Energy Recovery from Tapioca Processing Industry – Sustaining the Industry in the Post WTO Scenario

A Project Report

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ABSTRACT

The tapioca processing industry produces large quantities of wastewater that has very high COD and BOD. The industry is highly energy intensive and capital intensive. However, no standard relations between profitability and energy consumption and energy utilization hitherto exist. Its utilization pattern of both electrical and thermal energy is largely unaccounted for.

The high organic content of the wastewater makes it a suitable candidate for anaerobic digestion not only to reduce its COD and BOD but also to produce methane that can serve as an energy source to meet the industry's both electrical and thermal loads. The Upflow Anaerobic Sludge Blanket Reactor's (UASBR) applicability in special is widely acknowledged.

In the present work "**Energy Recovery from Tapioca Processing Industry – Sustaining the Industry in the Post WTO Scenario**" by calculations and field data a figure for energy consumed was attempted to arrive at. Laboratory scale experiments were done to analyze the possibilities for improving biogas generation and the results were translated to industrial scale.

17 Industries were carefully analyzed for their energy consumption data (in terms of electricity and fuel consumed) and based on these findings a reactor model was suggested that could give the compensating biogas to run a 300 kVA engine which could meet the requirements of the industry.

Finally the economic benefits of the technology along with the costs involved were analyzed. The role Government and Industrialists must take to survive the shrinking markets has been pointed out.

సంక్షిప్తం

తమిళ నాడులో సేలం ప్రాంతంలో కర్రపేండలాన్ని దంచి అందులో నిక్షిప్తమైన స్టార్చ్ కణాలనుంచి సగ్గుబియ్యం తయారు చేసె చిన్న తరహా పరిశ్రమలు ఎన్నో ఉన్నాయి. కాని వీటి వలన అక్కడ భూగర్భ జలాలు కలుషితం అవుతున్నాయి. ఈ కాలుష్యానికి కారణం ఈ పరిశ్రమ నుంచి వెలుబడె నీటిలో అధికంగా ఉన్న BOD మరియు COD పరిమాణాలు.

ఈ పరిశ్రమ కొన్ని ఏళ్ళుగా బాగా నష్టాల్లో నడుస్తోంది. ఇందుకు ఒక కారణం ఈ పరిశ్రమ వాడె శక్తి. ఈ పరిశ్రమని కాపాడక పోతె, వాటికె కాక వీటితా ముడిబడి ఉన్న మిగితా పరిశ్రమలు దెబ్బ తింటాయి. ఈ నీటిని సుభ్రం చేయడానికి UASBR అనె రియాక్టర్ని వాడుకోవచ్చు. దీని వలన ఇంకొక లాభం దీని నుండి వెలుబడె బయొగాస్.

ఇక్కడ 17 పరిశ్రమలను పరిశీలించి వాటి విద్యుత్ మరియు కర్ర ఉపయొగాలను పరిగణంలోకి తీసుకోని వీళ్ళు వాడె శక్తిని లెక్కవేయడమైనది. ఏంత బయొగాస్ ఉత్పత్తి అవుతుంది అని పరీక్షలు నిర్వహించబడినవి. వీటిని ఆధారంగా తీసుకొని ఈ పరిశ్రమను కాపాడలి అంటె ప్రభుత్వం ఏమి చర్యలు తీసుకొవాలా అన్నది చర్చించబడినది.

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CHAPTER 1

INTRODUCTION

1.1 TAPTIOCA: AN INTRODUCTION

Cassava (*Manihot Esculenta Crantz*) is better known the world over as Tapioca. This plant belongs to the Euphorbiacae family with 160 known varieties under cultivation. Tapioca or cassava is grown throughout the tropical parts and is one of the important starchy root crops in the tropic. The plant grows to a height of 1 - 3 m and several roots may be found on each plant.

TABLE 1.1 WORLD TAPIOCA CULTIVATION TRENDS

Sl. No.	Country	1979 – 80			1989 – 90			1999 – 2000		
		I	II	III	I	II	III	I	II	III
1	World	13.59	123.97	9.12	15.63	157.65	10.08	17.81	176.8	9.93
2	Asia	3.78	44.15	11.64	3.96	51.44	12.97	3.8	49.4	14.6
3	Africa	7.05	49.08	6.96	8.93	73.3	8.2	11.09	94	8.42
4	Latin America & Caribbean	2.73	30.58	16.41	2.72	32.71	17.25	2.8	31.9	18.25

With an annual output of tapioca during early 1980's standing at 126 million tonnes by the turn of the 90's it grew impressively by 22% and over the next decade a further improvement of 14% the annual production during the crop year 2000 was 175 million metric tonnes. Some world figures for tapioca cultivation area (I) (in million hectares), production (II) (in million tonnes) and productivity (III) (in tonnes/hectares) are shown in Table 1.1.

Sub-Saharan Africa countries account for 50% of world's production whereas the productivity levels have remained stagnant over many years. Tapioca as a food is more prominent in sub – Saharan Africa with an estimated 60% of total tapioca production consumed as food during 1980's. However, these levels are coming drastically down due to various reasons. Table 1.2 shows the trends in important Asian countries.

TABLE 1.2 TAPIOCA CULTIVATION TREND IN IMPORTANT ASIAN COUNTRIES

Sl. No.	Country	Under Cultivation (000 ha)			Production (000 tonnes)			Productivity (tonnes/ha)		
		1978	1988	1998	1978	1988	1998	1978	1988	1998
1	India	345	270	244	5921	5213	5868	18	19	22
2	Indonesia	1413	1303	7531	13500	15471	14728	10	12	19
3	Thailand	1053	1547	6527	15128	22307	15591	14	14	16
4	China	231	237	230	3390	3435	3600	14	14	15

1.2 TAPIOCA IN INDIA

Tapioca was first introduced in India during the 17^{th} Century in Kerala and was promoted by the erstwhile rulers of Kerala as a food crop to suit as a source of carbohydrate. This crop became more popular in the southern states of this country due to it's tolerance to draught, its ability to grow on a variety of soils, low levels of investments on comparison with other crops and low levels of known pest and other forms of damages. It is estimated that about 24 lakh hectares are under cultivation with an average production of 5.1 million tonnes.

Of the total area under cultivation in India 9% is contributed by Andhra Pradesh, 61% by Kerala and 29% by Tamil Nadu and the rest of the states like Karnataka, Assam, Meghalaya, Tripura. On comparison except Tamil Nadu where the average yield is about 30 – 35 tonnes/ hectare, the rest of the southern states record average yields of 10 – 13 tonnes/hectare whereas other states range between 2 tonnes/hectare to 6 tonnes/hectare.

Though Kerala ranks first in cultivation and production in India, Tamil Nadu stands first in respect of highest yields per hectare and in respect of processing of tapioca into starch and sago and hence, this crop has acquired a status of a commercial crop in the state. Tapioca and its finished products are used as food, animal feed and as raw material for several industrial products.

1.3 TAPIOCA IN TAMIL NADU

The relevance of tapioca in Tamil Nadu is ever increasing. Historically, the demand for starch during and after the World War II brought tapioca production to Tamil Nadu. During the 1960's, local restrictions imposed on exporting processed tapioca products from Kerala further encouraged tapioca farming in Tamil Nadu and the focus was always industry-centric. Table 1.3 shows figures from 70's to end of 90's.

During the early 60's the growth rate of Tapioca cultivation in Kerala was positive with 3.12% and fell to (1) 2.3% on comparison throughout the late 70's and early 80's. To put in a nutshell the happenings of they decades, the average annual growth rate of tapioca production in Tamil Nadu stood at 7.2 – 7.5% and in Kerala at 2.9%. The important difference between the two states is in their application for Kerala uses it as a food source whereas in Tamil Nadu it is produced for industrial purposes.

TABLE 1.3 TAPIOCA CULTIVATION & PRODUCTIVITY PATTERN IN TAMIL NADU

Sl. No.	Year	Average area in cultivation ('000 ha)	Average production ('000 mT)	Average productivity (T/ha)
1	1970 – 71	45.00	481.60	10.80
2	1980 – 81	46.00	909.00	18.00
3	1990 – 91	54.00	1582.60	29.00
4	1996 – 97	77.40	2794.00	36.00

1.4 SALEM: EXPERIENCE WITH SAGO SERVE

Salem has traditionally been the land of sago and starch. The Salem region offers good raw material, cheap labour and good sunshine for a longer period of the day throughout the operating season (from September to March) helping manufacturers to produce more tapioca-based products like sago and starch. In and around Salem, the yield of tapioca reaches as high as 30 tonnes/hectare, a world high, though the average yield is only 20 tonnes/hectare. The national average is 19 tonnes/hectare while the world average is 10 tonnes/hectare.

Currently Salem accounts for 95% of total sago and starch production of India, the remaining 5% being shared between Andhra Pradesh and other regions. The entire tuber required for the industry is now grown in Tamil Nadu itself. Initially tuber cultivation was concentrated in the old Salem district which has now, however spread to nearby regions of Attur, Namakkal, Dharmapuri, Erode, Trichy, Tanjavur and Cuddalore etc.

Prior to the formation of the Sago Serve an Industrial Cooperative Service Society was in operation. The manufacturers of sago and starch faced lot of problems pertaining to credit and marketing of tapioca products. Merchants had to offer lower prices while the middlemen profited because of lack of any organized marketing and warehousing facilities.

To overcome these limitations the manufacturers of sago and starch formed the "Salem Starch and Sago Manufacturers' Service Industrial Cooperative Society Ltd." in 1984 in Salem under the Tamil Nadu Cooperative Societies Act 1961. This society, now popularly known the world over as "Sago Serve" is functioning under the administrative control of Director of Industries and Commerce, which in turn is under the Small Industries Department of the Government of Tamil Nadu. Today all units are registered with Sago Serve and all their products sold at the same platform.

1.5 THE INDUSTRY

The industry has more than 800 sago and starch units, which are registered with Sago Serve. Out of this, only 450 units are active today due to economic recession. Almost all these sago and starch units are either proprietary or partnership firms. The industry does not maintain any records of its performance.

The industry is seasonal in nature with tuber crushing on typically 200 days and sago production on for about 300 days. Out of this, the industry will run at the rated load for about 150 days. Crushing depends on the starch content of the tuber. The industry employs casual labour during season and has only a few permanent staff as supervisors. Some units store wet starch during season and produce sago on a low capacity and as demand basis during off-season periods.

