TCF BLEACHED SISAL MARKET PULP: POTENTIAL REINFORCING FIBRE FOR COMMODITY PAPERS - PART 2

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ABSTRACT

Sisal pulp has physical characteristics superior to softwood kraft pulp. Depending on the furnish components and paper quality requirements, sisal pulp can replace softwood kraft at a rate of up to 2.8:1. This offers many opportunities for sisal pulp. For example, sisal pulp may be used as a reinforcing fibre in high recycle content papers, or its use may permit basis weight reductions while maintaining product quality. Sisal pulp as a value added replacement to softwood kraft in commodity papers is considered a viable alternative market.

Part 1 of this paper reviews the laboratory work to establish conditions for producing TCF bleached sisal pulp, and discusses the results of pilot scale trial tests on pulp samples which were distributed to paper companies for testing in various furnishes. Part 2 reviews a sisal estate plan to provide pulping fibre, tentative flowsheets for fibre preprocessing stations and a sisal market pulp mill using processes and equipment which are currently available on the market, and the estimated capital and manufacturing costs and economic analysis for a 50,000 metric ton per year sisal market pulp mill.

Keywords: sisal, line fibre, bole fibre, TCF bleaching

INTRODUCTION

In Part 1 of this paper, the following key issues were established:

- Although the process parameters were not optimized, the experimental and pilot plant work clearly show that high quality bleached pulp can be produced from fibre extracted from *Agave sisalana*.

  The processes investigated include using either a soda or a soda-AQ cook followed by either oxygen delignification and peroxide bleaching or simply peroxide bleaching.

  It appears that the final pulp brightness will be in the 80-84% ISO range if cooking is followed by peroxide bleaching only, and that the brightness will increase to the 85-90% ISO range if cooking is followed by oxygen delignification and peroxide bleaching. In both cases, it is anticipated that process optimization of all stages in the process - cooking, oxygen delignification and bleaching - will improve the overall results.

- Sisal pulp has a tear strength twice that of softwood pulp and three times that of hardwood pulp.

- Minor refining is recommended to develop the tensile strength of sisal pulp without hurting the tear strength.

- Sisal pulp could be used as a reinforcing fibre in many commodity paper grades, including grades which contain a high recycled fibre content.

- Sisal pulp could be used to replace softwood or other expensive high strength pulps.

- Although the specialty paper market would pay high prices for sisal pulp, the potential reinforcing fibre market would pay lower prices for sisal pulps, and the price would be relative to softwood kraft pulp and the respective properties of the two pulps.

- The market survey established a potential market for 286,000- 363,000 admt/year of sisal pulp of which 53,000-55,000 admt was unbleached pulp and the balance was bleached pulps of varying brightnesses from 80-92% ISO.

Part 2 of this paper establishes the overall project concept from the plant nurseries to the final pulp product taking into consideration various constraints such as the acreage required for sisal cultivation and the market opportunities.

PROJECT CONCEPT

The proposed sisal market pulp project was not simply the building of a pulp mill to exploit available fibrous raw material. Rather, it is the sum total of three distinct elements which together form the complete project:

- the sisal estates,
- the sisal fibre preprocessing stations, and
- the 50,000 admt/y sisal pulp mill.

Efficient growing of the sisal plant, harvesting of the leaves, and extraction of fibrous raw material to provide low cost pulping fibre are important elements to the success of the pulp mill.

Further, as the project location would be in Tanzania, several key parameters were established at the onset of the study which were reflected in both the research work and the mill design:

- The mill processes all would be based on well known and commercially well proven technologies currently in use in nonwood plant fibre or wood fibre pulp mills.

- The equipment used would be commercially available.

- The mill would be simple and easy to operate and maintain in a remote location.

TRADITIONAL SISAL FARMING AND PROCESSING

As traditional sisal processing for line fibre is the basis of available sisal fibre used for specialty pulps, a description of the current method of sisal cultivation and processing is provided.

a) **Planting Material & Nurseries**

The sisal plant flowers only once during its life. In Tanzania, if left uncut, the plant will flower after about 5 years, but plants whose leaves have been harvested regularly may flower only after as many as 9-10 years. After the plant has flowered, it dies.

When the plant flowers, a pole emerges from the top of the bole. The poles which grow at a rate of 10-12 cm per day reach a height of 5-6 m and are 10-15 cm in diameter. Just before reaching full height, the poles send out flowering branches. In Tanzania, seeds rarely develop on the flowering stem. After blooming, the flowers shrivel and, together with their ovaries, drop off the poles before seed formation. However, in addition to reproduction by seed, *Agave sisalana* also can reproduce itself vegetatively by means of both rhizomes and bulbils.

