CASSAVA RESEARCH AND DEVELOPMENT STRATEGIES IN INDIA

S. Edison[1]

ABSTRACT

India, with an annual root production of about 6.18 million tonnes from an estimated area of 0.235 million hectares, has a unique status on the cassava map of the world for its highest yield (26.32 t/ha). This could be possible because of the availability of high-yielding varieties and the willingness of farmers, especially of the industrial belts of Tamil Nadu and Andhra Pradesh states, to readily adopt these varieties along with their improved management practices. The Central Tuber Crops Research Institute (CTCRI), the only institute in the world doing work exclusively on all aspects of tropical root and tuber crops, continues to play a significant role in the research and development of these crops in India. During its existence over the past four decades, CTCRI has released 11 high-yielding cassava varieties, improved their cultural techniques, and developed strategies to manage major field and storage pests and diseases; in addition, it has developed integrated cropping systems as well as processing technologies for diversified markets. These technologies have been taken to the clientele system through various first-line extension programs as well as through specialized programs.

Keeping pace with the changing global agricultural scenario in the era of globalization and liberalization, CTCRI redesigned its research and development strategies on cassava in the recent past. Besides conventional breeding methods, biotechnological approaches are being increasingly used to develop new cassava varieties with desirable attributes, like high starch content, low HCN, high carotene etc., and for *in vitro* germplasm conservation and cryopreservation. Acknowledging the fact that cassava in Kerala is becoming more and more a companion (inter)crop in already existing cropping systems (banana-based/coconut-based/rice-based), greater emphasis is being placed on standardizing the cassava component of the cropping system.

To make Indian cassava globally competitive, low input management practices are being perfected to reduce production costs. To combat the dreaded cassava mosaic disease, a multidisciplinary approach that includes resistance breeding, detailed serodiagnostic investigation, management techniques etc. are currently in progress. For more effective utilization of cassava, efforts are also being made to produce value-added products, such as modified starches, starch derivatives, convenience foods etc. We have collaborations with international (e.g. CIAT and CIP), and national (EMBRAPA, NRI etc.) institutes, development departments and non-governmental organizations (NGOs) to foster better linkages and cooperation for the development of cassava in India. Some of the recent development strategies of cassava, such as the Institution-Village Linkage Programme (IVLP) in Kerala; Project UPTECH, a joint venture with the State Bank of India for cassava development in Andhra Pradesh; and participatory technology development, demand assessment and market-oriented research. These are also being discussed in the paper.

INTRODUCTION

Root and tuber crops are plants which produce underground structures that are used as human or animal feed. They are the third most important food crops of human kind after cereals and grain legumes, and constitute either staple or subsidiary food for about a fifth of the world population. Tropical Root and Tuber Crops (TRC) have their own role as an important staple in several countries in South America, Africa, Southeast Asia, etc. Inspite of the near satisfactory level of production of cereals and grain legumes, the socio-economic condition of small and marginal farmers in most countries in the above-

[1] Central Tuber Crops Research Institute, Thiruvananthapuram 695017, Kerala, India

mentioned regions necessitated them to depend on TRC as their staple. Tuber crops have a higher biological efficiency as food producers and show the highest rate of dry matter production per day per unit area among all the crops. They are also recognized as the most efficient converters of solar energy, cassava producing 250 x 10^3 Kcal/ha and sweet potato 240 x 10^3 Kcal/ha as compared to 176 x 10^3 for rice, 110 x 10^3 for wheat and 200 x 10^3 for maize. The TRC crops are known to supply cheap sources of energy, especially for the weaker sections of the population. Tuber crops can be broadly classified as temperate and tropical groups. Potato is primarily a temperate crop whereas all other edible tuber crops come under tropical tuber crops.

