CHAPTER I

INTRODUCTION

Tapioca is an important tuber crop cultivated in many tropical countries, while in some states (Kerala and North Eastern states) it is used as food crop. Tapioca industry is an agro based seasonal industry with huge employment potential in India. Tapioca is mainly processed into starch and sago. There are more than 1000 tapioca processing units in India producing starch and sago in cottage and small scale sectors. The major unit operations involved in sago production are peeling, washing, rasping, pulping, screening, settling and purification of starch, pulverization globulation, sizing, roasting, sun drying polishing and packing. The starch and sago factories in India have been using age-old technology, involving longer duration of extraction and unhygienic handling of the material leading to poor quality end products. Almost all tapioca processing industries in Tamil Nadu have prevailed with two major problems. The first problem is the huge requirement of water for better extraction of starch from tubers. Second is the generation of large volumes of effluent. Many factories are being closed due to the unavailability of water resource.¹

1.1 The Beginning and Growth of Sago Industries in Tamil Nadu

“Necessity is the Mother of Invention”. The Sago and Starch industry of Tamil Nadu is the result of scarcity created by the impossibility of imports of foreign Sago and starch from Singapore, Malaysia, Indonesia,
Holland, Japan and U.S.A during Second World War. In the year 1943 Mr. Manickam Chettiar, a dry-fish merchant of Salem had an occasion to go to Kerala very often in connection with the trade. He found tapioca flour to be a good substitute for American Corn Flour. So, he commenced the production of tapioca flour in Salem, and marketed at Madras. Mr. Popattal, G. Shah, an evacuee from Penang (Malaysia) came in touch with Mr. Manickam and taught him the technical known how to manufacture Sago out of tapioca flour. Thus tapioca was used in 1943 to manufacture both starch and Sago, but the methods adopted were crude and primitive.

To meet the daily increasing demand of Sago and starch, Mr. Manickam with the help of a genius mechanic Mr. Venkatachalam improved the methods and machinery of production. The productive capacity of a factory increased from 2 bags of 100 kilos to 20 to 25 bags per day. There was a severe famine in the country as a while and tapioca being edible, the collector of Salem prohibited the export of tapioca from Salem district.

The Sago and starch industry was born during Second World War. But the aftermath of the war posed a severe threat to its existence. Second World War was over and imports of starch and Sago began to increase from foreign countries under open general licence no. XI. The year 1953 began with a happy note for the industry, farmers, manufacturers, labourers and traders, who were directly or indirectly involved in the production of Sago and starch. Though it is a recent industry of Tamil Nadu, its role particularly
in Salem economy is very great indeed. It has already affected the pattern of agricultural production in the district and has vastly increased the trade potential, in addition to giving scope for employment opportunities for labour. Indeed the growth of the industry certainly a successful story, for which there are few comparisons in Indian industrial history.

The Sago industries in the Salem district and the adjoining areas have witnessed a phenomenal growth in the last 65 years, as shown below:

**Table 1.1 Growth of Sago Units and Production (Last 65 Years)**

<table>
<thead>
<tr>
<th>Year</th>
<th>No of units</th>
<th>Production (in tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1913</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>1945</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>1949</td>
<td>45</td>
<td>7000</td>
</tr>
<tr>
<td>1957</td>
<td>125</td>
<td>23000</td>
</tr>
<tr>
<td>1960</td>
<td>200</td>
<td>50000</td>
</tr>
<tr>
<td>1970</td>
<td>650</td>
<td>1.5 lac tons</td>
</tr>
<tr>
<td>1980</td>
<td>655</td>
<td>584660</td>
</tr>
<tr>
<td>1990</td>
<td>660</td>
<td>716800</td>
</tr>
<tr>
<td>2000</td>
<td>791</td>
<td>964700</td>
</tr>
<tr>
<td>2010-11</td>
<td>364</td>
<td>300,000 tons</td>
</tr>
</tbody>
</table>

*Source: Sagoserve, Salem.*

Tapioca is one of the richest sources of starch. Tapioca was introduced in India during the later part of the 19th century. Now, mainly grown in the states of Kerala, Andhra Pradesh, and Tamil Nadu. The other
important tapioca producing countries are Brazil, Nigeria, Zaire, Thailand and Indonesia. Products from tapioca like Starch and Sago introduced in India only in 1940s upwards. First by hand manually and later developed into indigenous production methods. There are about 364 Sago and Starch units situated throughout Tamil Nadu. Though the Sago industry is mainly spread over Salem, Namakkal, Dharmapuri, Erode, Tiruchirappalli, Perambalur, and Thiruvannamalai districts, the Salem and Namakkal districts are known to have the highest concentration of Sago units. While most of the centres are known for simple Sago production, some of the units at Salem also produce ‘Nylon Sago’ a special product which is made by subjecting the Sago balls to steam cooking. It is an important staple food cum industrial crop of the tapioca. More than two third of the total production of tapioca in the world is used as staple food. Almost 5 to 7 per cent are as industrial raw material and the rest as animal feed.