The rhizomes grow underground radially from the bole and then surface to form a new plant known as a "sucker". Left undisturbed, the sisal plant may produce up to 20 suckers. Suckers are removed as they tend to reduce the growth rate of the parent plant and would result in a field of sisal plants varying in age and fibre quality

Bulbils are formed on the flowering stem immediately below the point where the flowers and ovaries have dropped off. Bulbils are plantlets with reduced leaves and a rudimentary root system. A large flowering pole may bear 2,000-3,000 bulbils. When the formation of the bulbils is complete, they fall off the poles.

Both suckers and bulbils are collected from the fields and planted in nurseries. Immature plants are kept in the nurseries for about 6 months and then planted in the fields.

In Tanzania, the fact that sisal propagates itself only vegetatively is an advantage. The lack of seeding prevents the development of seedlings in the fields and allows controlled cultivation and harvesting by nursery and field hand planting. As propagation is by means of bulbils or suckers, each generation is the same as the parent plant.

Sisal poles with bulbils

New sisal field

Sisal Plantation

Leaf bundling

b) **Estate Development & Harvesting**

For line fibre production, the sisal fields are planted with about 3,000 plants per hectare. The sisal plants are planted in double offset rows with alleys between the rows. The planting arrangement has been designed to allow cutters access to individual plants.

First cutting of the plants can occur when the plants are 40-48 months old depending on climate and soil conditions. Leaf harvesting may be done once or twice per year, and a total of 50-60 leaves are removed per year. The leaf harvesting continues until the plants are 9-12 years old.

Leaf cutting is done entirely by hand. The cutters remove the mature bottom leaves, cut off the spines and tie the leaves in bundles of 30 leaves. The cutters deposit the bundles at the end of the rows for pick-up and transport to the decorticating plant.

c) **Line Fibre Processing**

At the decorticating plant, the bundles are untied and the leaves are fed to the decorticators which crush the leaves and scrape off the epidermis and pithy material from the line fibre. The line fibre is draped over "fences" and dried. Dried fibre is classified and baled for shipment.

Sisal decorticator feed

Line fibre sun drying

d) **Line Fibre Cost**

During 1992/93, the delivered cost of #3 grade sisal line fibre, the industry standard, was about US$ 400-500 per metric ton FAS Dar Es Salaam, Tanzania. Including transportation, brokers' fees, handling etc., the cost to end-users (the cordage industry and specialty pulp mills) amounted to US$ 750-850 per metric ton which partially accounts for the high cost of bleached sisal market pulp which ranges from US$ 2,400-2,600 per admt.

The use of sisal pulp as a reinforcing fibre in commodity papers will not be possible at the price range indicated above. In order to achieve a lower selling price for sisal pulps, the cost of raw fibre must be reduced.

RAW MATERIAL REQUIREMENTS FOR A PULP MILL

The traditional approach to sisal cultivation and processing was developed to produce "line fibre" which is used for the production of twine, cord, ropes, mats, etc. This approach ensures that the leaves have matured sufficiently to develop the required line fibre strength properties and to obtain the longest possible line fibre (0.6-1.0 metres length). Furthermore, the extracted line fibre must be light in colour and free from impurities. Any immature leaves remaining at the end of the cycle can be salvaged and used for second quality "line fibre".

However, the pulp mill's sisal raw material requirements are substantially different to those of line fibre. For the pulp mill, the strength and length of line fibre is not important. Line fibre is composed of bundles of smaller (3 mm in length on average) fibres, and it is these smaller, intrinsic fibres that are of interest to papermakers.

In the pulp mill, all fibre bundles will be reduced to intrinsic fibres which are then bleached, dried and sold as pulp. As such, the fibre bundles can be as short as 0.5 cm and, in fact, the pulp mill will operate better if the line fibre is chopped into pieces not more than 5 cm in length. Also, the colour and cleanliness of the chopped line fibre are not a factor for the pulp mill.

Given the significant difference presented by the pulp mill's raw material requirements, the entire sisal plant can be harvested at one time (including immature leaves at the top of the plant) for processing by the pulp mill.

Also, this difference from traditional line fibre requirements permits a rationalization and modification to the present practice of growing, harvesting and processing the sisal plant in order to meet the needs of the pulp mill for lower cost feedstock.

Regardless of the form of delivery of the sisal raw material to the pulp mill, the mill will require about 69,300 bdmt/y of sisal fibre to produce 50,000 admt/y bleached pulp.

MODULAR SISAL ESTATES

Based on the pulp mill's sisal raw material requirements and considering transportation costs for moving sisal leaves which contain a high fluid volume, agronomists working with HurterConsult developed the concept of self contained modular estates to supply fibre to the pulp mill. For sisal estates dedicated to producing raw material for the pulp mill, the proposed modular estate has the major parameters described in table 13.

