp. Int. Soc. Trop. Root Crops, held in Bangkok, Thailand. Oct 30-Nov. 5, 1988. p. 363.

Balagopalan, C. and M. Anantharaman. 1995. Cassava transfer of technology in India. *In*: R.H. Howeler (Ed.). Cassava Breeding, Agronomy Research and Technology Transfer in Asia. Proc. 4th Regional Workshop, held in Trivandrum, Kerala, India. Nov 2-6, 1993. pp. 97-109.

Balagopalan C. and R.C. Ray. 1993. Biotechnological approaches for cassava utilization in India. *In:* W.M. Roca and A.M. Thro (Eds.). Proc. 1st CBN meeting, held in Cartagena, Colombia. Aug 25-28, 1982. CIAT, Cali, Colombia. pp. 283-291.

Balagopalan, C., S.N. Moorthy and G. Padmaja. 1990. Diversification of tapioca for alternate uses. *In:* Green Book on Tapioca. Sagoserve, Salem, Tamil Nadu, India. pp. 47-51.

Balagopalan, C., G. Padmaja, S.K. Nanda and S.N. Moorthy. 1988. *In:* Cassava in Food, Feed and Industry. CRC Press, Florida, USA. 205 p.

George, M., S.N. Moorthy and G. Padmaja. 1995. Bio-chemical changes in cassava tubers during fermentation and its effect on extracted starch and residue. J. Sci. Food Agric. 69: 367-371.

Moorthy, S.N. and C. Balagopalan. 1996. Novel carbohydrates from cassava starch. *In:* C. Balagopalan, T.V.R. Nayar, S. Sundaresan, T. Premkumar and K.R. Lakshmi (Eds.). Proc. ISOTUC, held in Trivandrum, Kerala, India. Oxford IBH Publishing Co.., New Delhi, India. pp. 32-43.

Padmaja. G. 2000. Cassava ensiling. Tech. Bull. No.27. CTCRI, Trivandrum, India. pp. 26.

Padmaja, G., C. Balagopalan, G.T. Kurup, S.N. Moorthy and S.K. Nanda. 1990. Cassava processing, marketing and utilization in India. *In:* R.H. Howler (Ed.). Proc. 3rd Regional Workshop, held in Malang, Indonesia. Oct. 22-27,1990. CIAT, Bangkok, Thailand. pp. 327-338.

Potty, V.P., S.N. Moorthy and C. Balagopalan. 1982. Production of itaconic acid from cassava starch. *In:* K. Rajaramen *et al* (Eds.). Proc. Seminar on Post-harvest Technology of Cassava AFST(India), held in Trivandrum, India. Feb 22, 1980. AFST (Trivandrum Chapter). pp. 51-53.

Vijayagopal, K and C. Balagopalan. 1978. Saccharification of cassava starch with barley malt for ethanol fermentation. J. Root Crops 4: 49-51.