Having been classified as the third most important food crops of man, they possess high photosynthetic ability coupled with the capacity to yield under poor and marginal soils, adverse weather conditions etc. These attributes make tuber crops ideal for cultivation in the Less Developed Countries (LDCs) of the world. Cassava and sweet potatoes account for about 30% of the total production of root crops from developing countries, the rest being made up of potatoes, cocoyams and others (Scott *et al*., 2000). It is estimated that about 6% of the world's dietary energy is supplied by root crops, especially potatoes, cassava and sweet potatoes. Although root crops have generally been branded as "poor man's crops", supplying low cost energy and bulk to the diet and little else by way of nutrition (Horton, 1988), their potential as nutritionally rich sources of β-carotene, anti-oxidants, dietary fiber and minerals like calcium has begun to be recognized as a result of the multifarious research programs worldwide.

Importance of Tropical Root and Tuber Crops in India

Tuber crops are cultivated in India mainly in the southern, eastern and north-eastern states. Cassava is grown in India in an area of 0.23 million hectares with a total production of 6.5 million tonnes. Cassava production is mainly from the states of Kerala, Tamil Nadu and Andhra Pradesh. Trends in the area and production of cassava in these states during 1992-97 present a grim picture of only a marginal increase in 1996-97, the principal reasons being increased per capita income leading to better purchasing power of people, surplus availability of cereals to a major section of the society, shrinkage in area due to a shift to more remunerative crops etc. Lack of adequate expansion to non-traditional and backward areas is another factor, which has culminated from the poor awareness on the potential of tuber crops in meeting hunger and alleviating poverty.

Tuber crops like yams and aroids are even today considered as vegetables only and their full potential remains largely untapped. Commercial cultivation of yams and aroids is popular in Andhra Pradesh, Tamil Nadu, West Bengal, Uttar Pradesh and Orissa States, whereas the Salem belt in Tamil Nadu and the Samalkot belt in Andhra Pradesh are known for cassava as an industrial crop. Several minor tuber crops which possess medicinal properties are also available. In the context of surplus food sources, the role of tuber crops may seem to be trivial. However, being concentrated sources of energy, they can definitely turn out to be saviours of hunger in times of food crisis and famine.

With all the favorable attributes, there is a temporary set back of this group of crops in terms of its status in the agricultural economy of our country. The earlier emphasis on cereals to cope with the food production calls for a rethinking in the wake of disproportionate population growth and rapidly shrinking cultivable areas and increasingly fragile resources. Consequently, striking at alternate crops as sources of energy would lead to tuber crops as an inevitable choice to play the role. Further, tuber crops as such provide a vast scope for diversification and value addition, offering a great opportunity for non-traditional uses within the country and for exports.

Research on tuber crops in India is undertaken mainly at the Central Tuber Crops Research Institute (CTCRI) under the aegis of the Indian Council of Agricultural Research (ICAR). Since its inception in 1963, CTCRI has contributed enormously to the research and development of tuber crops and is presently an internationally recognized Premier Institution, dedicated solely to tropical tuber crops research. Nearly four decades of research have led to several innovations such as improved high-yielding early-maturing varieties, cropping systems for various agro-ecological zones, integrated pest and disease management packages for better production, technologies to reduce post-harvest losses and enhance the prospects of utilization in the food, feed and industrial sectors etc.

Research at CTCRI is accomplished through the Divisions of Crop Improvement, Crop Production, Crop Protection and Crop Utilization & Biotechnology, and the Section of Social Sciences. During the thirty five years of research, several technologies were generated on the production and utilization of tuber crops and scientific information was disseminated to extension personnel and farmers through training and outreach programs.

The important tropical tuber crops economically and socially are cassava, sweet potato, yams (greater yam, lesser yam, African yam), aroids (*Amorphophallus*, *Colocasia* or taro, *Xanthosoma* or tannia) and other minor tubers, namely Chinese potato, arrow root, yam bean, etc. **Table 1** gives some general details about these TRC.