The modular estate is premised on clear cutting a preset number of hectares per day and transporting all of the leaves to a central preprocessing station located on the estate. At the preprocessing station, the leaves would be chopped, masticated, washed and screened. The process will provide clean, chopped fibre suitable for charging directly into the pulp mill digesters.

Four (4) of modular estates would be required to supply the sisal raw fibre requirements of the proposed 50,000 admt/year bleached sisal pulp mill.

Using the modular approach offers several advantages and interesting opportunities including:

- In the modular estate, the maximum travel distance is 5 km which minimizes the transport cost for leaves.
- After preprocessing, the volume delivered to the pulp mill is only about 10-15% of the volume delivered to the preprocessing station significantly reducing transportation costs to the pulp mill site and allowing flexibility in the pulp mill site selection relative to the sisal estate locations.
- Central preprocessing on the estate means that the juice removed from the sisal plants during preprocessing is retained in one location on the estate at which it can be treated or used as a raw material for other products.
- Other solid non-fibrous materials removed from the sisal leaves during preprocessing also are collected in one location and can be used for other products.

Per table 14, the estimated capital cost for developing one modular estate is US$ 8.674 million. Thus, the capital cost of developing the four modular estates would be US$ 34.7 million spent over a three year period.

However, the modular estate design includes the concept of using one quarter of the estate land for a rotational crop of maize and soybeans at any given time. This rotational crop would be developed from the onset of the project and would provide an estimated revenue of US$ 1.107 million per year per modular estate. Given that the rotational crop would not provide revenues during the first year as the fields are being cleared, it is estimated that the rotational crop would provide total revenues of US$ 2.21 million per estate during the second and third years of the sisal estate development. This additional revenue if applied back to the sisal estate development would reduce the total cost of developing the four modular sisal estates by US$ 8.84 million leaving a balance of US$ 25.86 million which would have to be financed from other sources.

The total annual cost for operating one of the modular estates was estimated at US$ 1.45 million. Deducting the estimated revenue from rotational crops (US$ 647,300 per year per estate) reduced the cost of raw sisal fibre production in leaf form to US$ 803,500 per year, or US$ 46.38/bdm

PREPROCESSING STATIONS

Each of the four modular sisal estates includes a preprocessing station which has the major parameters described in table 15.

The preprocessing station receives whole leaves. The whole leaves are chopped and masticated, and the fibre extracted. Then, the fibre is washed and readied for shipment to the pulp mill. A block diagram of the system is provided in figure 1.

The capital cost estimate for one preprocessing station is provided in table 16. Thus, the estimated capital cost for four preprocessing stations, one per modular estate, was US$ 13.72 million.

The total estimated cost of operating one of the preprocessing stations and of delivering the fibre to the pulp mill based on a round trip of 60 km amounted to US$ 22.62/bdmt raw fibre.

Table 13. Sisal modular estate parameters

Total estate size	6,000 hectares
Area under sisal	4,500 hectares
Sisal planting density	6,000 plants/hectare
Rotational area	1,350 hectares
Nursery area	200 hectares
Nursery production	45,000 plants/day
Estate Roads	35 km main estate roads
	215 km secondary field roads
Harvest year	4th
Harvesting days	270/year
Harvest	1,320 mt whole leaf/day
Employment	600 persons
Preprocessing centres	1

Table 14. Estimated capital cost for one modular estate

Cost Component		000's US$
Pre-production expenses	estate design, operations plan, training, start-up expenses, etc.	860
Land (leased)		---
Estate Roads		860
Estate buildings	housing for permanent employees only	526
Equipment & machinery	mainly mobile equipment	3,002
Production inputs	fertilizers, herbicides, lime, pesticides, planting stock, fuels, oils, lubricants, spare parts, personnel costs	3,426
TOTAL		8,674