1.6 ADVANTAGES OF TAPIOCA PRODUCTION

The attractive aspects of tapioca production are:

1. On a per unit land comparison, tapioca yields higher amounts of carbohydrates.
2. The cost of cultivation is cheap
3. It is less vulnerable to diseases
4. It suits for inter-cropping with perennials

Though many governments the world over have given considerable importance to this crop, the ever changing scenario of food demand & supply, and preference to a particular quality of food demands reorientation of the present seriousness of R & D activities on crop production and related industrial activities.

1.7 PROBLEMS ASSOCIATED WITH THE INDUSTRY

Tapioca starch production was found to produce the wastewater in large quantity. The tapioca starch industry causes water pollution problems from its wet processing operation.

The combined wastewater chiefly comprises the streams from root washer and separators in the manufacturing processes. In general, tapioca starch wastewater is highly organic, but has relatively low nitrogen and phosphorus concentration. Starch wastewater contains minute suspended solid and dissolved solids. The amount of combined wastewater generated per 1-tonne starch produced is 30-50 m^3 and is highly concentrated. The combined tapioca starch wastewater is acidic in nature due to the release of some prussic acids by the tapioca roots.

The other important problems associated with this industry can be listed as follows.

1. The industry promoters are not educated and still depend on age-old machinery for processing.
2. Unfortunately in the last 10 years no industry has modernized.
3. Because the old plant and machinery were not modernized the industry became energy intensive.
4. Though the technology is available, many modern processes and techniques were not implemented. For e.g. drying of sago by open solar radiation can be further improved by solar driers; however, this has not been adopted.
5. Preheated water by solar water heaters could as a replacement for ambient water was not adopted.
6. Their products are not market driven but are run as conventional businesses. As a result, remunerative pricing mechanism could not help them.
7. It was observed that Sago Serve acted merely as an outlet of the product of the promoters, but has shown very little interest in the overall growth of the sago industrial activity in promoting the products or in value addition.

1.8 IMMEDIATE OPTIONS

1. Tapioca industry must derive its energy requirements from its internally available resources like peels, thippi and ETPs to produce biogas.
2. Treatment plants must be designed to meet the total energy requirements of the industry. Lower grade fresh tapioca tubers can be used as supplements.
3. Based on the location of industries as clusters, common energy sourcing plants along with wastewater treatment needs to be explored.
4. The overall total energy consumption by this industry can be switched over to generate electric power from Tapioca itself as an emerging new technology option.

With the options available Tapioca cultivation should be done with mind on energy security for the industry.

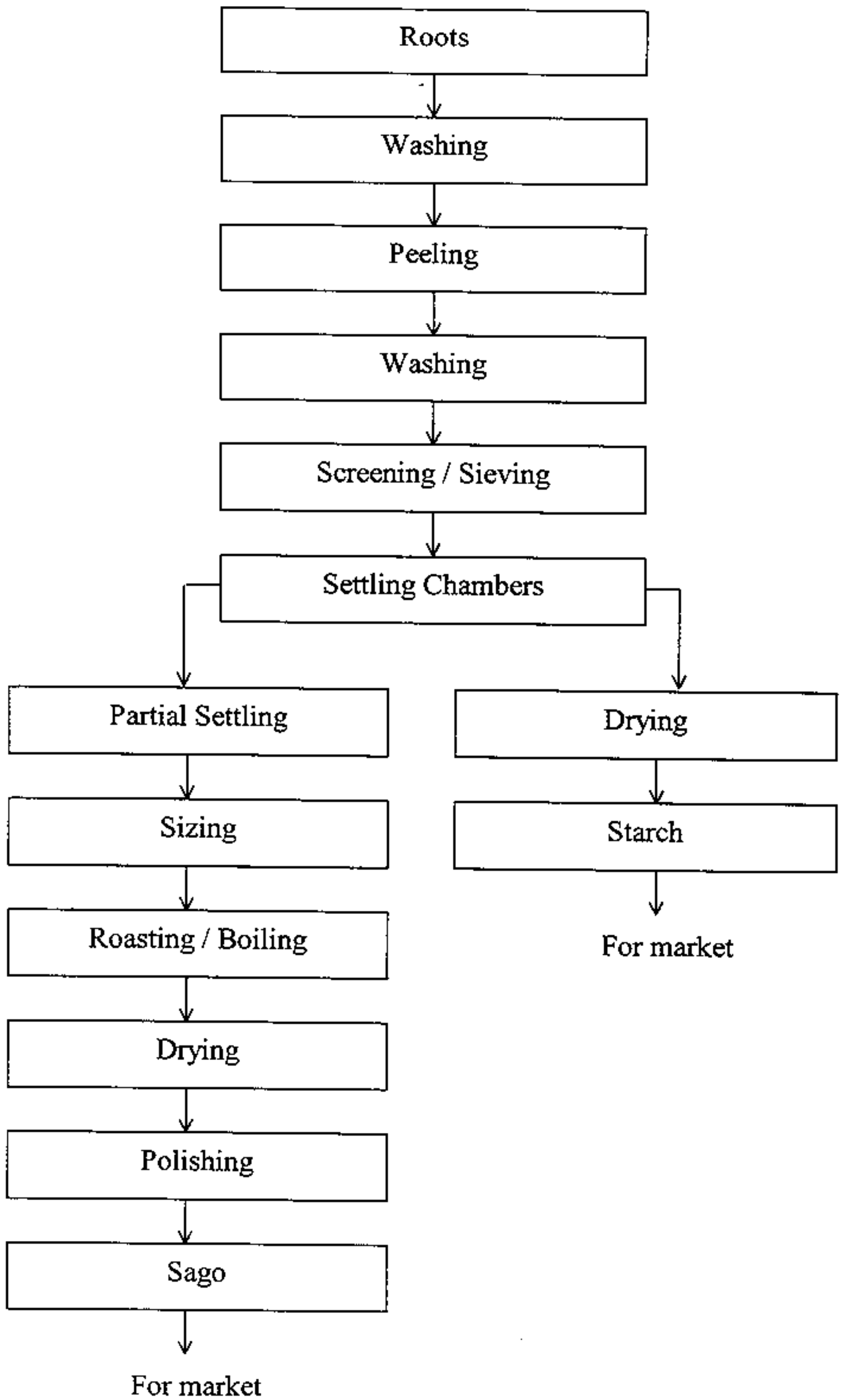

FIGURE 2.1 SAGO AND STARCH MANUFACTURING PROCESS

2.3.1 Roots Handling

First of all, any stalks must be removed. This is most easily done during harvest. Stalks will interfere with the peeling, blunt the rasps, and increase the fiber mass with adverse effect on the process. Loose dirt, sand, and gravel are removed in different ways; preferably a rotating bar screen is used for a dry cleaning of the roots prior to the washing step.

2.3.2 Peeling and Washing

Before peeling the roots are first passed through series of mechanical sieves where the extraneous dirt, mud and other impurities are removed. The soil also contains considerable quantities of nutrients, which will dissolve in the washing water and contribute to the environmental burden created by the effluent. The roots can be peeled manually or by using mechanical peelers. In manual peeling the roots are cut longitudinally and transversely to a depth according to the thickness of the peel. The peeled roots are then again cleaned in masonry tanks.

2.3.3 Rasping

The washed tubers are conveyed on an inspection belt to the pre-cutter. In order to feed the rasps properly, the roots are chopped into pieces. Rasping is the first step in the starch extraction process. The goal is to open all the tuber cells, so that all the starch granules are released. The slurry obtained can be considered as a mixture of pulp (cell walls), fruit juice, and starch. With modern high-speed raspers, rasping is a one-pass operation only. An even feed of the rasps is essential for a steady flow throughout the rest of the plant.

The raspers are usually swiftly moving surfaces provided with sharp intrusions which cut into the cell walls. The device is a wooden roller over which sheet metal rasping surfaces are nailed. During this process the cell walls get ruptured and the tapioca is turned into a mass in which the starch granules are released. Sometimes the pulp is subjected to secondary rasping.

2.3.4 Screening of Milk

Liberal amount of water is added at the rasping step. The roots are crushed and thick milk along with the cellulose and other cell solids form a colloidal mixture.

This is pumped through a series of filters that filter out the milk from the solids. The filters are made up of coarse to fine screens. The milk is pumped onto them and they are connected to eccentrics. These give the screen a shaking motion by which the milk filters out and the residue gets collected at the bottom end of the slanted screen. The collected solids from these multiple filtrations are called *thippi*.

2.3.5 Settling and Purification of Starch

The filtered milk is then, usually by gravity flow, sent to a settling tank. Here primary settling takes place in about six hours. The starch settles down at the bottom in the form of a layer. The supernatant fluid is pumped out and this is then subjected to washing. A high jet of water is forced onto this settled starch to clean it thoroughly. This is done for 4 to 6 hours depending upon the quality of crushed milk. Generally two settlings are sufficient to get pure starch. The settling is assisted by manual stirring as with people walking up and down the tank.

2.3.6 Drying

The wet starch from these tanks is taken out and dried in open yards. The type of flooring, i.e. whether it is normal cement floor or a granite floor, determines the rate of drying of starch.

2.3.7 Finishing and Packaging

The dried starch is in hard lumps. This is pulverized and dry screened through sieves and packed thus ensuring a uniform size of the starch powder.

2.4 SAGO MANUFACTURING PROCESS

The raw material for sago manufacture is the wet starch obtained from settling tanks. This starch typically contains about 40% of moisture which is ideally suited for sago manufacture. The settled starch is dug in the form of cakes and pulverized to get fine powder. This powder is then passed onto an eccentric provided with a gunny cloth surface. When shaken the powder gets agglomerated and forms globules. Depending on the sizes of these globules they are classified and taken for further processing.

2.4.1 Pearl Sago

Depending on the market demand, two kinds of sago are produced. One is called pearl sago. The starch globules from the eccentrics are loaded onto trays and then steam cooked. The globules get steamed and become translucent to transparent. However, because of the sticky nature of starch they get clustered. These clusters are then heated on open pans. The pans are heated using any kind of firewood available. The resulting clusters or lumps are then again open yard-dried. This type of sago takes two to three days to dry depending upon the sunlight availability and the kind of surface it is dried upon. To get the finished product the lumps are broken by passing them through disintegrators. This is also called as the polishing section. The dry polished sago is then packed in gunny bags.

2.4.2 Roasted Sago

Direct heating of the starch globules on open pans produces the second variety of sago. This too is yard dried but it takes lot lesser time to dry. The type of sago produced depends upon the market demand.