A Look into Cassava in General and in India

Cassava is a perennial shrub native to South America that is now grown throughout the tropics. Cassava was brought into cultivation by the American Indians probably 4,000 years ago, was later introduced to West Africa in the sixteenth century, and then spread to other tropical regions of the world. Although the crop can be grown between the latitudes of 30°N and 30°S and at elevation up to 2000 meters above mean sea level near the equator, most cassava is grown where the annual mean temperature is above 20°C and rainfall exceeds 700 mm. A major factor behind the extensive production of cassava is its adaptability to a wide range of soil, land and moisture conditions. Except at planting time, cassava can withstand periods of prolonged drought and is, therefore, a valuable crop in regions of low or uncertain rainfall. Light, sandy loams of medium fertility give the best results, and the crop can be grown successfully on soils with a pH ranging from 4.5 to 9.0; however, poorly drained and swampy soils are not suitable for cassava production. Cassava is one of the most important energy sources in the diet of people in the tropics; recent estimates suggest that its storage roots provide eight percent or more of the minimum calorie requirement of more than 750 million people. Its starchy roots produce more calories per unit of land than any other crop in the world, except perhaps sugarcane.

Cassava roots are generally rich in calcium and ascorbic acid, and contain significant amounts of thiamine, riboflavin, and niacin. The cassava leaves are rich in high quality protein, and are consumed in most of the tropical countries. However, the swollen roots contain little protein. In India, its cultivation is mainly confined to the States of Kerala, Tamil Nadu and Andhra Pradesh. The area, production, yield, state wise distribution of cassava is shown in **Table 2**.

Table 1. Scientific and common names of the major tropical root and tuber crops.

Common name (English)	Scientific name	Family	Vernacular name
Cassava/Tapioca	*Manihot esculenta* Crantz	Euphorbiaceae	Maracheeni Kizhangu (M), Kappa (M) Maravalli Kizhangu (T), Ezhilai Kizhangu (T), Maraganasu (K), Karrapendalamu (TE).
Sweet potato	*Ipomoea batatus* (L.) Lam.	Convolvulaceae	Mitha Alu (H), Shakarkand (H), Cheeni Kizhangu (M & T), Madhura Kizhangu (M), Shakkarevalli Kizhangu (T), Ganasu (K), Chelangada (TE), Ratalu (MR), Lal alu (B), Ranga alu (B)
Greater Yam	*Dioscorea alata* (L.)	Dioscoreaceae	Pind Aaluk (H), Peruvalli Kizhangu (T), Vettilavalli Kizhangu (T), Kachil (M), Kavath (M)
African Yam	*Dioscorea rotundata* (Poir)	Dioscoreaceae	Safed Aaluk (H), African Valli Kizhangu (T), African Kachil (M).
Lesser Yam	*Dioscorea esculenta* (Lour.) Burk	Dioscoreaceae	Kayu (H), Cheruvalli Kizhangu (T), Cherukizhangu (M)
Taro	*Colocasia esculenta* (L.) Schott	Araceae	Arvi (H), Kachalu (H), Ghuiya (H), Kachu (S), Chempu (M), Seppan Kizhangu (T), Kachchi (K), Shamagadde (K), Chamadumpa (TE), Chemagadda (TE), Alu (MR), Kachu (B)
Tannia	*Xanthosoma sagittifolium*	Araceae	Palachempu (M & T)
Elephant Foot Yam	*Amorphophallus poeniifolius* (Dennst.) Nicolson	Araceae	Zamir-kand (H), Arsaghana (S), Balukand (S), Chena (M), Karunai kilangu (T), Suvarna gadde (K), Kanda (TE), Suran (MR), OI (B).
Chinese Potato	*Solenostemon rotundifolius*	Labiateae	Koorka-kizhangu (M), Siru kizhangu (T).

H-Hindi, M-Malayalam, T-Tamil, TE-Telugu, K-Kannada, B-Bengali.

Table 2. Area, production and yield of cassava in India in 1998/99.