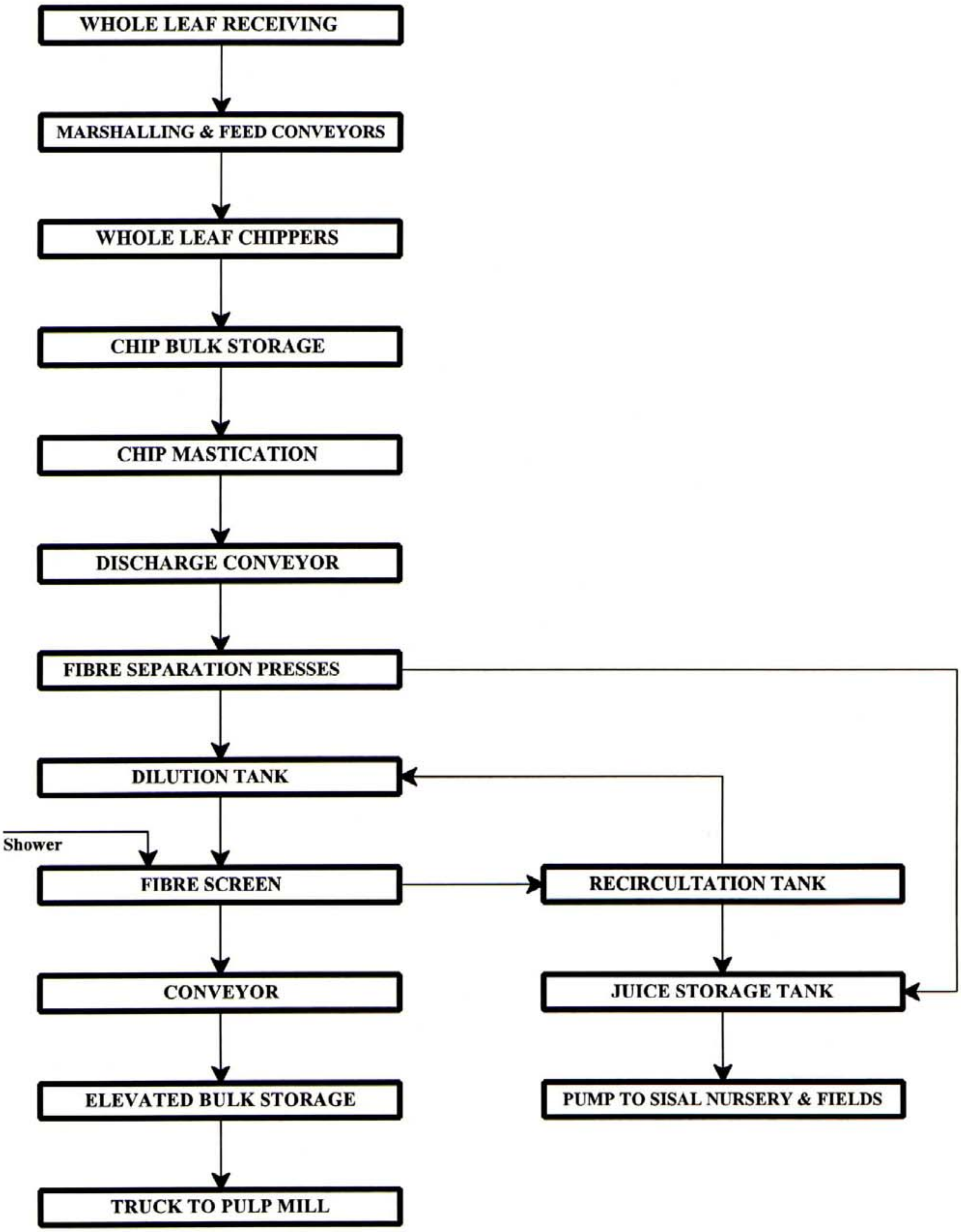
Table 15. Preprocessing station parameters

Operating days	270 days/year
Operating period	24 hours/day
Raw material received	1,320 mt whole leaf per day
Processed raw sisal fibre	64.17 bdmt/day
	17,325 bdmt/year
Employment	47

Table 16. Estimated capital cost for one preprocessing station

Cost Component	000's US$
Buildings & civil works	1,020
Equipment & machinery (delivered)	1,600
Erection & installation	190
Services	280
Subtotal Base Cost	3,090
Working capital	30
Contingency	310
TOTAL	3,430

Figure 1. Whole sisal leaf preprocessing station flow diagram



DELIVERED-TO-PULP MILL COST OF RAW FIBRE

Both the modular estates and the preprocessing stations would be owned by the pulp mill and would be considered as cost centres.

Table 17 summarizes the operating costs of the modular estate and the preprocessing station to arrive at the estimated cost of raw sisal fibre on a delivered-to-the- pulp mill basis for the case where a rotational crop is not included in the estate plan and the case where revenues from the rotational crop are included.

Table 17. Delivered-to-pulp mill cost of raw fibre

	Excluding Rotational Crop Revenue	Including Rotational Crop Revenue
	US$/bdmt raw fibre	
Modular estate operating costs	83.74	46.38
Preprocessing & delivery costs	22.62	22.62
Total delivered cost	**106.36**	**69.00**

Thus, by viewing the fibre requirements of the pulp mill as being different from traditional line fibre, we developed an appropriate system for the sustainable supply of sisal raw material to the pulp mill at a cost significantly lower than the cost of line fibre production.

Sustainable supply and low cost of the sisal raw material are key elements in the establishment of the sisal pulp mill project.

Further, the additional income from the rotational crop reduces the raw fibre cost by a further 35% which, in terms of the final production cost of the pulp, amounts to a savings of about US$ 57.00 per admt of bleached pulp.