CHAPTER 3

TREATMENT OF WASTE IN A SAGO FACTORY

3.1 WASTE FROM SAGO FACOTRY

Sago industry generates both liquid and solid waste. While the liquid waste is mainly the wastewater coming out after the process operations, solid waste are the peels or skins of the tuber and the non-starch material called *thippi* defined earlier.

3.1.1 Liquid Waste

A sago factory needs about 4 to 5 times water of its crushing capacity of tapioca roots. The water is primarily required in cleaning the roots, peeled tubers, crushing of tubers and finally washing of starch. The water from all these operations contains high amounts of organic matter apart from dirt, mud and other such extraneous particles. Table 3.1 lists the wastewater characteristics of a typical sago factory.

TABLE 3.1 WASTEWATER CHARACTERISTICS

Sl. No.	Parameters	Untreated	Treated
1	p^H	4.75	8.25
2	Total Suspended Solids (mg/l)	1060	20
3	Total Dissolved Solids (mg/l)	4195	1420
4	Chloride (as Cl) (mg/l)	365	365
5	Sulphates (as SO_4) (mg/l)	540	204
6	Oil and grease (mg/l)	8	Nil
7	BOD (mg/l)	7680	142
8	COD (mg/l)	10560	24
9	Ammonical nitrogen (mg/l)	1.6	0.56
10	Total kjeldhal nitrogen	37.55	2.24
11	Sulphide (as S)	4	Nil

3.1.2 Solid Waste

The industry also generates solid waste up to 10% of the tuber processed comprising of 2% as the skin or peels of the tuber and 8% as the process waste

So many ETPs have incorporated the Upflow Anaerobic Sludge Blanket Reactor (UASBR) as their main COD and BOD reducing agent. Figure 3.1 shows a typical wastewater flowsheet in an ETP.

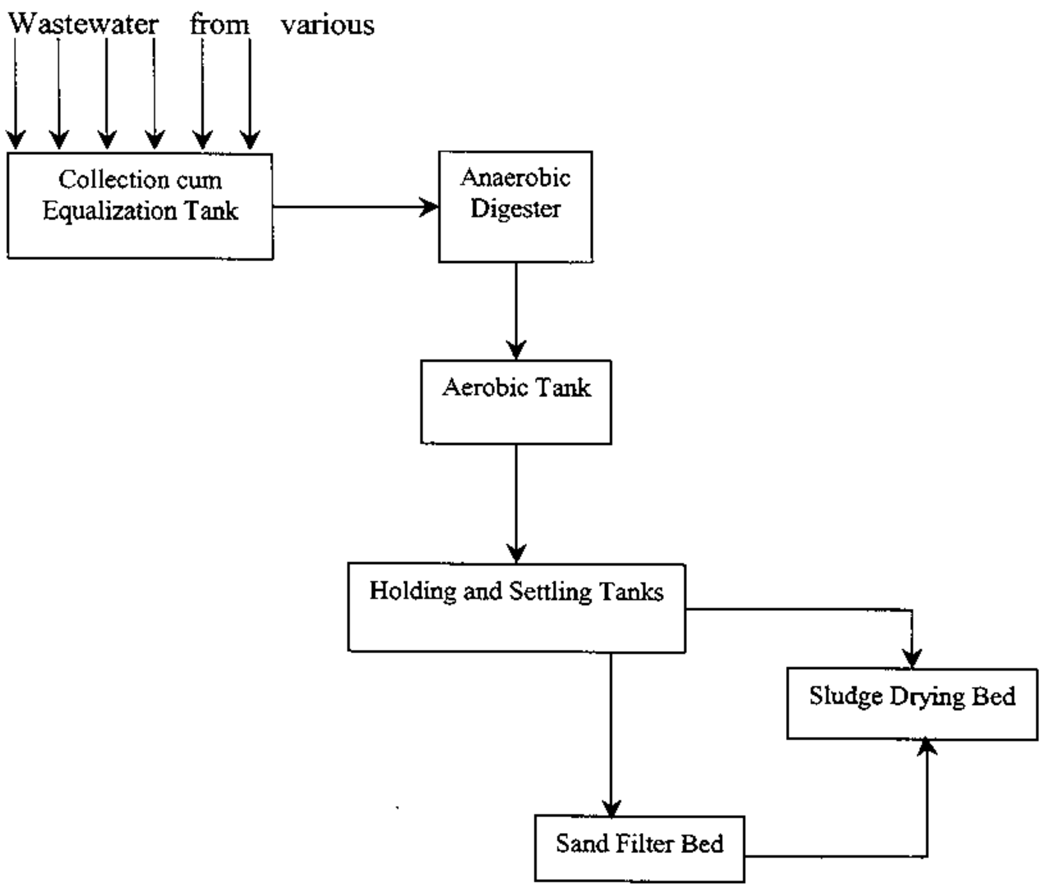

FIGURE 3.1 A TYPICAL ETP FLOWSHEET

Anaerobic digestion of wastewater has proven to be much more useful and effective in treating the wastewater. In a normal ETP the wastewater from various sources is collected into a collection tank. Here, if required, the p^H of the solution is brought to the desired value.

Anaerobic treatment processes are capable of high COD conversion efficiency to methane with minimal biomass production. At solids retention time values greater than 20 days maximum conversion of solids may occur at temperatures above 25°C. Without pilot-plant studies and extreme measures to control effluent suspended solids concentration such as chemical flocculation or membrane separation, anaerobic processes alone cannot be depended on to achieve secondary treatment levels. Some form of aerobic treatment would be necessary to provide effluent polishing, either attached growth or suspended growth processes. For high strength wastewaters the combination of anaerobic and aerobic treatment can be economical.

3.4 UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR

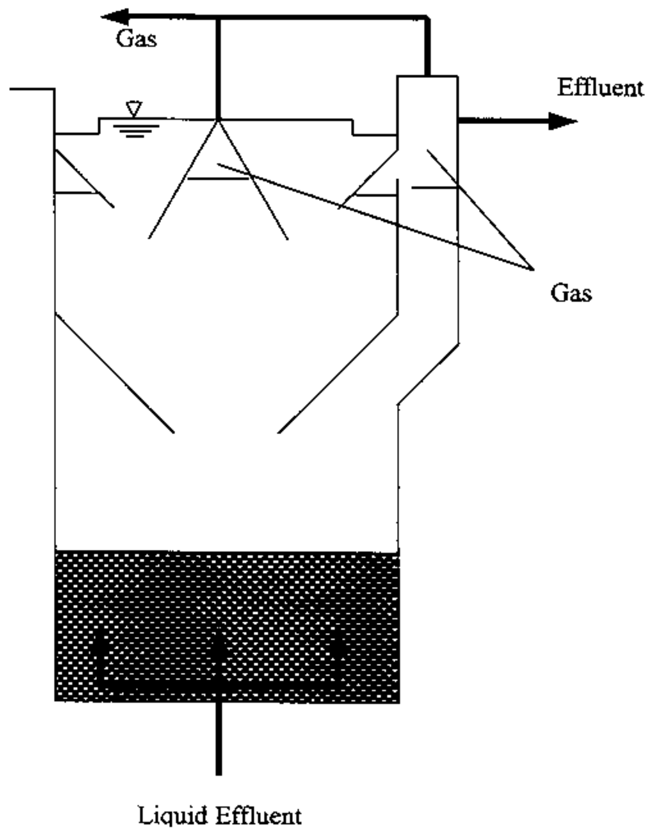

FIG 3.2 UASBR

3.4.1 PROCESS

The basic UASBR is illustrated in Figure 3.2. The influent wastewater is distributed at the bottom of the UASBR and it travels in an Upflow mode through the sludge blanket. Critical elements of the UASBR design are the influent distribution system, gas-solids separator and the effluent withdrawal design. The one modification followed in this industry is the inclusion of a settling tank.

The key feature of the UASBR process that allows the use of high volumetric COD loadings compared to other anaerobic processes is the development of a dense granulated sludge. Because of the granulated sludge floc formation, the solids concentration can range from 50 to 100 g/L at the bottom of the reactor and 5 to 40 g/L in a more diffuse zone at the top of the UASBR sludge blanket. The granulated sludge particles have a size range of 1.0 to 3.0 mm and result in excellent sludge thickening properties. Other factors affecting the development of granulated solids are p^H, Upflow velocity and nutrient addition.

Important design considerations for UASBR are:

1. Wastewater characteristics in terms of composition and solids content
2. Volumetric organic load
3. Up-flow velocity
4. Reactor volume
5. Physical features including the influent distribution system and
6. Gas collection system

CHAPTER 4

ENERGY CONSUMPTION PATTERN

4.1 FORMS OF ENERGY CONSUMED

The two forms of energy utilized in the industry are:

i. Electrical and
ii. Thermal
  a. Active : Direct burning of fuels
  b. Passive : Utilization of Solar thermal energy

The energy utilization however depends upon the product. The sago industry consumes both thermal and electrical energy but the starch units consume only electrical energy. Starch is the intermediary product which is either solar dried and packed for the market or sent for further processing to produce sago. For sago production additional steps, as explained earlier are required.

4.2 ELECTRICAL ENERGY UTILIZATION

Electrical energy is required to operate the various equipments used in the factories. The important types of equipments used are:

i. Elevators
ii. Conveyors
iii. Motors
iv. Pumps
v. Sieves
vi. Crushers
vii. Peeling machines

Few industries also have hydro cyclones. The number of electrical utilities installed in a factory depends upon various factors.

All units consume TNEB grid power. For emergencies few have diesel-fired generators. However, running load depends on the number of unit operations and additional features like cyclones, *thippi* screws etc.

With increasing power tariff and reduced product margins any reduction in the energy bill will make the industry more competitive.

4.3 NON-CRUSHING SEASON

The Sago industry operates for a nominal season period of six months or approximately 180 days. During this time tapioca roots are bought from the field and crushed. However, sago is produced even in the off-season from the wet starch stored though this principally depends upon market demand. During the off-season the plant load will be only 25% or 1/4th of the total. During this season of non-crushing only wet starch is again washed and roasted and boiled and hence the energy consumed will be only 25% of normal thermal and electrical energy.

4.4 THERMAL ENERGY UTILIZATION

Active Thermal: Wood or some other fuel provides the active thermal energy in the industry that is mainly utilized for producing sago from starch. The fuel is burnt and the heat is indirectly transferred to starch globules. For drying sago higher thermal energies are required. Calculation of the heat duty for roasted sago drying is presented in 4.5.