Starch has a great demand for industrial use and being the most important use to the sector such as: textile, paper, adhesive, dextrin, food and sweetener industries. In addition to the major industries which use starch, there are number of other applications of starch which are encountered in many fields. Though these industries use starch in small quantities, the total quantity of starch utilized is quite large. Some of the major uses are soap and detergent industry, laundry starch, cosmetic uses, pharmaceutical uses, horticultural uses, fire proofing preparations, in
explosives, in drilling muds in optical whiteners, in leather treatment. Sago processed from edible starch is a very popular food as it is easily digestable and it is widely used in several parts of India for feeding invalids and infants. Also it can be used to prepare a variety of dishes. A number of processes of fortification of Sago and starch products have been described.

In recent years, the quality of sago has been fall down due to adopting of unhealthy business practices by some of the sago manufacturers. Actually the sago industry is passing through a changing phase, where the conflict is between traditional type of production and new technology, through which production can be increased multi fold. A thorough research should be needed at once keeping in mind the uses of sago and acceptance of taste and varieties in India. The general sago consumers are losing confidence in sago and sago products. They are facing problems at the time of food preparation as “Sticky Khichadi”, bad smell, undigestive or begin liquid after soaking in water. But scientists have suggested that sago is a very pure and good, digestive food and is very good for health, sago is not harmful, harmful are the chemicals used in production of the sago.

In India, pearl sago is called ‘Javvarisi’, ‘Sabudana’ (Hindi) and ‘Saggubeeyam’ (Telugu) among other regional and local names, and is used in a variety of dishes such as desserts boiled with sweetened milk on occasion of religious fasts. In the UK both sago and tapioca have been used in milk puddings, and have become confused to the extent that “sago” as
sold in supermarkets is now almost invariably made of tapioca starch. In Ayurvedic medicine, it is believed that sago porridge can be an effective and simple food to “cool and balance one’s body heat” when taking strong medicine or antibiotics.

Next to Salem District, tapioca is cultivated in Namakkal district in abundance, using tapioca as raw material about 136 units are engaged in the production of starch and sago in this district. There is a good market for sago and sago products in north India. In Tamilnadu, this crop is being cultivated over an area of about 82,000 hectares providing employment for thousands of workers over fields and in 800 processing units. In Salem district alone, 34,000 hectares of land is under tapioca cultivation and there are 650 units engaged in tapioca processing. The district offers good raw material, cheap labour and good sunshine for a longer period of the day throughout the year, helping manufacturers to produce more tapioca finished products. Sago and starch and therefore the district of Salem is known as the land of sago, even in the international forums.

1.2 Manufacturing of Sago Production

Tapioca Sago is generally Known as SAGO (SABUDANA in Hindi or JAVAVARISHI in Tamil) in India. Sago is a produce, prepared from the milk of tapioca root. Its Botanical name is "Manihot Esculenta Crantz Syn.Utilissima". This is a well known crop that is recognized by several names in the various regions where it is consumed. Tapioca root has a high
resistance to plant disease and high tolerance to extreme stress conditions such as periods of drought and poor soils. Fresh roots contain about 60 to 70 per cent moisture, 7 to 12 per cent protein, 5 to 13 per cent starch (32 to 35 per cent total carbohydrate) and trace amounts of fat. The high starch and moisture content render it extremely perishable. Processing is therefore indispensable to facilitate preservation, improve palatability and product quality as well as reduce cyanogenic glycoside toxicity.