DESCRIPTION OF PROPOSED PULP MILL

a) **General Design Features**

The following general design features were used in the development of the proposed mill:

- The mill output would be 50,000 admt/year of TCF bleached sisal market pulp.
- 35-40 hectares would be allocated for the mill site to provide space for future expansion.
- Due to the warm climate, outdoor construction would be used as much as possible, and fully enclosed buildings used only where absolutely necessary.
- The mill layout follows an axial roadway design with the mill pulping and bleaching line on one side of the central roadway, and chemical recovery and mill services on the other side. Pipe bridges and walkways connect the main process building with the chemical recovery system and mill services.
- As the mill is in a remote location, it must include all services required to maintain and operate the mill.
- Housing is provided nearby the mill site for most mill personnel.
- As the availability of suitable transport equipment is limited, the mill will own and operate its own truck fleet.

Figure 2 provides a block diagram of the fibre processing line.

b) **Sisal Raw Material Receiving, Storage and Delivery to the Pulp Mill**

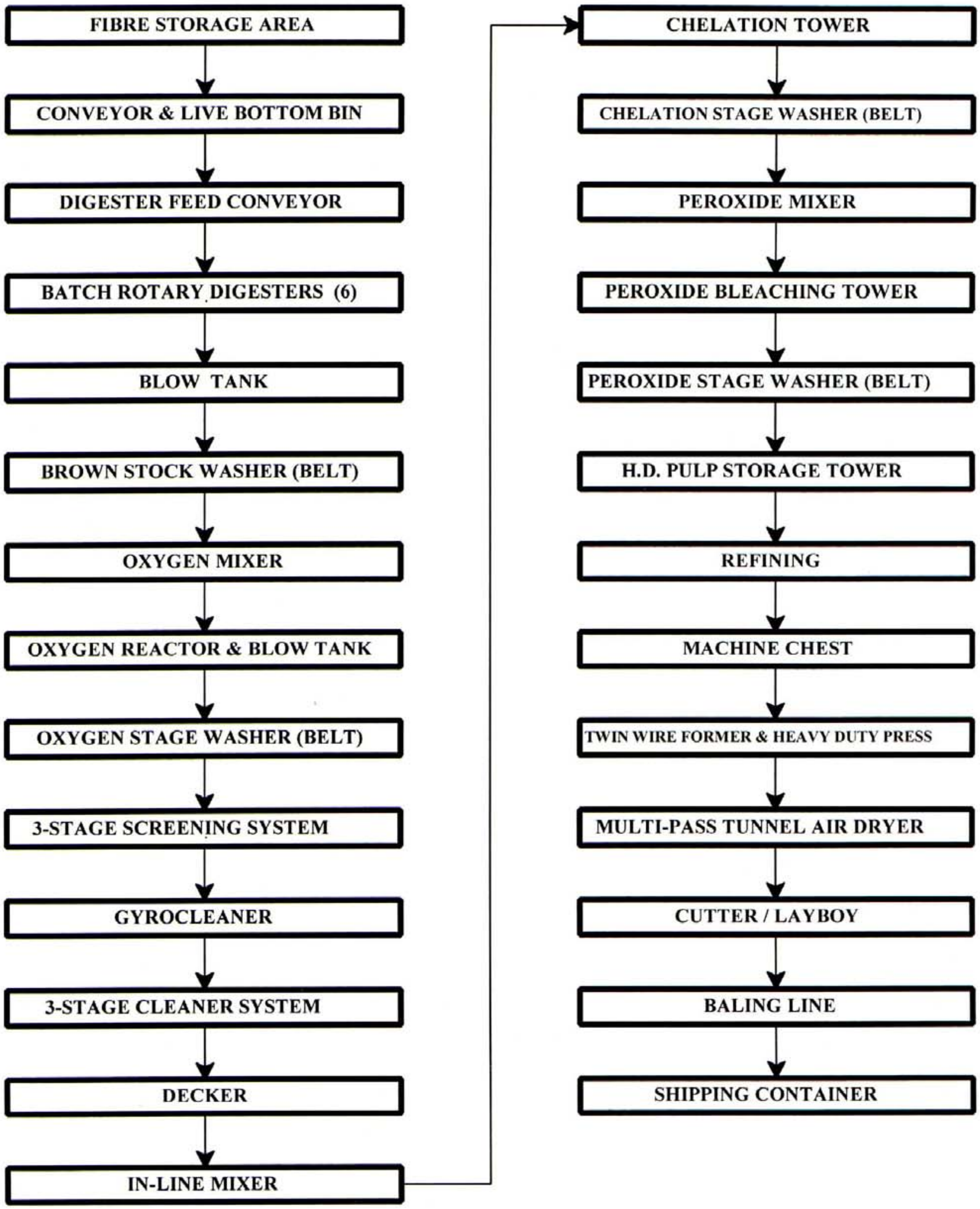
The sisal pulp mill processes and equipment are based on the sisal raw material being delivered to the pulp mill in cut, depithed and washed form from the preprocessing stations.