Passive Thermal: Industries manufacturing only starch and for final drying of sago crystals open yard solar drying method is followed. The usual drying time is 6 – 8 hours of sunshine for starch and 10 to 12 hours for sago. The average monthly solar insolation incident on a horizontal surface is 5.235 kWh/m^2/day at Salem.

4.5 HEAT DUTY CALCULATIONS FOR ROASTED SAGO DRYING

For producing Roasted Sago the starch globes are directly heated on a pan. The initial moisture content of the starch is about 40%. On the heat plates or pans this is reduced to about 20%. The fuels used to heat the pans are usually local available firewood and dried coconut husks.

Heat must be applied to accomplish the following:

i. Heat the feed (wet starch) to the vaporization temperature

ii. Vaporize the moisture

The amount of heat required to vaporize the moisture is much higher than the heat required to heat the feed as only the outside unbound moisture content is being removed. So, a general equation for heat duty calculations can be applied. If m_s is the mass of starch to be dried per unit time and X_a and X_b are the initial and final moisture contents of the starch, then the quantity of heat transferred per unit mass of solids q_T/m_s is:

$$q_T/m_s = c_{ps}\,(T_{sb} - T_{sa}) + X_a\,c_{pL}\,(T_v - T_{sa}) + (X_a - X_b)\,L$$

where,

c_{ps}	: Specific heat of starch = 1.22 J/kg K
$T_{sa,}$ and T_{sb}	: Temperatures of starch
T_v	: Temperature of vaporization of water
X_a and X_b	: Moisture content of sago
c_{pL}	: Specific heat of water = 4.5 kJ/kg K
L	: Latent heat of vaporization of water = 2257 kJ/kg

Here,

T_{sa}	= 30 °C
T_{sb}	= 100 °C
T_v	= 100 °C
X_a	= 0.4
X_b	= 0.2

The values of specific heats and latent heat of vaporization for water substituted in the above equation we get,

$$q_T/m_s = 577.5 \text{ kJ/kg}$$

i.e. about 600 kJ of energy is required to heat one kg of sago to reduce its moisture content from 40% to 20%.

For different industries, the m_s, i.e. the number of bags handled per hour changes.

CHAPTER 5

MATERIALS AND CALCULATIONS

5.1 FIELD DATA FROM INDUSTRIES

In order to understand the energy consumption pattern of the industry the factories listed below were visited and data collected. The Table 5.1 lists the names of the industries surveyed.

TABLE 5.1 LIST OF INDUSTRIES

Sl. No.	Factory Name
1	M/S Raja Sago Factory, Salem
2	M/S Sennimalai Sago Factory, Attur
3	M/S Shanmugananda Sago Factory, Attur
4	M/S Ravichandran Sago Factory, Attur
5	M/S S.N.K Starch Industries, Attur
6	M/S Kannan Sago Factory, Annadanapatti
7	M/S S.S. Sago Factory, Ammambalayam
8	M/S Sri Venkateswara Rice & Sago Factory., Ammambalayam
9	M/S Anbu Rice, Oil & Sago Factory, Attur
10	M/S Palaniswamy Starch Industries, Therukkadu
11	M/S Tirumal Sago Factory, Paittur
12	M/S Sri Tirupati Venkateswara Sago Industries Pvt. Ltd., Namakkal
13	M/S Sri Vel Murugan Starch Factory, Salem
14	M/S Sri Arul Murugan Starch Factory, Salem
15	M/S Sri Jyothi Sago Factory, Rasipuram
16	M/S Dhandayudhapani Starch Factory, Rasipuram
17	M/S Pappu Sago Factory, Ayilpatti

These factories were surveyed for the following data:

i. Connected Load

ii. Types and quantities of fuels utilized

iii. Hours of operations etc.

With these data the corresponding energy consumed by an industry in a given day can be calculated. Sample energy calculations are given below.

5.2 ENERGY CONSUMPTION CALCULATIONS

5.2.1 Electrical Energy Consumption

Crushing capacity of the industry = 100 tonnes/day

= 100 000 kg of tuber/day

Connected load:

Crushing section = 132 (hp) = 132 (hp) x 0.746 (kW/hp)

= 98.472 (kW)

Sizing section: = 20 (hp) = 14.92 (kW)

Starch rewashing section: = 7.5 (hp) = 5.95 (kW)

The crushing and sizing sections work for about 15 hours in the day whereas the starch rewashing section works for 8 hours.

Hence, total energy consumed = 98.472 x 15 + 14.92 x 15 + 5.95 x 8 (kWh)

= 1758.48 (kWh)

Taking unit cost of power as Rs. 4, the cost of power is

= 1758.48 x 4.25

= 7032 (Rs)

The starch content is about 25% of tuber. Taking the amount of sago produced to be 25000 kg and a bag of sago weighs 90 kg; hence,

Bags of sago produced = 278 (approx.)

Hence, number of units of power consumed per bag

= 1758.48 / 278 = 6.323 (kWh/bag)

This value varies from industry to industry between 5 units to 8 units.

5.2.2 Thermal Energy Consumption

The following standard values for the calorific values of fuel used are considered in the following calculations:

Firewood: 3500 (kcal)

Coconut shells & other high energy content fuels: 4500 (kcal)

Hence, say an industry is using 2 tonnes per day of firewood then the heat content of this can be converted into electrical unit equivalents as follows:

Quantity of fuel:	2 (tonnes) = 2000 (kg)
Calorific value of fuel:	3500 (kcal/kg)
Hence, the total energy content of the fuel used:	2000 x 3500
	= 7000000 (kcal)
1 (kWh) = 860.427 (kcal)	
Hence, unit equivalent of this energy:	7000000 / 860.427
	= 8135 (kWh)

The open grate plates / pans being used in the present industry to heat sago globules have very poor efficiency, ranging from 10% to 15%.

That is to say that though the factory is using 2000 kg of fuel wood, only 15% of it's heat content is being utilized and the rest being wasted.

5.3 M/S RAJA SAGO FACTORY

Name of Industry:	M/S RAJA SAGO FACTORY
Address:	71 D, Santhaipettai main Road, Shevapet, Salem 2
Contact Person:	Mr. R. Mathivanan
Product:	Starch, Boiled Sago & Roasted Sago
Tuber crushing capacity:	100 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	195 hp
Tuber Crushing Section:	50 hp
Starch Rewashing Section:	7½ hp
Sago Sizing Section:	25 hp
Sago Polishing Section:	35 hp
ETP:	7 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Eucalyptus tree roots
Quantity of type 1:	2 tonnes/day
Type 2:	Firewood
Quantity of type 2:	2 tonnes/day
<u>Hours of Operation:</u>	
Crushing Section:	10 hours/day
Starch Rewashing Section:	10 hours/day
Sizing Section:	10 hours/day
Polishing Section:	8 – 10 hours/day
ETP:	12 hours/day
Solar Drying Times:	
Starch:	4 – 6 hours of sunshine
Roasted Sago:	6 hours of sunshine
Boiled Sago:	12 hours of sunshine
<u>Energy Consumed:</u>	
Electrical	2390 units
Wood Thermal	
Used	15810 units
At 15% efficiency	2370 units

5.4 M/S SENNIMALAI SAGO FACTORY

Name of Industry:	M/S SENNIMALAI SAGO FACTORY
Address:	Vadasennimalai, Attur Taluk Salem
Contact Person:	Mr. R. Jagannadhan
Product:	Starch & Roasted Sago
Tuber crushing capacity:	40 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	88 hp
Starch Rewashing Section:	7½ hp
Sago Sizing Section:	15 hp
ETP:	15 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Biogas
Quantity of type 1:	-
Type 2:	Firewood
Quantity of type 2:	1 tonne/month
<u>Hours of Operation:</u>	
Crushing Section:	10 hours/day
Starch Rewashing Section:	8 hours/day
Sizing Section:	10 hours/day
Polishing Section:	8 – 10 hours/day
ETP:	12 hours/day
Solar Drying Times:	
Starch:	4 – 6 hours of sunshine
Roasted Sago:	10 hours of sunshine
<u>Energy Consumed:</u>	
Electrical	940 units
Wood Thermal	
Used	115 units
At 15% Efficiency	18 units

5.5 M/S SHANMUGANANDA SAGO FACTORY

Name of Industry:	M/S SHANMUGANANDA SAGO FACTORY
Address:	Vadasennimalai, Attur Taluk Salem
Contact Person:	Mr. R. Shanmugam
Product:	Starch & Roasted Sago
Tuber crushing capacity:	30 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	81 hp
Starch Rewashing Section:	15 hp
Sago Sizing Section:	10 hp
ETP:	23 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Biogas
Quantity of type 1:	-
Type 2:	Firewood
Quantity of type 2:	1 tonne/month
<u>Hours of Operation:</u>	
Crushing Section:	8 hours/day
Starch Rewashing Section:	8 hours/day
Sizing Section:	10 hours/day
ETP:	12 hours/day
Solar Drying Times:	
Starch:	4 – 6 hours of sunshine
Roasted Sago:	8 - 12 hours of sunshine
<u>Energy Consumed:</u>	
Electrical:	850 units
Wood Thermal:	
Used:	115 units
At 15% Efficiency:	18 units

5.6 M/S RAVICHANDRAN SAGO FACTORY

Name of Industry:	M/S RAVICHANDRAN SAGO FACTORY
Address:	Sadasivapuram post, Attur Taluk, Salem Dt.
Contact Person:	Mr. Ravichandran
Product:	Starch & Roasted Sago
Tuber crushing capacity:	100 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	132 hp
Starch Rewashing Section:	7½ hp
Sago Sizing Section:	20 hp
ETP:	12 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Biogas
Quantity of type 1:	-
Type 2:	Diesel
Quantity of type 2:	20 - 50 liters/day
<u>Hours of Operation:</u>	
Crushing Section:	15 hours/day
Starch Rewashing Section:	8 hours/day
Sizing Section:	15 hours/day
ETP:	12 - 15 hours/day
Solar Drying Times:	
Starch:	4 – 6 hours of sunshine
Roasted Sago:	12 hours of sunshine
<u>Energy Consumed:</u>	
Electrical:	1850 units

5.7 M/S S.N.K. STARCH INDUSTRIES

Name of Industry:	M/S S.N.K. STARCH INDUSTRIES
Address:	Sadasivapuram post, Attur
Contact Person:	Mr. Ravi
Product:	Starch
Tuber crushing capacity:	50 tonnes/day
Connected Load:	
Tuber Handling Section:	125 hp
Starch Rewashing Section:	15 hp
ETP:	10 hp
Fuel Types and Quantities Utilized	
Type 1:	Biogas
Quantity of type 1:	-
Hours of Operation:	
Crushing Section:	12 hours/day
Starch Rewashing Section:	10 hours/day
ETP:	12 hours/day
Solar Drying Times:	
Starch:	4 – 6 hours of sunshine
Energy Consumed:	
Electrical:	1230 units