State	Area ('000 ha)	Production ('000 tonnes)	Yield (t/ha)	% of cropped area
Kerala	142.0	2,588.3	20	4.7
Tamil Nadu	65.7	3,043.2	45	1.1
Andhra Pradesh	22.0	17.4	10	0.1
Karnataka	0.9	7.1	10	---
India (1998/99)	245	5,668	23.95	0.1
World (1998/99	1,619	158,620	9.79	

Improved Cultivation Practices of Cassava

Cassava is very flexible with respect to planting dates, and hence under irrigated conditions in the tropics, planting can be undertaken at any time of the year. Time of planting of cassava for the different states in India is shown in **Table 3**.

Table 3. Optimum time of planting cassava in four States of India.

States	Rainfed	Irrigated
Kerala	April - May September - October	December - January
Andhra Pradesh	June	March
Madhya Pradesh	June	March
Tamil Nadu	June	September (higher yield)

Land preparation

Loosening the soil to a depth of 20-25 cm, either by tractor plowing or spade digging, helps in better rooting. In drought-prone areas with infertile soil, deep plowing encourages deep root penetration. The systems of cultivation vary with the type and topography of the soil. For example, the mound system may be adopted in soils having high clay and restricted drainage, whereas the ridge system may be adopted on slopes to prevent soil erosion. Flat bed method of cultivation may be followed in level lands having good drainage. Under irrigated conditions, the ridge and furrow method of planting is practiced.

Spacing and plant population

Based on the branching behaviour, cassava genotypes can be classified into branching, semi-branching and non-branching types. Both branching and semi-branching types require a wider spacing, and hence planting them at 90x90 cm is optimum. Non-branching types grow well at a spacing of 75x75 cm. Cassava is flexible to spatial arrangement provided the plant population per unit area is maintained constant. Under medium level of soil fertility, branching and semi-branching types require a wider spacing of 90x90 cm accommodating 12,345 plants per hectare while non-branching types can be planted at a closer spacing of 75x75 cm, accommodating 17,770 plants per hectare. Normally one stake is planted per hill/mound. By adopting a spacing of 90 x 90 cm, about 2000 stems are required for planting one hectare of land.

Improved varieties

A large number of varieties/cultivars are grown in different regions of the country. An introduction from Malaya, called M4 (by the University of Kerala) in1940 is a popular variety used for culinary purpose in southern Kerala. A total of eleven improved high-yielding varieties have been released since 1971 from the Central Tuber Crops Research Institute (CTCRI), of which H-165 and H-226 are still the most popular varieties in the industrial belt of Tamil Nadu and Andhra Pradesh. The salient features of the improved varieties are given in **Table 4**.

Table 4. Characteristics of improved varieties of cassava released by CTCRI and TNAU[1)] in India.

Variety	Duration (days)	Starch (%)	Yield (t/ha)	Salient features
H-97	260-300	27-29	25-35	Good drought tolerance
H-165	220-240	22-25	33-38	Easy harvestability, early bulking, good root shape
H-226	260-300	28-30	30-35	Popular variety for starch production
Sree Sahya	300-320	29-31	35-40	Hardy and highly resistant to drought
Sree Visakham	270-300	25-27	36-50	Rich in carotene (446 IU/100g)
Sree Prakash	210-240	29-31	30-40	Early and shallow bulking type
Sree Harsha	300	38-41	35-40	Triploid variety, high starch content
Sree Jaya	180-210	24-27	26-30	Early maturing, excellent cooking quality
Sree Vijaya	180-210	27-30	25-28	Early maturing, good cooking quality
Sree Rekha	300	45-48	28.2	Excellent cooking quality. Suitable for general cultivation in upland and lowland
Sree Prabha	300	40-45	26.8	Suitable for general cultivation in upland and lowland
CO-1	260-275		30.0	Tolerant to CMD and scale insects
CO-2	260-275		37.5	Highly branched
CO-3	240-270		40	Branching type, high starch content, sweet taste
H-119	225	35.2	36	Non-branching, better consumer acceptance