Sisal raw material is delivered to the pulp mill by truck from the preprocessing stations located at the sisal estates. On entry to the mill, full trucks pass over a weigh scale. Empty trucks are weighed when exiting the mill. Weights are recorded to permit calculation of the delivered weight to the mill.

The sisal fibre is stored in wet bulk form. The storage area consists of two sloped concrete slabs located on opposite sides of a conveyor. The trucks bring the sisal fibre to the raw material storage area, and dump the full load onto one of the concrete slabs. A bulldozer then pushes the sisal into a sloped pile approximately 10 m high. Drainage troughs are provided across the width of the storage area with drainage towards the belt conveyor. A water collection zone, with perforated covers, covers the full length of the edge of the conveyor on each side. The liquid drained from the moist raw sisal piles is collected in a trough beneath the perforated covers. The troughs are sloped to allow the liquid to drain towards the raw sisal levelling system. A pumping system recycles the liquid to the top of the storage piles for continual soaking of the piles to sustain the fibres in moist form.

Sisal is taken from the pile on a first-in, first-out basis to provide uniformity to the feed stock. The bulldozer pushes the sisal across the width of the pile towards the conveyor. The conveyor discharges raw sisal fibre into a levelling bin which discharges the fibre at a controlled rate to the feed conveyor for delivery to the digesters.

Figure 2. TCF bleached sisal market pulp mill fibre line



c) **Pulping**

Sisal fibre is discharged from the conveyors into the batch rotary digesters (further work on sisal cooking may result in a change from batch digesters to a continuous horizontal tube digester). Simultaneously, cooking liquor and low pressure steam are added to the digesters. When a digester is filled, the cover is closed, rotation of the digester is started, and high pressure steam is admitted. When the cook is completed, the digester is stopped in the vertical position and is connected to a blow line by a quick-connect coupling. The digester contents are then blown into the blow tank. The steam flashed on blowing is used in the blow heat recovery system to produce hot water for washer showers in pulp washing and bleaching.

d) **Brown Stock Washing, Oxygen Delignification and Screening & Cleaning**

Pulp from the blow tank is pumped to a belt washer, where the pulp is washed and thickened. The washed, thickened stock is pumped through a continuous oxygen reactor where oxygen is added for further delignification after which the stock is washed again on a belt washer.

After the oxygen delignification washer, the pulp is screened in pressure screens, cleaned in centrifugal cleaners, and thickened by a decker before dropping into the screened stock chests.

The rejects are accumulated in a box fitted with a perforated bottom and are added to the lime mud prior to the lime kiln.

e) **Pulp Bleaching**

The two-stage bleach plant (Q-P) has an upflow tower for the Q stage (chelating stage) and a downflow tower for the P stage. Provision has been made in the mill layout for a second peroxide bleaching stage if required. As in the case of pulp washing, belt washers are used after each stage. A solution of chelating agents is added to the first stage and a solution of hydrogen peroxide (H_2O_2) is added to the second stage. After the second stage washer, the washed pulp is acidified with SO_2 water and is pumped to high-density storage tower. The Q stage washer filtrate is sent to the effluent treatment system and excess P stage filtrate pumped to other upstream process areas.

f) **Pulp Forming, Drying & Baling**

Bleached pulp from the high-density storage tower is moderately refined and pumped to the pulp dryer machine chest. From this chest, the pulp is pumped to the twin-wire pulp former which de-waters the pulp to a consistency of 35-40%. Next, the pulp sheet goes through roll presses which bring the consistency to 46-48% before the sheet enters the multi-pass tunnel dryer.

Wet broke is returned to the machine chest. Dry broke is repulped in a small pulper and is cleaned before being returned to the machine chest.

The formed wet pulp sheet (2600 mm wide) is dried in a continuous multi-pass tunnel air dryer. The dried sheet is then cut into four 650 x 900 mm sheets in the cutter/layboy. The cut sheets are accumulated in piles and are then automatically transferred onto a conveyor to the wrapping and baling line.

Finished bales are transported by forklift truck, and loaded into standard 20 foot containers for shipping.

g) **Chemical Recovery System**

The chemical recovery system includes a complete soda recovery unit including evaporators, concentrator, recovery furnace, recausticizing line and lime kiln.

The spent liquor (black liquor) extracted from the brown stock washers and the post oxygen delignification washers is pumped across the pipe bridge to the chemical recovery system. Recovered white liquor is pumped back to the main process building using the same pipe bridge which also carries the steam lines, the fresh water line and the main power cables.