5.8 M/S KANNAN SAGO FACTORY

Name of Industry:	M/S KANNAN SAGO FACTORY
Address:	4-355, Rama Gounder Thotam, Annadanampatti, Salem 2
Contact Person:	Mr. Venkatesan
Product:	Boiled & Roasted Sago
Tuber crushing capacity:	15 tonnes/day
Connected Load:	
Tuber Handling Section:	50 hp
Starch Rewashing Section:	12½ hp
Sago Sizing Section:	15 hp
ETP:	5 hp
Fuel Types and Quantities Utilized	
Type 1:	Firewood
Quantity of type 1:	2 tonnes/day
Hours of Operation:	
Crushing Section:	6 hours/day
Starch Rewashing Section:	6 hours/day
Sizing Section:	6 hours/day
ETP:	6 hours/day
Solar Drying Times:	
Starch:	20 hours of sunshine
Roasted Sago:	8 hours of sunshine
Energy Consumed:	
Electrical:	620 units
Wood Thermal	
Used:	6910 units
At 15% efficiency:	1040 units

5.9 M/S S.S. SAGO FACTORY

Name of Industry:	M/S S.S SAGO FACTORY
Address:	Cuddalore Main Road, Gandhipuram, Ammambalayam Post, Attur Taluk, Salem Dt.
Contact Person:	Mr. S. Selvam
Product:	Starch & Roasted Sago
Tuber crushing capacity:	55 tonnes/day

<u>Connected Load:</u>

Tuber Handling Section:	127 hp
Starch Rewashing Section:	7½ hp
Sago Sizing Section:	20 hp
ETP:	13 hp

<u>Fuel Types and Quantities Utilized</u>

Type 1:	Firewood
Quantity of type 1:	3 – 5 tonnes/day
Type 2:	Coconut shells
Quantity of type 2:	-

<u>Hours of Operation:</u>

Crushing Section:	10 hours/day
Starch Rewashing Section:	8 hours/day
Sizing Section:	8 hours/day
ETP:	8 – 10 hours/day
Solar Drying Times:	
Starch:	12 hours of sunshine
Roasted Sago:	8 hours of sunshine

<u>Energy Consumed:</u>

Electrical:	1210 units
Wood Thermal:	
Used:	15560 units
At 15% Efficiency:	2330 units

5.10 M/S SRI VENKATESWARA RICE & SAGO FACTORY

Name of Industry:	M/S SRI VENKATESWARA RICE & SAGO FACTORY
Address:	Cuddalore Main Road, Ammambalayam
Contact Person:	Mr. T. Balaji
Product:	Starch
Tuber crushing capacity:	70 tonnes/day
Connected Load:	
Tuber Handling Section:	110 hp
Starch Rewashing Section:	5 hp
ETP:	10 hp
Fuel Types and Quantities Utilized	
Type 1:	Biogas
Quantity of type 1:	-
Hours of Operation:	
Crushing Section:	12 hours/day
Starch Rewashing Section:	10 hours/day
ETP:	8 – 10 hours/day
Solar Drying Times:	
Starch:	6-8 hours of sunshine
Energy Consumed:	
Electrical:	1100 units

5. 12 M/S PALANISWAMY STARCH INDUSTRIES

Name of Industry:	M/S PALANISWAMY STARCH INDUSTRIES
Address:	Therukkukadu, Chodanchalai, Attur
Contact Person:	Mr. A. P. Asokhan
Product:	Starch & Roasted Sago
Tuber crushing capacity:	100 tonnes/day
<u>**Connected Load:**</u>	
Tuber Handling Section:	140 hp
Starch Rewashing Section:	10½ hp
Sago Sizing Section:	20 hp
ETP:	12 hp
<u>**Fuel Types and Quantities Utilized**</u>	
Type 1:	Firewood
Quantity of type 1:	3 – 5 tonnes/day
Type 2:	Diesel
Quantity of type 2:	20 - 50 liters/day
<u>**Hours of Operation:**</u>	
Crushing Section:	10 hours/day
Starch Rewashing Section:	4 hours/day
Sizing Section:	10 hours/day
ETP:	18 hours/day
Solar Drying Times:	
Starch:	4 – 6 hours of sunshine
Roasted Sago:	12 hours of sunshine
<u>**Energy Consumed:**</u>	
Electrical:	1390 units
Wood thermal:	
Used:	17290 units
At 15% efficiency:	2590 units

5.13 M/S TIRUMAL SAGO FACTORY

Name of Industry:	M/S TIRUMAL SAGO FACTORY
Address:	Paittur Road, Attur
Contact Person:	Mr. Ari
Product:	Starch & Roasted Sago
Tuber crushing capacity:	100 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	135 hp
Starch Rewashing Section:	15½ hp
Sago Sizing Section:	20 hp
ETP:	12 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Biogas
Quantity of type 1:	-
Type 2:	Firewood
Quantity of type 2:	5 – 10 tonnes/month
<u>Hours of Operation:</u>	
Crushing Section:	10 hours/day
Starch Rewashing Section:	8 – 12 hours/day
Sizing Section:	10 hours/day
ETP:	12 – 16 hours/day
Solar Drying Times:	
Starch:	6 – 8 hours of sunshine
Roasted Sago:	10 –12 hours of sunshine
<u>Energy Consumed:</u>	
Electrical:	1420 units
Wood thermal:	
Used:	860 units
At 15% efficiency:	130 units

5.14 M/S TIRUPATI VENKATESWARA SAGO IND. PVT. LTD.

Name of Industry:	M/S TIRUPATI VENKATESWARA SAGO INDUSTRIES PVT. LTD.
Address:	T. Pachudayampalayam Post, Rasipuram Taluk, Namakkal District
Contact Person:	Mr. Babu
Product:	Starch & Roasted Sago
Tuber crushing capacity:	200 tonnes/day

Connected Load:

Tuber Handling Section:	122 hp
Starch Rewashing Section:	10 hp
Sago Sizing Section:	10 hp
Sago Polishing Section:	12
ETP:	16 hp

Fuel Types and Quantities Utilized

Type 1:	Coconut Shells
Quantity of type 1:	4 – 5 tonnes/day
Type 2:	Firewood
Quantity of type 2:	5 – 10 tonnes/month

Hours of Operation:

Crushing Section:	10 hours/day
Starch Rewashing Section:	8 – 12 hours/day
Sizing Section:	10 hours/day
Polishing Section:	10 – 12 hours/day
ETP:	12 – 16 hours/day
Solar Drying Times:	
Starch:	6 – 8 hours of sunshine
Roasted Sago:	10 –12 hours of sunshine

Energy Consumed:

Electrical:	1320 units
Wood Thermal	
Used:	23090 units
At 15% efficiency:	3460 units

5.15 M/S VEL MURUGAN STARCH FACTORY

Name of Industry:	M/S VEL MURUGAN STARCH FACTORY
Address:	Kandampatti Road, Erode Highway, Salem
Contact Person:	Mr. Selvam
Product:	Starch, Boiled & Roasted Sago
Tuber crushing capacity:	50 tonnes/day
Connected Load:	
Tuber Handling Section:	85 hp
Starch Rewashing Section:	7½ hp
Sago Sizing Section:	10 hp
Sago Polishing Section:	10 hp
ETP:	10 hp
Fuel Types and Quantities Utilized	
Type 1:	Firewood
Quantity of type 1:	5 tonnes/day
Type 2:	Coconut shells
Quantity of type 2:	5 – 10 tonnes/month
Hours of Operation:	
Crushing Section:	8 hours/day
Starch Rewashing Section:	4 hours/day
Sizing Section:	8 hours/day
Polishing Section:	8 hours/day
ETP:	12 – 16 hours/day
Solar Drying Times:	
Starch:	15 hours of sunshine
Roasted Sago:	8 hours of sunshine
Energy Consumed:	
Electrical:	770 units
Wood Thermal:	
Used:	18400 units
At 15% efficiency:	2760 units

5.16 M/S ARUL MURUGAN STARCH FACTORY

Name of Industry:	M/S ARUL MURUGAN STARCH FACTORY
Address:	Kandampatti Road, Erode Highway, Salem
Contact Person:	Mr. Ramu
Product:	Sago
Tuber crushing capacity:	50 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	96 hp
Starch Rewashing Section:	7½ hp
Sago Sizing Section:	15 hp
Sago Polishing Section:	10 hp
ETP:	15 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Firewood
Quantity of type 1:	3 tonnes/day
<u>Hours of Operation:</u>	
Crushing Section:	10 hours/day
Starch Rewashing Section:	6 hours/day
Sizing Section:	10 hours/day
Polishing Section:	10 hours/day
ETP:	12 hours/day
Solar Drying Times:	
Starch:	15 hours of sunshine
Roasted Sago:	8 hours of sunshine
<u>Energy Consumed:</u>	
Electrical:	1070 units
Wood Thermal:	
Used:	10370 units
At 15% efficiency:	1560 units

5.17 M/S SRI JYOTHI SAGO FACTORY

Name of Industry:	M/S SRI JYOTHI SAGO FACTORY
Address:	1/527, Mettala, via Attur Road, Rasipuram Taluk, Namkkal District
Contact Person:	Mr. Dhandayudha Pani
Product:	Roasted Sago
Tuber crushing capacity:	35 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	68 hp
Starch Rewashing Section:	15 hp
Sago Sizing Section:	7½ hp
ETP:	10 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Biogas
Quantity of type 1:	-
<u>Hours of Operation:</u>	
Crushing Section:	8 hours/day
Starch Rewashing Section:	8 hours/day
Sizing Section:	6 hours/day
ETP:	8 – 12 hours/day
Solar Drying Times:	
Roasted Sago:	8 – 10 hours of sunshine
<u>Energy Consumed:</u>	
Electrical:	620 units