[1)] Tamil Nadu Agricultural University

Planting

Cassava is a vegetatively propagated crop and is raised by planting stem cuttings. Disease- and pest-free stems of 8-12 months maturity having a thickness of 2-5 cm are to be selected for planting after discarding 1/3rd portion of the stem from the top and about five cm from the bottom. Stakes can also be raised in a nursery and the sprouted mosaic symptom-free plants may be uprooted carefully at about three weeks and planted in the field. While preparing stakes, it is better to have a smooth circular cut rather than an irregular cut for better root initiation. A stake length of 15-20 cm is ideal for high yield. Irrigation may be provided for establishment, in case rains are not received. Planting the stakes in a vertical position is better as compared to horizontal or slanted methods. The stakes may be planted to a depth of five cm; deeper planting results in swelling up of the mother stake with a consequent reduction in root yield. Root bulking begins during the second month after planting.

Gap filling/Thinning

Under field conditions, all the planted stakes may not establish due to the use of poor quality planting material and/or adverse weather conditions. At the time of planting itself, 5-10% of the setts may be planted at a close spacing of 4.5 x 4.5 cm with irrigation so that 20-25 day old plants can be up-rooted for 'gap transplantation'.

Replanting the unsuccessful stakes at 15 days after planting with fresh cuttings of longer size (40 cm) also helps to improve the yield of the replanted stake. Retaining two healthy shoots per plant at opposite sides was found to be better than retaining either many or one shoot. Removal of excess sprouts by nipping at the initial stages of establishment (10-15 days after planting) helps to reduce mutual shading and competition between plants.

Irrigation

Irrigation is not practiced in Kerala where cassava is grown as a rainfed crop. But cassava is raised under irrigation in many parts of Tamil Nadu and Andhra Pradesh, where one irrigation is given on the day of planting followed by another two irrigations at an interval of 3-5 days till the plants are well-established.

Manures and fertilizers

Traditionally cassava is grown with organic manures such as farm-yard manure (FYM) and wood ash. Farm-yard manures or compost may be applied at a rate of 10-15 tonnes per hectare at the time of land preparation. A fertilizer dose of 100 kg N, 50 kg P_2O_5 and 100 kg K_2O/ha is recommended for high-yielding varieties and half this dose is suggested for local varieties. For the short-duration varieties, like Sree Prakash, application of NPK at 75:25:75 kg N, P_2O_5 and K_2O/ha is recommended under a close spacing of 75 x 75 cm for Tamil Nadu. Cassava has a high potassium requirement. If potassium is not present in the soil in sufficient amounts, yields are reduced, and the roots have a lower starch and higher hydrogen cyanide (HCN) content.

Inter-culturing and earthing-up

Inter-culturing in the early stages of the crop is essential for proper control of weeds and for improving the soil condition. The first inter-culturing shall be sufficiently deep, done at 45-60 days after planting, and a shallow inter-culturing and earthing-up is made one month later.

Cropping system

In Kerala, cassava is grown as a monocrop in uplands, as an intercrop in coconut gardens and as a sequential crop after paddy in lowlands. In Tamil Nadu, the crop is mainly grown as a monocrop under irrigation for industrial processing into starch. In the Northeastern Hill region, cassava is grown mostly in mixed stands of shifting cultivation plots on the hill's slopes, mainly as a rainfed crop.

Intercropping

Legumes are the most suitable intercrops for cassava. Groundnut (bunch type TMV-2 and TMV-7) and french bean (cv'Contender') were found to be promising and economical. These crops can give an additional net income of Rs.3,000-5,000/ha within 3-3 1/2 months. In Tamil Nadu, the black gram variety CO-1 and bellary onion were also found to be suited for intercropping with cassava. In Andhra Pradesh, black gram or green gram is recommended, while in Assam soybean and French bean are found to be promising as intercrops for cassava.