Lime mud from the lime mud filter is conveyed to the lime kiln where it is combined with fresh limestone, and burnt at high temperature to provide burnt lime (CaO). The burnt lime is conveyed to the lime slaker.

h) **Water Treatment**

Fresh water drawn from the nearby river flows through bar and cup screens into a concrete wet well from which it is pumped to the mill site.

The mill process water is pumped through a grit removal system to a reactor clarifier where lime, alum, etc., are added to the water. Overflow from the clarifier passes through gravity filters to the filtered water clear well from which it is distributed to various points in the mill.

Cooling water for the evaporator condenser follows a separate loop. As it does not contact the process, the cooling water does not contain any process contaminants, and it is discharged back to the river without treatment.

i) **Effluent Treatment**

There are three mill systems - the storm water drainage system, the sanitary sewer system, and the mill process sewer system. The storm water drains discharges directly into the river. The sanitary sewers discharges into a septic tank and sanitary sewage treatment system.

The mill effluent is collected in the mill process sewer system from various sections of the mill, and combined prior to treatment. It is neutralized and then fed to a reactor clarifier which precipitates and removes the solid material. The clarified effluent is sent to an activated sludge aeration lagoon to convert BOD material. From this lagoon, the effluent is sent to a secondary clarifier to remove the resultant solids before returning to the river. The solids removed by the clarifiers are thickened using a belt press. These solids are sent either to a sanitary land fill site or, more likely, will be used as a fertilizer/soil conditioner on the surrounding sisal estates or farms.

j) **Power Generation**

The pulp mill produces its own electric power requirements using two diesel oil fired gas turbines. Waste heat from the turbines is recovered in a waste heat boiler which generates process steam. The waste heat boiler is equipped for additional oil firing to ensure that the total steam demand of the mill is met.

A diesel-electric set is provided for plant start-up and emergencies, and to supply the power required during construction. Air compressors to supply compressed air for the mill also are located in the steam and power area.

k) **Mill Support Facilities**

The mill includes the following support facilities:

- mill shops including machine shop, welders and pipefitters shop, carpenters shop, electrical and instrument shop, painters shop, oilers shop and cleaners shop which include the equipment required for preventive and routine maintenance for the mill

- mill stores which carry a stock of consumable materials, spare parts, tools, and maintenance materials required to keep the mill in operation

- an equipped garage for servicing mobile equipment

- a fully equipped and air-conditioned central laboratory and test stations to monitor the operation of the mill and to test raw materials and finished product.

- a fire protection system, including an internal dry pipe sprinkler system, an exterior hydrant system and an alarm system

- fully equipped and air-conditioned offices for administrative, engineering staff and production superintendents; and locker rooms, washrooms, toilets, first-aid station, and cafeteria for all personnel.

TOTAL PROJECT ESTIMATED CAPITAL COST

The estimated capital costs for modular estate development and the preprocessing stations are given earlier. Table 18 provides the total estimated capital cost for the project including the pulp mill, the modular estates and the preprocessing stations.

Table 18. Total project estimated capital cost

Cost Component	000's US$
Modular Estates (4)	25,860
Preprocessing Stations (4)	12,140
Pulp Mill	
• Pre-Production Expenses	6,200
• Land	---
• Site Development	1,300
• Buildings & Civil Works	9,320
• Equipment & Machinery	53,410
• Erection & Installation	8,260
• Services	15,000
• Subtotal Base Cost	**93,490**
• Working Capital	8,360
• Total Pulp Mill	**101,850**
TOTAL PROJECT	
Project Subtotal	139,850
Contingency	10,490
Interest During Construction	8,930
PROJECT TOTAL	**159,270**

Notes: 1. Estimated costs for site development, civil works & buildings, and erection and installation jointly developed with Tanzania's largest general contractor.
2. Interest during construction is generated by the computer model.

SISAL PULP MANUFACTURING COSTS

Table 19 provides the variable manufacturing costs to produce one admt bleached and unbleached sisal pulp. These costs are directly proportional to the production output of the pulp mill. In addition to the variable manufacturing costs identified, the financial analysis includes shipping costs of US$ 125/admt pulp and selling costs as 1% of revenue.

Table 19 provides the fixed manufacturing costs such as salaries, insurance, administration costs, etc., which are independent of production and which will be incurred regardless of the production output. Concerning the fixed manufacturing costs, it should be noted that the financial analysis was conducted in constant dollars as discussed later.