Currently, Tamilnadu stands first in respect of processing of tapioca into starch and sago, in India. In India, Sago was produced first in Salem and in Namakkal Districts of Tamilnadu. About in 1943-44, Last 65 years ago, sago production started on a cottage scale basis in India by pulping the tapioca roots, filtering the milk-extract and after settling the milk, forming globules and roasting these globules. There is about 30 to 35 per cent starch contents generally in Indian tapioca root. India is one of the leading countries in tapioca production.
**Table 1.2 Manufacture of Starch**

<table>
<thead>
<tr>
<th>Source</th>
<th>Kg.</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots</td>
<td>1000</td>
<td>-</td>
</tr>
<tr>
<td>Cleaned roots</td>
<td>980</td>
<td>98.0</td>
</tr>
<tr>
<td>Cleaning loss</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>Starch</td>
<td>250</td>
<td>25.0</td>
</tr>
<tr>
<td>Azhukkumavu</td>
<td>20</td>
<td>2.0</td>
</tr>
<tr>
<td>Dried thippi</td>
<td>70</td>
<td>7.0</td>
</tr>
<tr>
<td>Drying loss (water)</td>
<td>-</td>
<td>6.4</td>
</tr>
</tbody>
</table>

**Table 1.2.1 Manufacture of Sago**

<table>
<thead>
<tr>
<th>Source</th>
<th>Kg.</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots</td>
<td>1000</td>
<td>-</td>
</tr>
<tr>
<td>Cleaned and peeled roots</td>
<td>800</td>
<td>80.0</td>
</tr>
<tr>
<td>Cleaning loss</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td>Peels (refined)</td>
<td>200</td>
<td>20.0</td>
</tr>
<tr>
<td>Thippi dry</td>
<td>35</td>
<td>3.5</td>
</tr>
<tr>
<td>Sago</td>
<td>235</td>
<td>23.5</td>
</tr>
<tr>
<td>Broken sago</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Azhukkumavu</td>
<td>20</td>
<td>2.0</td>
</tr>
<tr>
<td>Drying loss (water)</td>
<td>-</td>
<td>61.5</td>
</tr>
</tbody>
</table>

Source: Sagoserve, Salem
1.3 Process of Sago Production

The Tapioca root, received from the farms are hygienically cleaned in water and after peeling the skin, it is crushed, allowed to pass the milk after retaining all fiber and impurities. The milk is going to settle in a tank for nearly 3 to 8 hours, thus all residual impurities float to the top of the tank and are drained out of the settled milk. From this settled Milk Cake, Globules are made by a very special and unique type system on very simple indigenous machine. After sizing the globules by filtering through sieve, it is roasted on hot plates or heated in steam, depending upon the desired final product as Sago in globular shape and than dried under direct sunlight in big platforms. Roasted Sago is known as **Sago Common** and Boiled Sago as **Nylon Sago**.

The process of manufacturing came into being many decades ago in Salem as a home industry and even today the process involves manual labourers. Salem district offered several advantages for the establishment and nature of the Sago/ starch industries, the important being favourable weather conditions like good sunlight and dry weather. The average temperature and humidity in this district are about 30 to 40 and 75 to 78 percent, respectively. This low humidity and high temperature suits very much to one of the important unit operations in the manufacturing of starch and Sago drying. Also the rainy season has a short spell of about 3 months in this district. Another advantage is the availability of raw material grown in
Salem and neighbouring districts of South Arcot and Dharmapuri. Manufacturers are also getting tubers from Kerala to fill the gap between demand and supply which is hardly 300 kilometers away from Salem. Availability of cheap labour, incentives provided by the Government of Tamil Nadu in the district of Salem are other positive features.5

**Chart 1.1 Manufacturing Process Flow Sheet for Production of Starch and Sago**

**TAPIOCA ROOTS**

↓

Peeling and washing

↓

Rasping

↓

Screening

↓

Dewatering

↓

Drying

↓

Pulverization

↓

Globulation

↓

Sizing

↓

Roasting

↓

Drying

↓

Polishing

↓

Dry screening

↓

Packing

↓

**Product Starch**

↓

Product Sago
Fresh roots are washed in large open tanks, mechanically crushed in a rotating drum fed continuously with water, and the resultant slurry sieved over a series of reciprocating screens to separate the starch ‘milk’ from the fibrous pulp. The milk then flows into granite lined settling tanks or tables. After a period of settling and compaction, assisted by labourers walking on the starch, the waste is drained away to secondary settling tanks. The settled starch ‘cake’ is dried on large concrete sun drying yards, before finishing and bagging. The fibrous residue from the screening process and starch from secondary settling is dried and sold for animal feed.