Plant Protection

Cassava mosaic disease, caused by a virus transmitted by whitefly, is a serious problem affecting growth and yield under severe infestation. By systematic rouging, this disease can be controlled. Disease-free plants should be identified well in advance and used as planting material.

Spider mites, which occur in the dry season, can be controlled by spraying water at run off level on the foliage at 10-day intervals. In addition to this, scale insects have been found to affect stems when stored for subsequent planting. Spraying dimethoate or methyl parathion (0.05%) thrice at monthly intervals during January-February is effective in controlling these pests.

Harvesting and yield

Early bulking varieties can be harvested from the seventh month onwards. Retaining the plants in the field after attaining the optimum stage of harvest may lead to fiber formation inside the smaller roots. A normal crop of cassava yields on average 25-35 tonnes of fresh roots per hectare. Although it can remain in the ground for many months, once it is harvested, the roots deteriorate rapidly and begin to rot after 48 hours. Cold storage where possible at 0-2°C and 85-95% relative humidity has been reported to extend the storage life for periods up to 6-12 months. Storage of cassava planting material is necessary when harvest and subsequent planting do not coincide with each other. Healthy stems for subsequent planting may be collected from the field immediately after harvest and stored under tree shade or in thatched sheds in a vertical position. The stems so stored may be used for the subsequent planting within two months so as to get optimum sprouting.

Processing

A major problem with the use of cassava is the toxicity from the cyanide compounds found in fresh roots. The cyanide is concentrated in or near the skin of the root, and is freed into its active form when the skin is broken. The cyanide content, however, varies from variety to variety and changes under environmental conditions, such as humidity, temperature, and age of plants. Proper processing cassava for consumption is the most effective solution to solve this problem. This can be done in a variety of ways, but is often done by washing the cassava in clean water or by fermenting it.

Cassava can be processed into different forms for a wide variety of end uses, and much of this processing can be carried out locally, providing jobs and income to the rural population. It can be made into food products and also used as animal feed. It is now commonly used as a raw material in the manufacture of various industrial products like starch. In Brazil, the roots are sometimes used commercially to make alcohol.

In India, as far as utilization pattern is concerned, cassava is used as a secondary staple in Kerala, while it is used as raw material for production of starch and sago in Tamil Nadu and Andhra Pradesh. Annually 300,000 tonnes of sago and starch are being produced, of which Tamil Nadu's share is more than 80%. Chips is another value added product; nearly 70,000 tonnes are produced from cassava, more than 50% of it from Andhra Pradesh. The export items of cassava are starch, sago, flour and chips and the importing countries are Australia, EU, Bangladesh, Sri Lanka, Nepal, USA and Canada. Total amount of products exported annually ranges from 30,000 to 50,000 tonnes.

Research Strategies

Although enough infrastructure facilities have been created and are under use to meet the R & D requirements of cassava, some of the emerging areas are being attended by following a set of strategies as explained below:

a. Developing an alternate technology for the production of disease-free planting material of cassava through a nursery technique.

Spread of diseases through vegetative planting material is an inevitable feature in vegetatively propagated crops, and cassava is no exception. Cassava Mosaic disease, primarily transmitted through planting material, can cause yield losses ranging from 2 to 90%. Hence an alternative technology is advocated to contain if not eliminate the disease. In this technology, setts of 3-4 node cuttings derived from apparently disease-free plants are collected and planted in a nursery at a close spacing of 4x 4 cm so that about 500 setts can be accommodated in one square foot of land. Daily watering of the setts is done for the first 10 days and on alternate days thereafter. The CMD symptoms appear about 10 days after planting and the settlings showing even mild symptoms are removed and burnt. This rouging is continued up to 20-25 days; by that time healthy plants are transplanted to the main field. Supplementary irrigation is given in the transplanted field till the plants are well established. Screening for disease symptoms and rouging of infested plants is continued in the field at weekly intervals up to harvest. By adopting this technique, it is possible to produce healthy plants.