Table 19. Estimated variable manufacturing costs per admt sisal pulp

Raw Material	Unit Cost	Bleached Sisal Pulp		Unbleached Sisal Pulp	
		Consumption Rate	US$/admt	Consumption Rate	US$/admt
Sisal pulp Sisal raw fibre	69.00 US$/bdmt	0.900 bdmt pulp 1.385 bdmt	95.54	0.900 bdmt pulp 1.343 bdmt	92.69
Sodium carbonate	154.00 US$/mt	0.068 mt/bdmt pulp	9.42	0.066 mt/bdmt pulp	9.14
Limestone	7.55 US$/mt	0.100 mt/bdmt pulp	0.68	0.097 mt/bdmt pulp	0.66
Caustic soda	754.00 US$/mt	0.065 mt/bdmt pulp	44.11	0.000 mt/bdmt pulp	0.00
Magnesium sulphate	352.00 US$/mt	0.003 mt/bdmt pulp	0.95	0.000 mt/bdmt pulp	0.00
EDTA	1,115.00 US$/mt	0.010 mt/bdmt pulp	10.04	0.000 mt/bdmt pulp	0.00
DPTA	1,215.00 US$/mt	0.002 mt/bdmt pulp	2.19	0.000 mt/bdmt pulp	0.00
Hydrogen peroxide	742.00 US$/mt	0.040 mt/bdmt pulp	26.71	0.000 mt/bdmt pulp	0.00
Sulphur	130.00 US$/mt	0.008 mt/bdmt pulp	0.94	0.000 mt/bdmt pulp	0.00
Diesel oil (power generation)	311.50 US$/mt	0.263 mt/admt pulp	81.92	0.235 mt/admt pulp	73.20
Diesel oil (on-road vehicles)	482.71 US$/mt	0.020 mt/admt pulp	9.65	0.020 mt/admt pulp	9.65
Water	0.00 US$/$m^3$	60 m^3/bdmt pulp	0.00	40 m^3/bdmt pulp	0.00
Consumable supplies & misc. chemicals			14.11		9.27
TOTAL			**296.26**		**194.61**

Table 20. Sisal pulp mill estimated fixed manufacturing costs (in 000's US$ per year)

Cost Component	Year 1	Year 2	Year 3	Years 4-10	Years 11+
Local salaries & fringe benefits (423 employees)	1,110	1,110	1,110	1,110	1,110
Expatriate management assistance	2,500	1,000	1,000	500	0
Maintenance materials	850	850	850	850	850
Insurance	430	430	430	430	430
General overhead	300	300	300	300	300
Land lease	10	10	10	10	10
TOTAL	**5,200**	**3,700**	**3,700**	**3,200**	**2,700**

FINANCIAL ANALYSIS

a) **Financial Analysis Assumptions**

The key assumptions used in the financial model were:

- The project would be analysed using the discounted cash flow rate of return method to account for the value of money over time.
- The analysis would be carried out in constant 1993 dollars.
- The project would be implemented in 33 months and would have a productive life of 20 years.
- The debt/equity ratio would be 75/25.
- Terms for the capital loan were set at 8% interest with a 3-year grace period from the loan signing date followed by a 10-year repayment period.
- Only bleached sisal pulp would be produced.
- The selling price was set at US$ 1,200/admt pulp delivered to the port-of-entry which is the low end of the US$ 1,200-1,400/admt pulp for reinforcing fibre.
- A tax holiday would be in place for of 8 years as an incentive for new industry after which a 40% tax rate would be applied.

b) **Financial Analysis Results**

Table 21 provides the projected financial results for the total project which includes the 4 modular estates, the 4 preprocessing stations and the 50,000 admt/year bleached sisal market pulp mill.

Sensitivity analysis of the key parameters shows that the project is most sensitive to variations in the selling price followed by variable manufacturing costs and production rate.

For example, a 15% increase in the selling price to US$ 1,380/admt pulp increases the ROI to 22.7% and the ROE to 32.1%. Given that the study was undertaken during 1992/93 when woodpulp prices were severely depressed, it is highly conceivable that higher selling prices for sisal pulps would be achievable under better market conditions.

Table 21. Projected Financial Results

Project Return	Total capital requirements	US$ 159,268,000
	ROI	18.5%
	Net Present Value (NPV)	US$ 187,229,000
	Pay back period	4.6 years
Return on Equity	Total equity requirements	US$ 39,817,000
	ROE	23.9%
	Net Present Value (NPV)	US$ 116,541,000
	Pay back period	3.4 years

CONCLUSIONS

The market survey establishes that there is a market opportunity for high strength pulps, an opportunity which could be filled by sisal pulps. Although specialty pulp markets exist, the larger market would be as a reinforcing fibre in commodity paper grades.

The laboratory and pilot plant work has established that high quality TCF bleached sisal pulps can be produced with brightnesses ranging from 79 - 87 %ISO depending on the process selection. Process optimization still is required to finalize the process parameters.

The modular sisal estate concept incorporating preprocessing on the estates offers a method to provide low cost sisal fibre to the pulp mill.

The suggested 50,000 admt/year TCF bleached sisal market pulp mill project offers a good rate of return while providing a low cost, high quality pulp suitable for both specialty papers and as a reinforcing fibre in commodity papers.

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