5.18 M/S DHANDAYUDHA PANI STARCH FACTORY

Name of Industry:	M/S DHANDAYUDHA PANI STARCH FACTORY
Address:	Mettala, via Attur Road, Rasipuram Taluk, Namkkal District
Contact Person:	Mr. Dhandayudha Pani
Product:	Starch
Tuber crushing capacity:	35 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	60 hp
Starch Rewashing Section:	10 hp
Sago Sizing Section:	10 hp
ETP:	10 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Biogas
Quantity of type 1:	-
<u>Hours of Operation:</u>	
Crushing Section:	8 – 10 hours/day
Starch Rewashing Section:	8 – 10 hours/day
Sizing Section:	6 – 8 hours/day
ETP:	8 – 12 hours/day
Solar Drying Times:	
Roasted Sago:	8 – 10 hours of sunshine
<u>Energy Consumed:</u>	
Electrical:	670 units

5.19 M/S SRI PAPPU SAGO FACTORY

Name of Industry:	M/S SRI PAPPU SAGO FACTORY
Address:	Ayilpatti PO, Rasipuram Taluk, Namkkal Dt.
Contact Person:	Mr. Govindan
Product:	Starch & Roasted Sago
Tuber crushing capacity:	37.5 tonnes/day
<u>Connected Load:</u>	
Tuber Handling Section:	133 hp
Starch Rewashing Section:	7½ hp
Sago Sizing Section:	20 hp
Sago Polishing Section:	10 hp
ETP:	15 hp
<u>Fuel Types and Quantities Utilized</u>	
Type 1:	Coconut Shells & Country wood
Quantity of type 1:	2– 3 tonnes/day
<u>Hours of Operation:</u>	
Crushing Section:	10 hours/day
Starch Rewashing Section:	10 hours/day
Sizing Section:	8 hours/day
Polishing Section:	10 hours/day
ETP:	8 – 10 hours/day
Solar Drying Times:	
Roasted Sago:	8 – 10 hours of sunshine
<u>Energy Consumed:</u>	
Electrical:	1350 units
Wood Thermal:	
Used:	8890 units
At 15% efficiency:	1330 units

The consolidated table for electrical units, wood burnt and sum of these compared to the crushing capacity is given in Table 5.2.

TABLE 5.2 INDUSTRY-WISE TOTAL ENERGY CONSUMED

Factory	Crushing Capacity (tpd)	Electrical Units Consumed per day (kWh)	Electrical Equivalent of Wood Required per day $(kWh)_e$	Total Energy Consumed (kWh)
1	100	2390	2370	4760
2	40	940	18	958
3	30	850	18	868
4	100	1850	–	1850
5	50	1230	–	1230
6	20	620	1040	1660
7	55	1210	2330	2540
8	70	1100	–	1100
9	40	790	520	1310
10	100	1390	2590	3980
11	100	1420	130	1550
12	200	1320	3460	4780
13	50	770	2760	3530
14	50	1070	1560	2630
15	35	620	–	620
16	35	670	–	670
17	37.5	1350	1330	2680

CHAPTER 6

BIOGAS GENERATION POTENTIAL AND OPERATION DESCRIPTION

6.1 BIOGAS GENERATION POTENTIAL

6.1.1 Biogas from Wastewater

For an industry with 50 tonnes per day crushing capacity, the availability of thippi on average stands at 6 tonnes. The water required for crushing roots ranges between 4 to 5 liters per kg. Hence, the effluent water will be about 200 m^3. The total solids will be 1250 kg, the total volatile solids 935 kg. For every 1 kg of volatile solids about 0.8 m^3 of gas can be generated. However, this is only the theoretical potential. The actual gas that can be obtained from a biogas plant however, typically stands at 40% of this value. The biochemical potential of wastewater:

Wastewater available per day:	200 m^3
Total solids in the above:	1250 kg
Total volatile solids:	935 kg
Gas potential per day:	750 m^3
Practical gas possible at 40% of potential:	300 m^3

The biochemical potential of thippi too is almost the same. To ensure that the solids in each digester go up to 4% the amount of thippi required to be added is calculated. With these values, tables were generated to calculate the total practical gas that could be obtained from the wastewater and thippi. The total energy being consumed at present by the factories were evaluated from the data collected in Table 5.2. Taking Table 5.1 as the reference for names of industries, Table 6.1 gives the gas potential from the wastewater generated from the industry.

6.1.2 Biogas from Thippi

As the wastewater alone has very less quantity of volatile solids, the biogas generated from this alone usually will not be sufficient. And the thippi, instead of being sold as cattle feed, can be used to enhance the biogas generation. The biochemical potential of thippi is very similar to wastewater, in that though it has excess amounts of volatile solids, the amount of biogas generated from these essentially remains the same.

6.1.3 Total Biogas and Power Generation Potential

The sum of biogas generation potentials from these two means, i.e. from wastewater and thippi are summed up in Table 6.3. With experiments carried out to evaluate the percentage of methane in the biogas generated, it was found that with sufficient hydraulic retention time or solids retention time, (i.e. the amount of time the incoming volatile solids spend inside the digester) a maximum percentage of 64% methane can be achieved. This HRT or SRT depends on the constituent of the wastewater from any particular industry.

At lower categories of 100 kW_e – 250 kW_e on a 100% gas mode engine, per m^3 of gas with 60% methane 2 units of power can be generated. However, as there is some %age of parasitic load, it can be safely assumed that for every m^3 of biogas, 1.85 units of power can be obtained. Table 6.3 includes a column of power production capability based on this figure.

6.1.4 Energy Conservation and Share of Captive Power Generation

The present industry is using age old equipment and these are particularly inefficient. So, for these factories to take advantage of the package they have to improve their efficiencies at least by 10%. With this improved efficiency, the share of captive power generation capability of each industry compared to the energy consumed is given in Table 6.4.

The industries with greater than 100% captive power generation capability percentages have the best opportunity to go for captive power generation as they can completely cut off their grid power consumption, and in the near future, even sell back the power to the grid! For those with lesser percentage, going for captive power generation will reduce their grid power consumption and they can improve their margins of profits.

6.2 OPERATION DESCRIPTION

6.2.1 Final Collection Tank for Effluent Water and Thippi

Since the industry produces effluent due to its everyday crushing the overall availability of effluent water requires to be regularized. To affect this, final collection tank will be operated which houses at least three days equivalent storage for wastewater before it is mixed with hydrolyzed thippi. Concurrently, the amount of thippi required will be calculated based on the installed capacity of the plant and the hydrolytic material will be maintained as in the case of effluent water for at least three days. Both these tanks are independent of each other and their dimensions are calculated based on requirements.

6.2.2 Hydrolytic Treatment of Thippi

The sago and starch industry has been looked upon to discharge effluent water with a range of 2 to 6 mg per liter of starch. However, in practice, the levels of non-extractable starch in the overflowing waters will never cross 2 to 3 mg per liter. As a result, using thippi which has very little importance to feed industry, in which it is presently used, compared to peels, can be advantageous for bio-methanation. For obvious reasons, the non-absorbent nature of thippi enjoys the longevity in natural conditions. Thippi can be stored over two to three years period without much physical changes except loss of water. All these characteristics indicate that biological hydrolysis of thippi will take more time and requires not only space and money but also time to achieve any noticeable results. It is found that the thermo-chemical break down of thippi can give better results. Basic calculations made on captive power plants ranging from 100 kW to 500 kW reveal that the thippi requirement for a 250 kW system would fall between 2 to 2.75 tonnes per day.

Keeping these issues in mind, a 100 kW thermal wood based gasifier can be installed to produce as high as +8000 kcal of thermal power over a period of time. It is estimated that to rise 2000 liters of water to 100 °C 1.4 x 10^5 kcal is required and to evaporate at least 1500 liters of water 6.6 x 10^5 kcal is required; to super heat to steam of around 110 °C a total of 8 x 10^5 kcal of power is required. A 100 kW thermal gasifier unit can deliver this power over a period of 3 to 3.3 hours.

This gasifier will give the required energy to hydrolyze 2.5 tonnes of thippi over a period of 3 hours. This helps in easing the bio-methanation of thippi. To this effect, 2 days equivalent hydrolyzing tank can be used on a day to day basis. The prolonged exposure followed by gradual cooling will have excellent effect on thippi to make it more suitable for bio-methanation.

6.2.3 Additional Advantages of Gasifier

In the event of the fermentor matrix to be heated to maintain ±37 °C the gasifier can be employed at low rating and produce the water at required temperatures which can be circulated to exchange heat during the night ours for at least 4 to 6 hours. This operation will help in fast depletion of total solids and to keep the fermentor fit for fresh loading. The same heat exchange system can also be used during day hours by circulating engine exhaust by allowing suitable levels of dilution.

6.3 DIGESTER

This operates like hybrid high rate bio-methanation plant with necessary modifications being incorporated to suit the bio-chemical potential characteristics behavior of the mixed feed in the digester. The volume of the digester can be decided based upon wastewater availability. This works on slightly modified concept of UASBR. To ensure active sludge to support obligate anaerobic conditions, the sludge will be constantly maintained, supported by inorganic materials like baked bricks or suitable gravel and the feed itself will form a complex sludge.

The temperature of the fermentor will be maintained by incorporating suitable half inch GI/ SS serpentine structure to dissipate passive thermal energy by heat transfer to the matrix. Depending on the operational conditions either hot water or exhaust gas, whichever appears to be cheap, will be circulated at temperatures below 75 °C for conductive heat transfer with the sludge to maintain 35 °C.

The design is project specific and depends on the volume of the digester required and the feed material configuration. This device will be primarily kept in operation only during night hours to ensure bio-methanation process will reach higher levels so that the next feeding operation will not drastically alter the nutrient levels/p^H levels and the like.

This design also takes care by providing necessary baffles in the form of mesh structures at different levels which will automatically take care of discouraging floating of thippi and peels.