b. New processing technologies

Root and tuber crops offer immense scope as food, feed and industrial raw material. A wide variety of instant and ready-to-eat food products such as cassava rava and porridge, sweet potato energy drink, sweet potato jam, pickle, sauce, etc. can be prepared, which can enhance market appeal for tuber crops products. Similarly, there are several food products like cutlets, puffs and samusas, etc. for which these crops can also be used. Apart from the utilization as food and animal feed, cassava roots can be used in a vast number of industrial applications, such as alcohol, gums, dextrins and cold water soluble starch. Of late, the starch-based biodegradable plastics developed from cassava have received wide attention due to the ability to reduce pollution and being eco-friendly.

Many processing technologies to produce value-added products from tuber crops are being made available by R & D efforts of CTCRI. These technologies range from home front to the industrial front.

(i) Home front technologies

1. Method to prolong the shelf life of fresh cassava

Pits are made under shade and moist sand/soil is spread at its bottom (moisture 10-15%). Bunches of undamaged roots still attached to the stem are arranged layer by layer with moist sand or soil in between the layers. After arranging three layers, pits are covered with moist sand/soil. The germinated buds are to be removed frequently.

Low-cost value added intermediary products like jams, sauces, pickles, pregelatinized starches, instant drinks, etc. are readily available for transfer.

(ii) Farm front technologies

Conservation technologies like cassava ensiling for the *in situ* utilization of cassava as animal feed, by-product utilization of cassava starch factory waste as poultry feed etc. are available. Hand-operated, pedal-operated and motorized chipping machines, harvesting tools and a peeling knife were also developed by CTCRI.

1. Cassava ensiling technique

Whole roots of cassava are chopped and then exposed to sunlight to reduce the initial cyanogens load. Then mix the sliced cassava with rice straw in the ratio 90:10 and pack the mix tightly into plastic silos. The ensiling process is completed in three weeks and this stabilized silage can be preserved in the silo till it is opened for utilization.

2. By-product utilization of cassava waste (thippi) as poultry feed

Cassava flour and thippi are mixed in equal proportions (1:1). Steam treat the mix for 30 minutes. Dry the mix in sunlight. Mix with dehydrated fish meal, groundnut meal and vitamin-mineral premix. Granulate for better-feed efficiency.

(iii) Industrial front technologies

1. Development of starch-based adhesives

Adhesives can be prepared using cassava starch along with Polyvinyl Alcohol (PVA). The resulting adhesive has excellent sticking power in paper-paper, paper-card board, plywood-hardwood, ceramic-wood and ceramic-ceramic systems.

2. Starch succinate for the food industry

Starch succinate can be prepared by treating cassava starch with succinic anhydride I alkali (pH 8.5). The derivative can be used as a thickener in the food industry.

3. Cassava starch-based bio-degradable plastics

This technique is an eco-friendly way of meeting the demand for plastic packaging products from India. The process for production of starch-based plastics standardized at

CTCRI is a pioneering work. It involves blending of polyolefins with cassava or maize starch in the presence of a compatibilizer and other chemicals; the product has a bio-degradability ranging from 6 months to 5 years depending on the composition. This eco-friendly technology has already been transferred to four licensees in the states of Delhi, Haryana, Himachal Pradesh and Karnataka through the National Research Development Corporation (NRDC), New Delhi, India. This technology has received a European patent.

4. Cassava starch for binding in fish feed and its use in tissue culture

Cassava starch has high viscosity enabling its use as a binding material in pelleted fish feeds. Cassava with its desirable attributes like high energy value and the adhesive quality of starch can be a forerunner crop. Research conducted at CTCRI has shown the potential use of sago (granulated cassava starch) as a solidifying agent in tissue culture media.