The starch extraction process requires large volumes of fresh water, many factories with the availability of fresh water is the necessary quality and an increasing problem due to expanding domestic, agricultural and industrial demand for water. Furthermore the water consumed in starch production in many factories is discharged as highly polluting effluent, often with minimal treatment to adjacent water courses. Water authorities, in most location are extremely concerned about the situation, but the lack of effective and affordable treatment technology and the socio-economic implications of enforced factory closures mitigate the remedial action. The introduction of technology to reduce water consumption in starch production would have two advantages, firstly, an alleviation of the restriction on processing on capacity imposed by shortage of fresh water and, secondly, a reduction in the volume of waste waters produced.\textsuperscript{6}
1.4 Processing Operation of Sago Industry

The separation of the starch granules from the tuber in a pure form is essential in the manufacture of tapioca flour. The granules are locked in cells together with all the other constituents of the protoplasm, which can only be removed by a purification process in the water phase. Processing the starch can be divided into the following stages:

i. Washing and Peeling

Root tubers are washed manually to remove adhering dirt. The tubers are then cut longitudinally and transversely to a depth corresponding to the thickness of the peel, which can be easily removed. Any dirt remaining on the smooth surface of the core of the tuber is then washed off and the peeled tubers are put in a concrete tank, where they remain immersed in water until taken out for rasping.

ii. Rasping

The peeled roots are subjected to high-pressure water jets during conveying for rasping. It is necessary to rupture cell walls in order to release the starch granules. Rasping facilitates rupture of cell walls and release of starch granules. This is carried out by pressing the roots against a swiftly moving surface provided with sharp protrusions. A large quantity of water is added to the roots during this process. The cell walls get ruptured during rasping and the whole root is turned into a mass in which substantial portions of the starch granules are released. It is difficult to remove all the
starch in a single operation even with efficient rasping devices. Therefore, the pulp is subjected to a second rasping process after straining. Rasping is usually done in machines using a wooden roller over which the sheet metal rasping surfaces are nailed with the burry facing outward.

iii. Straining

After rasping, the pulp is screened in the shaking screens. In separating the pulp from the free starch, a liberal amount of water is added to the pulp as it is delivered by the rasper and the resulting dispersion is stirred vigorously before screening. The fresh pulp after mixing with water in distribution tanks and after it is transferred by pipes to the higher end of the screen. During screening, the dispersion passes through a set of screens with increasing fineness, the first one retains the coarse pulp, the others the fine particles. The ‘overs’ from the first screen are returned to the fine rasp and then returned for re-screening.

iv. Settling and Purification of Starch

After the separation of starch by screening, the starch milk is subjected to a settling process. The starch milk is pumped to a tank fitted with effluent outlets at varying heights. Settling takes about 6 to 20 hours depending on the quantity as well as the size of the settling tank. Settling is an important unit operation in tapioca processing where the extracted starch is separated from its aqueous dispersion under gravity. The upper layer of sediment flour, which has a yellowish green tint, contains many impurities
and is generally scraped off and discarded. The remaining moist flour is then stirred up with water and transferred to another tank where starch is settled. The final settled moist flour is removed by using a crowbar. In Tamil Nadu, most of the tapioca starch industries invariably adopt settling tank for separation of starch.

v. Drying

Drying of starch is generally done by sun drying in the drying yards and then sent for further processing for the production of sago. The removal of free water from the starch sediment obtained from settling tanks or centrifuges must be dried by evaporation either in the open air (sun drying) or by mechanical dryers. The mechanical dryers used for this purpose include drying ovens, chamber dryers, drum dryers, belt dryers, tunnel dryers, pneumatic dryers etc. Though mechanical drying is costly, more uniform and quicker drying is possible while using mechanical dryers besides facilitating drying throughout the period irrespective of whether condition.

vi. Hydrogen Cyanide (HCN) in Tapioca

Cyanagenic glucosides are synthesized in the Cassava leaves and stored in the roots. The problems of inherent nutritional hazard and high perishability of the roots call for elaborative processing prior to consumption. The major factor which limits or affects the utilization of as a food for man is its content of the toxic hydrogen cyanide in both free and
bound forms. Effective processing can reduce all cyanogens in Cassava products to below the safe level.

**vii. Effluent from Cassava Industries**

Because of the rapid chemical changes occurring in the solution of starch dispersion, fermentation takes place resulting in the production of alcohol and organic acids especially butyric acid. Hence the process of separation of pure starch from starch milk should be done without time delay. Wastewater from tapioca processing factories containing high chemical oxygen demand and causes of water pollution.