6.4 DIGESTER DESIGN

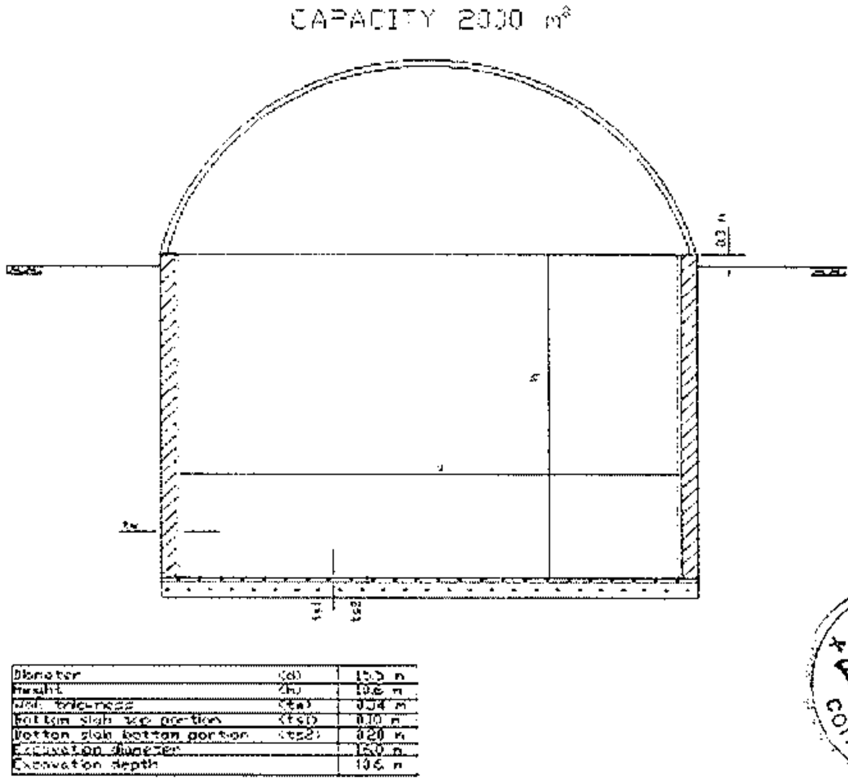

FIGURE 6.1 CIVIL STRUCTURAL DIAGRAM

From the survey of the 17 industries undertaken it was found that a 300 kW system operating for a 10 hour/day period can satisfy the requirements of these industries. Laboratory experiments conducted tallied with practical values.
The civil structural diagram is given in Figure 6.1. The laboratory model was scaled up keeping in mind the mechanisms of suspended growth and the following

design suggested. A 2000 m^3 per day digester can provide the biogas for such a system.

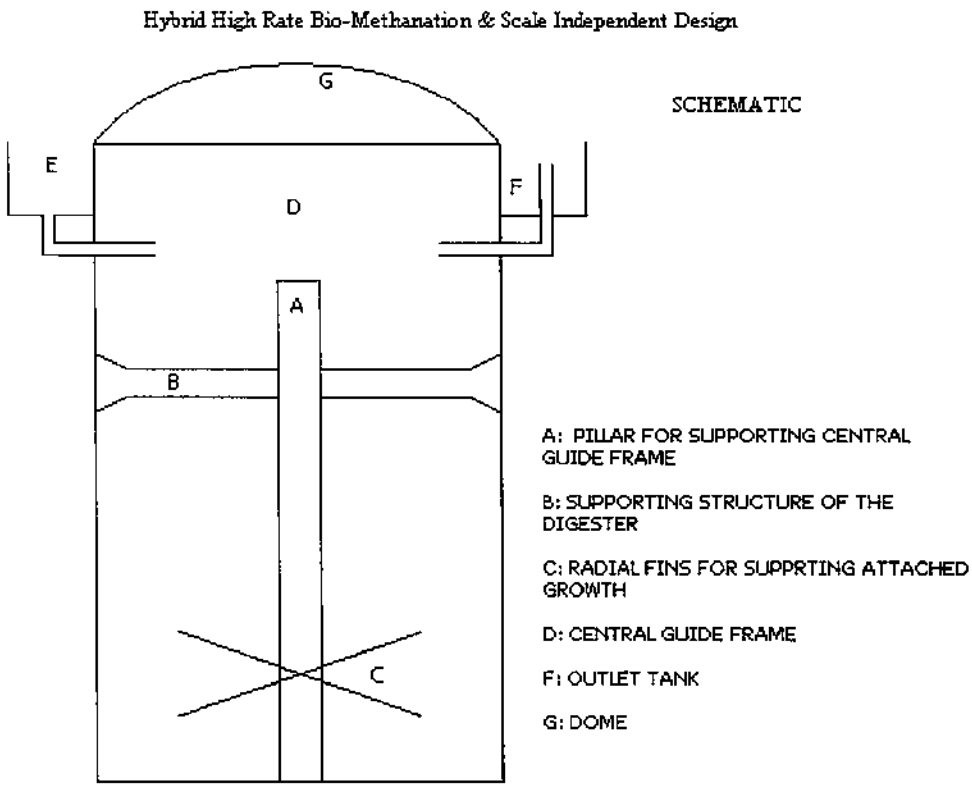

FIGURE 6.2 PROCESS REGULATED KINETIC REACTOR

The location of these mesh baffles will bpe decided depending on the volume of the digester and other characteristics. Since the digester temperatures are monitored and controlled to work at >35 °C and to accelerate liquid gas separation, necessary structures will be provided to ensure liquid gas separation will give maximum advantage. The process regulated kinetic reactor shown in Figure 6.2 gives a schematic diagram of the reactor model. The fins provided at the bottom (C) support the attached growth that is required for the sustenance of bacteria. It prevents the blow down of the microbial organisms and other sludge forming material.

The digester will operate in lowest possible parasitic energy requirements for the following reasons:

1. There is an imminent requirement to ensure that the nature of crushing should not have an immediate bearing on the operational conditions of the digester.
2. Keeping this in view, the bio-chemical values are taken at the optimum level to ensure that process is not affected by external factors.
3. As a result, some of the thumb rules generally used to calculate the power equivalent requirements of biogas can be taken at 10% higher to the whole process.
4. This leverage has a say on the cost of the project and the volume of the digester requires to be 5 to 10% more. At the same time in the off-season period, to keep the digester operating a mixed feed is fed for tapioca based feed is minimum.

6.5 GAS CLEANING

Necessary provisions will have to be incorporated to trap the moisture at the beginning. There is no provision required to remove the CO_2 since it is neutral in gas engines. The amount of H_2S in tapioca based industrial waste is reasonably less.

At present, many ETPs with final collection tanks converted to biogas plants are being fitted with coated tarpaulin which will house the gas. However, this is a temporary measure and necessarily this gas requires to be pumped to the gas holding tank. Depending upon the size of the digester the design incorporates if necessary MS gas holders to ensure maximum levels of gas storage and is supported by gas storing facility primarily of bullets maintained at required pressure to support both the thermal and electrical operations.

CHAPTER 7

CASH FLOWS AND PACKAGES

7.1. PROJECT COSTING

The total project cost depends on the digester construction which includes land, civil, mechanical and electrical costs. For the factories surveyed, few can go for a 300 kVA generator. To do so a 2000 m^3 digester is to be constructed. The typical project cost will be as follows.

7.2 EXPENDITURE STATEMENT

7.2.1 Civil

1.	Construction of RCC Digester with FRP dome	Rs.	35 00 000
2.	Feed Mixing Tanks	Rs.	5 00 000
3.	Fittings and Plumbing	Rs.	1 50 000
4.	Miscellaneous	Rs.	5 00 000
	Total	**Rs.**	**46 50 000**

7.2.2 Electrical Equipment Required

1.	Local Synchronizing Equipment	Rs.	1 50 000
2.	Miscellaneous	Rs.	60 000
	Total	**Rs.**	**2 10 000**

7.2.3 Mechanical

1.	Modified 100% Gas Mode Engine (Indian Make)	Rs.	35 00 000
2.	Feed Mixing Equipment & Recirculation Pumps	Rs.	80 000
3.	Gas Cleaning Equipment	Rs.	3 50 000
4.	Miscellaneous	Rs.	3 00 000
	Total	**Rs.**	**42 30 000**
1.	Cost of Land	**Rs.**	**5 00 000**
	Total Cost	**Rs.**	**95 90 000**
1.	Project consultancy @ 3%	Rs.	2 87 700
2.	Staff expenditure @ 1%	Rs.	95 900
	Total Cost of Project	**Rs.**	**99 73 600**

The total cost of project is Rs. 99,73,600. This is too huge a cost for any single promoter to generate for himself. To meet this cost the promoter can go for bank loan.

7.3 CASE 1: CASH FLOW WITH BANK LOAN

Case 1: The first case is that the promoter goes for a digester based upon his own methods and means of financing. The promoter can obtain a bank loan for a maximum of 80% of his total project cost. The term loan can be taken for a period of 8 years.

Total Project Cost (C_{TP})	Rs. 99,73,600
Loan @ 80% of Total Cost (L)	Rs. 79,78,880
Term Years (n)	8
Installment (P)	Rs. 9,97,360
Interest Rate (r)	10%

The expenditure and savings for the first year will be as follows.

7.3.1 Savings in First Year

The annual installment (P) to be paid every year is:

$= C_{TP} / n$

= Rs. 79,78,880 / 8 = Rs. 9,97,360

P = Rs. 9,97,360

The interest rate will be applicable for the entire loan amount in the first year. Hence, the interest for first year will be (I)

= 10% X 79,78,880 = Rs. 7,97,888

I = Rs. 7,97,888

The operation and maintenance costs (C_{OM}) can be taken as 2.5% of total costs as the equipment is relatively new

= 2.5% X (P + I) = 0.025 X (9,97,360 + 7,97,888)

= Rs. 44,881

C_{OM} = Rs. 44,881

The total expenditure (E) for the factory will be:

$P + I + C_{OM}$

= Rs. 9,97,360 + Rs. 7,97,888 + Rs. 44,881 = Rs. 18,40,129

E = Rs. 18,40,129

Energy saved from the 300 kVA generator per year in terms of money (P_s)

= Units / hour X Hours of operation / day X Days of Operation / Year X Rs. / unit

= 300 X 10 X 150 X 4.25

= Rs. 19,12,500

P_S = Rs. 19,12,500

Annual savings (S) = Energy Saved – Total Expenditure

= 19,12,500 – 18,40,129

= 72,371

S = Rs. 72,371

After three years the operation and maintenance cost increases. Similarly, there will be a corresponding increase in the power tariff. So assuming there is a 10% increase in both after three years, the values have been revaluated with power tariff at Rs.4.5/unit and operation and maintenance costs at 5%. This trend is repeated at the end of 6 years, i.e. a further increase in operation and maintenance costs to 7.5% and corresponding increase in power tariff to Rs.5/unit. The values with these corrections have been included in Table 7.1.

It can be found from these values that the promoter has a good chance of not only earning profits but also recovering the entire loan amount within six years (including the installments paid).

7.4 CASE 2: CASH FLOW FOR DIESEL USAGE

Case 2: However, say the promoter wants to go for other options rather than construct a digester, then he will find that such an option is not only troublesome but also that he cannot earn enough profits to keep him afloat for a single year! Supposing that his geographical location hinders proper supply of current continuously, then he can go for another alternative, like diesel.