5. Microbial technique to extract starchy flour from cassava roots

A mixed culture inoculum with microorganisms, e.g. *Lactobacillus cellobiosus, Streptococcus lactis, Corynebacterium sp., Pichia membranaefaciens* has been developed to prepare sweet and sour flour.

The inoculum source is added to cassava roots (big pieces) and then fermented for 48-72 hours rendering the root pieces soft. Steep water is decanted, the fermented roots are dried, powdered and sieved to obtain a starchy flour. The flour can be used as an ingredient in bakery products.

6. Mobile starch extraction unit

Simple, electrically operated, low cost starch extraction unit, which can be transported from one place to other has been fabricated. This unit will grate the cassava roots, wash out the starch from the tissue and separate the starch. The unit has been tested in Kerala and Orissa states and has shown its potential scope. The unit has the capacity of extracting starch from 200 kg of cassava or 135 kg of sweet potato per hour with 84 and 75% of starch recovery from cassava and sweet potato, respectively. Approximate cost of the unit is Rs.60,000/-.

7. Method to eliminate cyanide and reduction of BOD (Biological OxygenDemand) & COD (Chemical Oxygen Demand) in factory effluents.

The effluent treatment system for cassava starch/sago factory waste waters developed by CTCRI include initial settling, anaerobiosis, filtration through sand, charcoal and gravel columns and final aerobic polishing. The gas generated (methane) can be used as a fuel, and the treated/cleaned water could be used to support aquaculture. The technology has been successfully demonstrated in the field.

CURRENT CHALLENGES IN RESEARCH

Many new challenges remain and research at CTCRI is now concentrating on the following areas:

a. Genetic Resources Management

Root and tuber crops germplasm is being conserved at CTCRI in field gene banks. The genetic diversity and genetic purity of the collections are being studied using isozyme patterns, RFLP markers and other DNA analytical methods or DNA fingerprinting in the Genetic Resources Management Unit. Another area of importance is the creation of computerized data banks for storing, analysis and retrieval of information for identification of core collections and genetic duplicates.

b. Biotechnology

Cryo-preservation methods for long-term storage of *in vitro* based gene banks have to be formulated. Developing transgenics in tuber crops (mechanical or vector mediated) for incorporating useful genes for disease resistance, suppression of anti nutrient factors as well as tolerance to stress are other challenges.

c. Triploid varieties for industrial use

As cassava is gaining importance as an industrial crop in Tamil Nadu and Andhra Pradesh, the need for developing high-yielding varieties having a higher starch content became essential. The triploidy breeding program has established the scope for such varieties at CTCRI. For example, the triploid cassava variety Sree Harsha has a yield potential of 60 t/ha with 38-41% starch. This research needs to be streamlined and strengthened in the future.

d. Integrated production systems

The cassava area under traditional upland rainfed conditions is declining gradually in Kerala. On the other hand, the area under lowland cultivation is increasing with the gradual replacement of rice by cassava. Therefore, research is needed to standardize the production technology of cassava under lowland conditions.

e. Cassava Mosaic Disease

Cassava Mosaic Disease is the most serious problem in all the cassava growing areas of India; no resistant varieties are yet available. Standardization of regeneration and transformation techniques for cassava for developing a CMD-resistant transgenic cassava is essential. CMD is reducing cassava yields by about 15-20%, especially in the industrial belt of Tamil Nadu.

f. Root rots

Root rots have become a very serious problem in cassava, especially in the irrigated areas of Tamil Nadu. Hence, investigations are needed to determine the host-pathogen-environment interaction, the mode of perpetuation and spread of the pathogen, and to develop suitable management practices, including biocontrol.

g. Production of disease-free planting material

This is a persistent problem to meet the requirement of the cassava growing farmers. There is an increasing demand for disease-free planting materials from Tamil Nadu, Andhra Pradesh, Gujarat and Kerala.