**viii. Finishing and Packaging**

Crude dry tapioca flour consists of hard lumps of starch. As it cannot be used as such, it has to be subjected to a pulverizing process followed by dry-screening. Roller crushers can be employed for pulverizing and a sieve size of 100 to 200 meshes is used for screening. It is finally packed in jute bags.⁷
CHART 1.2 USES OF TAPIOCA ROOTS

Tapioca Roots

- Sago
  - Human: Direct food
  - Animals: Chips, Pellets, Pulp

- Starch
  - Direct food
  - Industries: Food Industries, Non-food Industries

Food Industries
- Glucose Industry
- Seasoning Powder Industry

Non-food Industries
- Paper Industry
- Textile Industry
- Plywood Industry
- Glue Industry
- Alcohol Industry
CHART -1.3
Tapioca Root processing into value – Added products

Tapioca Root

- Tapioca starch
  - Direct Consumption
    - Sago pearls
    - Noodles
    - Traditional desserts
  - Modified starch
    - Acetylated: Sauces, frozen food, instant soup, pastries, glue
    - Cross linked: salad dressing, canned food, sauces, desserts
    - Oxidized: Candies, instant soup, salad dressing, paper, textiles
    - Cationic: Paper, textiles
    - Alpha: animal food, mosquito coil, sauces, desserts
- Tapioca chips and Pellets
  - Animal food
  - Alcohol: fuel
  - Citric acid
- Direct Consumption
  - Boiling roasting
  - Drying: flour
- Peels and Pulp
  - Animal food
  - Compost
  - Mushrooms

- Sweeteners
  - Glucose/ Dextrose: Candies beverages, canned food, medicine, creamers
  - Fructose/ high fructose syrup: beverages, pastries, dessert, candies, sauces
  - Sorbitol: toothpaste, cosmetics, Vitamin C

- Alcohol
  - Ethanol: liquor, industrial and medical alcohol

- Organic acid
  - Citric acid

- Amino acid and derivatives
  - Monosodium glutamate
  - Lysine: animal food
1.5 Uses of Starch and Sago

Broadly speaking starch is employed by two categories namely food and non-food industries. The industries utilizing starch can be basically divided into food and non-food sectors. As such starch for the animal feed sector, is included as a non-food.\textsuperscript{8}

1.5.1 Uses of Sago

|-------------|--------|----------|

1.5.2 Uses of Starch

I. Food Sector

1. Bakery and Pastry Products
2. Noodles, Vermicelli, Rava, Maida
3. Soups, Sauces
4. Ice Creams, Yoghurts, Lactic Drinks, Puddings
5. Processed Meats
6. Sweets, Chocolates, Candy, Chewing Gum
7. Marmalades, Jams
8. Canned Fruits, Juices
9. Soft Drinks, Beers
10. Snack Foods
11. Taste Enhancers, Colour Enhancers

12. Fat Substitutes for Dietary Products

13. Alternative Protein Sources

14. Sweetners

II. Non Food Application of Starches

i. Adhesives

1. Hot – Melt Glues

2. Stamps, Bookbinding, Envelopes

3. Labels (Regular and Waterproof)

4. Wood Adhesives, Laminations

5. Automotive, Engineering

6. Pressure Sensitive Adhesive

7. Corrugation

8. Paper Sacks

ii. Explosives Industry

1. Wide Range Binding Agent

2. Match – Head Binder

iii. Paper Industry

1. Internal Sizing

2. Filler Retention

3. Surface Sizing

4. Paper Coating (Regular and Colour)
5. Carbonless Paper Stilt Material
6. Disposable Diapers, Feminine Products

iv. Construction Industry
1. Concrete Block Binder
2. Asbestos, Clay or Limestone Binder
3. Fire-Resistant Wallboard
4. Plywood or Chipboard Adhesive
5. Gypsum Board Binder
6. Paint Filler

v. Metals Industry
1. Foundry Core Binder
2. Sintered Metal Additive
3. Sand Casting Binder

vi. Textiles Industry
1. Warp Sizing
2. Fabric Finishing
3. Printing

vii. Cosmetic and Pharmaceutical Industry
1. Dusting Powder
2. Make–Up
3. Soap Filler or Extender
4. Face Creams
5. Pill Coating, Dusting Agent