The cost of a diesel engine with its assortments and all comes to Rs. 35,00,000. Assuming that a bank loan for this amount at 10% interest is taken for a term loan of 8 years, the annual installment to be paid will be:

$$I = 35,00,000 / 8 = Rs. 4,37,000$$

In such an engine, 1 liter of diesel produces 3.8 units of power. The cost of diesel at present is Rs 35. Hence,

The unit cost of production = Rs. 9.21 / unit.

Assuming the operation and maintenance costs stand at 2.5% and the cost of power from grid is Rs. 4.25 / unit, Table 7.2 lists the amount to be paid and the money needed to produce 300 kW of power for a 10 hour period in a day for 150 crushing days.

It can be found from Table 7.2 that the cost of producing power using a diesel engine is so huge, that it would not be possible for the factory to survive a single year. Hence, diesel as a sole – fuel source is unfit for all obvious reasons.

7.5 CASE 3: CASH FLOW FOR NATURAL GAS

Supposing that natural gas is provided at the doorstep of the promoter without charging him the cost of laying and transportation, the cost of natural gas per cu. m. is Rs 12. The power generation can be done in an Enbacker / Wakusa / Duetes Gas engine whose cost is Rs.65,00,000, without the import duty of 36% as these are not available in India as Indian generators cannot be used.

Enbacker / Wakusa / Duetes Generator:	Rs.	65,00,000
Import Duty @ 36%:	Rs.	23,40,000
Installation & commissioning charges @ 2% of total cost:	Rs.	2,00,000
Total	**Rs.**	**90,40,000**

Again assuming that a bank loan is taken to meet this cost for a term period of 8 years at 10% interest the cash flow is given in Table 7.3.

1 m^3 of NG gives 3.8 units of power.

Total m^3 of NG required to produce 300 kW for 10 hours /day for 150 days =

$$300 \times 10 \times 150 / 3.8 = 118{,}420 \text{ m}^3$$

Cost of NG per year = 118,420 X 12 = Rs. 14,21,040

From Table 7.3 it can be seen that even this option will cost hugely, not to mention the cost of getting natural gas to the promoter which doubtlessly will increase the cost of natural gas.

7.6 CASH FLOW FOR PROJECT WITH GOVERNMENT SUPPORT

As Case 1 shows project performance in the absence of Government support also looks attractive. However, as the initial cost of the project is huge and the largest investment required is in fixed assets, if this burden is lessened on the promoter it would be easy for him to adopt the technology.

Supposing that a subsidy of Rs. 15,000 per kW is given to the promoter then the numbers would look like this.

Project Cost:	Rs. 9,973,600
Govt. Subsidy:	Rs. 4,500,000
Loan amount:	Rs. 5,473,600
Term Years	8
Principal	Rs. 684,200
Interest Rate	10%

The cash flows are given in Table 7.4.

With a Government support of Rs. 15,000 per kW, for a 300 kW system, the subsidy would be Rs. 45,00,000. With this amount meeting partially the initial cost the loan required reduces to Rs. 54, 73,600. The cash flows of Table 7.4 indicate and show how money invested can be recovered.

The loan amount can be recovered from the profits by the sixth year! However, an important point to note is that the promoter MUST adopt energy conservation mechanisms to improve the efficiency of his system at least by 10%. These can include mechanisms like replacement of old equipment with energy efficient ones, proper utilization of solar energy etc.

CHAPTER 8

CONCLUSIONS

8.1 MAJOR OBSERVATIONS

- It is observed that cost of cultivation and cost of quality of the tuber has not significantly effected the industry.
- The Industry was popularly dominated by less technically educated entrepreneurs.
- The industry produces wastewater categorized by the Pollution control Board of Tamil Nadu under yellow category.
- *Thippi* is not a recommended nutritive product. Hence, remunerative price cannot be obtained to support the main process activity.
- The industry consumes electrical power, biomass for thermal energy and diesel to augment power failure.
- Unfortunately, the industry was never subjected to energy audit, and no major areas for energy conservation identified.
- The industry's' equipment on average is just over a decade old, and up-gradation of plant and machinery was never on the agenda of the promoters.
- The share of power in terms of end product is basically understood loosely. These calculations never include biomass cost supporting thermal energy.
- There is no definite documentation of data on the quantity of biomass and diesel purchased for various applications.
- The reason number of industries are being closed every year is primarily due to non-compliance of pollution norms in treatment of wastewater etc.
- Many of the industries are also being subjected to strict scrutiny for want of quality of end product, and many industries are also being closed to meet this challenge.
- 80% of the industries when compared the number of unit existing two decades back stand closed.
- Based on the observations made, this study was undertaken to understand and explain the above issues. The remedial measures explained in this

thesis also do not attract any undue investments. However, assuming that the promoters are to upgrade their plant and machinery on immediate basis, accumulative effect of the said above should be in the order of 15% of the total energy consumed. Under these circumstances, the Thesis explains how industry can sustain on its own in the competitive post WTO scenario to produce quality products, and reduce the share of cost of the energy to ensure the products to attract international attention. Based on the study conducted the following are the major recommendations hereby made not only to the industry but also to the government to strictly impose some of the remedial measures to ensure the industry survives.

8.2 MAJOR RECOMMENDATIONS

The following are the major recommendations arrived at after studying the industry and also studying 17 industries in depth.

1. It is observed that there is an urgent need to undertake energy auditing of each and every individual industry, and to upgrade the energy savings by employing energy conservation methods to a tune of 15% on immediate basis.
2. The above said exercise must concurrently be undertaken by upgrading the plant and machinery, accessories and adopting modern methods of process technology.
3. The energy consumption of this industry needs to be carefully documented at every point of the total process involved.
4. It is observed that the amount of wastewater which has been generated can be considered as a source of energy by extracting biogas and converting the same for power and thermal applications.
5. If there is any shortfall in achieving energy self-sufficiency, suitable amount of Thippi can be added to make up the requirements to ensure the industry becomes energy independent.
6. The slurry of the biomethanation plant may require very nominal amount of aeration and thus the energy required for it is considerably less. This helps in re-circulating water back to the main process to reduce the

dependence on fresh water. This helps in achieving near zero water requirements and the total process of the industry will become energy efficiency in all fronts.

7. All the above said issues will make the industry more successful and the products are acceptable.

APPENDIX: TAPIOCA SAGO GRADING AND MARKING RULES

1. Short title application and commencement. -

(1) These Rules may be called the Tapioca Sago Grading and Marking Rules, 1980.

(2) They shall apply to tapioca Sago manufactured from the starch obtained from Tapioca tubers (*Manihot esculenta crantz syn utilissima*).

2. Definitions - In these rules,

(a) "Agricultural Marketing Adviser" means the Agricultural Marketing Adviser to the Government of India,

(b) "Schedule" means a Schedule appended to these rules.

(c) "Authorized packer" means a person or body of persons, who has been issued a certificate of authorisation by the Agricultural Marketing Adviser to the Government of India, for getting the commodity graded and Agmarked in accordance with the grade standards and procedure prescribed under the rules.

3. Grade designation- The grade designation to indicate the quality of Tapioca sago shall be as set out in column 1 of Schedule I.

4. Definition of Quality- The quality indicated by the respective grade designation shall be as set out against each grade designation in columns 2 to 11 of Schedule I.

5. Method of marking-

(i) The grade designation mark shall be securely affixed to each container in a manner approved by the Agricultural Marketing Adviser.

(ii) In addition to the grade designation mark, the following particulars shall be clearly marked on each container in such a manner directed by the Agricultural Marketing Adviser to the Government of India, namely:-

(a) Name of manufacturer
(b) Date of packing
(c) Lot number
(d) Net weight
(e) Any other particulars as may be specified by the Agricultural Marketing Adviser

(iii) An authorised packer may, after obtaining the prior approval of the Agricultural Marketing Adviser, mark his private trade mark on a container in a manner approved by the said officer, provided that the private trade mark does not represents quality or grade of tapioca sago different from that indicated by the grade designation mark affixed to the container in accordance with these rules.

6. Method of packing

(1) Only new, sound, clean and dry containers made of jute, cotton, paper, polythene or any other material as may be approved by the Agricultural Marketing Adviser shall be used for packing. The containers shall be free from any insect infestation or fungus contamination, or any undesirable smell.

(2) The containers shall be securely closed and sealed in the manner approved by the Agricultural Marketing Adviser.

(3) Each package shall contain tapioca of one grade designation only.

7. Special conditions of certificate of authorisation.-

In addition to the conditions specified in rule 4 of the General Grading and Marking Rules, 1937, the following shall be the conditions of every certificate of authorization issued for the purpose of these rules namely:-

(1) An authorised packer shall make such arrangements for testing Tapioca sago as may be prescribed, and samples there of shall be forwarded to

such control laboratories as may be specified, from time to time, by the Agricultural Marketing Adviser.

(2) An Authorised packer shall provide all facilities to the inspecting officers duly authorised by the Agricultural Marketing Adviser in this behalf, for sampling, testing, affixation of grade designation marks and other matters as may be prescribed by the Agricultural Marketing Adviser from time to time.

SCHEDULE I

(See Rules 3 and 4)

Grade designation and definition of quality of Tapioca Sago commercially known as JAVVARISHI (Tamil) or SABOODANA (Hindi)

TABLE A1 SCHEDULE I

Grade designation	Moisture percentage by weight max	Total ash, percentage by weight on dry basis max	Acid insoluble ash, percentage by weight, on dry basis max	Starch percentage by weight, on dry basis min	Protein percentage by weight on dry basis max.	Sulphur dioxide ppm max	Crude fiber, percent age by weight on dry basis max	PH. of aqueous extract	Colour of gelatinize alkaline paste in the porcelain cuvetta or he lovi bond Scale not deeper than
1	2	3	4	5	6	7	8	9	10
Milk White	12.0	0.4	0.1	95	0.3	100	0.2	4.5 – 7.0	0.2R + 1.0Y
Special	12.0	0.4	0.1	92	0.3	100	0.2	4.5 – 7.0	0.3R + 1.0Y
General	12.0	0.4	0.1	90	0.3	100	0.2	4.5 – 7.0	0.4R + 1.5Y

GENERAL CHARACTERISTICS OF TAPIOCA SAGO

Tapioca Sago shall:

(a) be manufactured from the starch obtained from the tubers of tapioca (Manihot esculenta Crantz syn. Utilissima) grown in the States of Kerala and Tamil Nadu.

(b) be sweet, clean, hard, and wholesome;

(c) be in sound merchantable condition , brokens not exceeding percent;

(d) be completely free from mould obnoxious smell and any extraneous matter;

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