6. Tablet Binder or Dispersing Agent

viii. **Mining Industry**

1. Ore Floatation

2. Ore Sedimentation

3. Oil Well Drilling Muds

ix. **Miscellaneous**

1. Bio-degradable Plastic Film

2. Dry Cell Batteries

3. Printed Circuit Boards

4. Leather Finishing

**III. Chemical and Pharmaceutical Industry**

1. Glues, Paints, Cements

2. Soaps, Detergents, Bleaches, Insecticides

3. Explosives

4. Oil Drilling Materials

5. Bio-Degradable Plastics, Polyesters,

6. Industrial Alcohols

7. Combustibles, Ethanol, Oils

8. Pharmaceuticals, Vitamin c and b\textsubscript{12}, Antibiotics

9. Cosmetics

10. Water Treatment Agents.
1.6 Food Industries

Tapioca flour is largely used by food industries because of its special characteristics. They include the fact that it aids the thickening and solidifying process, gives a sticky and preserves the balance of water in various foods. Tapioca flour is consequently employed as a feed stock by industries making such products as soup, candy, pudding, sausages, bread, ice-cream and vermicelli. It is used as a binder by the pharmaceutical industry in making palletized machine. Moreover, due to its saccharification property tapioca flour is used for manufacturing food seasoning, glucose, fructose, soft drinks and canned food.

1.6.1 Glucose Industry

Tapioca starch accounts for as much as 80 per cent of the total raw materials made use of by the glucose industry. The flour however, has to be of the ‘super grade’ variety demand for this type of tapioca flour by the glucose industry is estimated at 10,000-15,000 tonnes annually. Glucose syrup is a solution derived from saccharification of starch. It is further purified and made into a concentrate, which is highly popular and is used for making sweets and drinks.

1.6.2 Seasoning Powder Industry

Seasoning powder is highly popular. It scientific name is monosodium glutamate. The substance was first synthesized by a Japanese professor who used sea-wed for the production of amino acid. Now tapioca
starch and molasses are used instead. It is estimated that 2.4 tonnes of tapioca starch which accounts for 50.06 per cent of total raw materials is required to produce one ton of seasoning powder.

1.7 Non-food Industries

The bulk of tapioca starch is used as feed stock for the production of paper, textiles, glue plywood and alcohol.

1.7.1 Paper Industry

Raw materials, such as wood, grass, straw and biogases are defibrized into pulp, which is further processed into paper. Surface treatment is needed in the production of quality paper, as it increases surface smoothness, improves appearances, increases strength and prevents water penetration into the paper. A solution made from tapioca starch and other substances including sizing agent and pigment particles, is used in the surface treatment process. This process is called surface sizing, in which the starch solution increases the smoothness of the surface and tills up pores, making it smoother to write on and harder for penetration. Some of the solution will penetrate into the paper, making it stronger and more resistant to shear.

1.7.2 Textiles Industry

Tapioca starch is used by the textile industry in treating yarn smoother and less fluffy while increasing its tensile strength. Starch is applied to the yarn in the warp sizing process. The treated yarn is dried
mechanically and printed. Tapioca flour assists in making printing more even.

1.7.3 Plywood Industry

Tapioca starch is used for making glue which is an important raw material of the plywood industry. The strength and the quality of plywood depend largely on the quality of the glue. Tapioca starch is highly appropriate for making this glue and is consequently used in large quantity, accounting for about 50 per cent of the raw materials. Glue made from tapioca starch has fine texture and is relatively cheap.

1.7.4 Glue Industry

Tapioca starch becomes sticky when it is mixed with hot water or certain chemicals. It stays over a very long period of time. However, only purified, low-acidity tapioca starch is fit for making industrial glue, namely dextrin and oxidized starch.

1.7.5 Alcohol Industry

Increased priority has been given to alcohol along with other non-oil energy like wind, solar power and bio-gas. In several agricultural developing countries experiments have been conducted to produce alcohol as a substitute for petroleum. Where a large volume of alcohol is produced yearly and is mixed with gasoline to form what is called ‘gasohol’. The mixture proves as good as gasoline and less polluting when used in motor vehicles. In Thailand, ethanol is produced 70 per cent of it being for domestic
consumption and the rest for export. The former is accounted for mainly by the alcoholic beverage industry and hospitals. Tapioca is an raw material for alcohol manufacture, while supply is abundant all year round and its prices low. Production of ethanol per unit of tapioca is quite high, as experiments show that ton of fresh tapioca yields 180 litres of 95 per cent ethanol.

There is a great need for diversification of tapioca processing industry. Polarization of tapioca for cattle and poultry feed is a promising one. Also more attention should be given for starting of more tapioca starch leased industries for the production of alcohol, liquid, glucose, dextrin and lactic acid in the small sector for which indigenous equipments, machineries and process are to be made available.\(^\text{11}\)

1.8 New Cassava Products of Future Potential in India

Cassava (\textit{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 neighbouring state of Tamil Nadu. Cassava cultivation in Kerala and the North-Eastern 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 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 the 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 neighbouring 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.
1.8.1 Food Products

i. 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 process developed suits the cottage and small-scale industry programmes. 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 per cent 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 per cent. 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, and puddings products which require fast miscibility of starch in milk and water. 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 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 flavour to the product.

ii. 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.

iii. 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 colours and salt are added.

iv. Wafers

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

**v. Fried Chips**

Fried chips are made by deep frying thin french fries made from cassava. The roots are washed thoroughly and the peel and rinse 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.

1.8.2 Poultry and Animal Feeds from Cassava

i. 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 per cent 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.

ii. Ensiling Technology

The poor post-harvest 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.
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. Cassava silage substituted at levels of 28 per cent 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.

1.8.3 Cottage Industries

i. 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.

ii. 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.

**iii. 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 colour 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 is gelatinized. The consistency of the paste is gauged by the appearance and flow ability 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 flavour. However, it cannot be stored for more than two days as the pastiness is lost, and it becomes too thick to handle.

**iv. Gums Prepared by 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 flow ability, 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.

1.8.4 Large-Scale Industries of 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 colour of starch or sago, and improved waste disposal by way of conversion to feed, fertilizers and biogas, this can help the starch manufacturers to increase product turnover through augmented internal demand and export opportunities.

i. 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 per cent. 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.

1.8.5 Sweeteners

i. 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 per cent dextrose, which is used by many confectionery industries in India.

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

ii. 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 isomerised to fructose using commercial glucose isomerise enzyme at 62°C in glass-lined tanks for 6 h at pH 8.0. The fructose solution
is decolourized and vacuum-concentrated to obtain a syrup containing 45 per cent fructose, 50 per cent glucose and 5 per cent oligosaccharides. Though the technology is readily available, the Indian industry has yet to come forward to exploit it fully.

**iii. Maltose**

Maltose is obtained commercially from starch by enzyme treatment. There are three types of commercial maltose syrups, high maltose syrup, extremely high maltose syrup and high conversion syrups. The process for maltose manufacturing involves in two steps, liquefaction of starch by heat and a thermo labile a-amylase, and saccharification using microbial. The maltose syrup is used in brewing, baking, soft-drink manufacturing, canning and confectionery industries.

**iv. 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 y-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 or 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 lactic acid and citric acid can be produced from starch.

v. Bio-Degradable 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 per cent of the requirements being met by imports. Agricultural and packaging
sectors account for about 50 per cent 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 in mixing and blending starch with suitable synthetic polymers, 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 per cent cassava starch and appropriate amounts of suitable gelatinizing, plasticizing and coupling agents.

Films containing starch above 20 per cent 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 per cent 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 per cent as the starch content varied from 10 per cent to 40 per cent. In comparison, the tensile strength and elongation values of the LDPE control films were 10.97 MPa and 38.4 per cent, 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 bio-degradation (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 bio-degradable 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 bio-degradability 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.

vi. 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.

1.8.6 Future Thrust Areas for Cassava Utilization

i. 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 South-Eastern 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.

ii. 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 are ideal food items for village-based food industries. Similarly, the technology developed for the production of gums, adhesives, cold soluble starches, may also promote rural industrial growth in Kerala, Tamil Nadu, Andhra Pradesh and the North-Eastern provinces. The target markets for such products are urban and semi-urban areas.

1.8.7 Cassava-Based Large-Scale Industrial Units

Novel products made out of cassava, such as bio-degradable 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 bio-degradable polymers incorporating cassava starch has given new hope to the country in tackling the problem effectively. The bio-degradable 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. 12
END NOTES


4. Sago an introduction
   http://www.sabuindia.com/sago1.htm

5. Process of sago production
   http://www.sagoserve.com/tapioca.com/production.htm


