A Case Study on Efficient Utilization of Tapioca Fibrous Waste Residue*

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Abstract

The magnitude of products and the monetary return from the efficient utilization of 600 metric tons of tapioca fibrous waste residue produced per day in and around Salem (Tamil Nadu) is indicated, based on the R&D investigations carried out in CFTRI, Mysore over a period of 5 years. The aim of the exercise is to generate the interest of the industry in this vital alternative to the extensive biological treatment of the waste which involves heavy capital investment and substantial recurring expenses. Among the various products that could be obtained, the utilization of the waste for production of confectioner's syrup, ethanol and enzymes showed commercial feasibility.

Introduction

India produces about 5.8 million metric tons of tapioca annually[1] and the tuber is processed annually for about 1.16 million metric tons of the production of starch and sago by more than 800 large and small scale industries mainly concentrated in Southern India[2]. Out of these, about 600 units are situated in and around Salem (Tamil Nadu) and crush over 3000 tons of tapioca roots|chips per day for manufacturing starch and sago[3]. At a rate of about 20% of the roots|chips processed[2], these units generate about 600 metric tons of tapioca fibrous waste residue (TFWR). It contains about 50-65% starch on dry weight basis[4] and the starch granules in it are located in the root cells that were not ruptured during the rasping process[2]. The slurry of TFWR contains about 20% solids and is dewatered by physical means to contain about 30% solids and then sun-dried by small scale industry for selling[2] as animal feed or glue but the return is low[2]. The mechanical drying of the slurry which was followed earlier by large scale industry stands discontinued due to the prohibitive fuel cost.

Due to its high BOD and COD loads, TFWR causes serious atmospheric pollution if discharged without treatment[5-8]. The biological treatment needed is extensive[7,8] and thus involves high capital investment and considerable recurring expenses. Due to the non-productive nature of the waste treatment and the heavy expenditure on it, the cost of manufacture of starch and sago increases to an uneconomical level. Consequently, the waste is discharged without any treatment in most cases. In recent years, the industry is under pressure, from local authorities and the public, for proper disposal of TFWR.

Thus, the efficient utilization of TFWR to obtain value-added products is an economically and industrially important alternative as it would lead to nearly total saving on waste treatment and would also give an additional return to the industry. An array of products can be obtained by utilization of TFWR and intensive efforts were put up in CFTRI., Mysore for their exploration[4,9-14]. The complexity of the unit operations involved in these utilization processes and the financial input as well as output are the main decisive factors in selecting the best approach. These are critically analyzed with reference to the utilization of TFWR available in and around Salem in the present communication.

The laboratory scale data[4,9-14] was extended to determine the magnitude of the products resulting from the efficient utilization of 600 metric tons of TFWR generated in and around Salem per day. The commercial values of these possible products are based on the price structure existing in early 1986. The economics is worked out in potential feasible cases and is based on the prevailing market prices in early 1984.

Chemical Composition of TFWR

The results of the analysis of sun-dried TFWR samples from large and small scale industry are presented in Table 1[4,9]. The presence of 60-63% starch indicates the employment of inefficient rasping processes by the industry for recovery of starch from tapioca roots|chips. It also confirms the feasibility of utilization of TFWR in converting this higher level of starch into value-added products and thereby providing over-all better return to the industry. It is worth while to note that the sun dried TFWR contains about

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TABLE 1

CHEMICAL COMPOSITION OF SUN-DRIED TAPIOCA FIBROUS WASTE RESIDUE

Constituents	g/100 g sun-dried TFWR Small Scale industry	Large Scale industry
Moisture	13.00	12.50
Starch	63.00	61.80
Crude fibres	14.50	12.80
Crude protein	2.00	1.50
Total ash	0.65	0.58
Free reducing sugars	0.43	0.37
Hydrocyanic acid	0.009	0.008
Pentosan	2.40	1.95
Other polysaccharides	4.001	8.492

80-90 ppm hydrocyanic acid and that it gets destroyed during the processing of TFWR[9].

The analysis was carried out in 1979 and it did not show any appreciable differences in the starch content of the samples from large and small scale industry. In the subsequent years, one of the large scale industries was able to reduce the starch percentage in TFWR to about 50% by using efficient rasping technique.

Approach to TFWR Utilization

The efficient utilization of TFWR is limited to the utilization of starch present in it or its saccharification and consequent utilization of the saccharified product. The exploratory studies carried out in CFTRI, Mysore on these lines were confined to the products such as confectioner's syrup, high conversion glucose syrup, high fructose syrup, ethanol, single cell protein, biogas and enzymes. It is worthwhile to note that good demand exists for these products in Indian market.

High Conversion Glucose Syrup

It can be obtained either by acid-enzyme[10] or enzyme-enzyme[9] hydrolysis of the starch Present in TFWR. In both the processes, 10% slurry of sun-dried TFWR was employed to obtain about 7% reducing sugars in the hydrolysate. After down-stream processing and concentration, a syrup of 95-98 dextrose equivalent (DE) was obtained and the conversion of starch is of the order of about 95-98%.

The process is not economically feasible due to several reasons. The need to apply drastic conditions for release of starch granules from the intact root cells for subsequent complete saccharification to reducing sugars imparts intense color to the hydrolysate which in turn demands very high expenses on decoloration and deashing. Drastic modification of and the addition to the existing glucose plants is necessary for use of TFWR as raw material. The manufacturing cost is also higher. Inspite of higher expenses on the downstream processing of the hydrolysate, the product still will be inferior to that obtained from tapioca or maize starch.

High Fructose Syrup

The saccharified TFWR, obtained either by acid-enzyme or enzyme-enzyme hydrolysis, could be subjected to the action of immobilized glucose isomerase after purification and partial concentration to about 40° Brix. In this case also, all the disadvantages associated with the use of TFWR for production of glucose syrup are applicable. Further, extensive purification is essential as glucose isomerase is very sensitive to impurities. In addition, the market potential for high fructose syrup is poor in India due to the availability of cane sugar at much lower cost.

Single Cell Protein

The use of saccharified TFWR as a source of carbon for production of protein was explored and it demonstrated the need for its supplementation with nitrogen, phosphate, magnesium, trace elements and growth factors for optimum yield of the yeast, *Candida utilis* or *Saccharomyces cerevisiae*. The process though technologically feasible, is not economically viable due to the availability of other carbon substrates at much cheaper cost. Moreover, the market potential of single cell protein is also poor as other protein sources are available at lower cost. In addition, all the disadvantages associated with the production of high conversion glucose syrup are applicable though this process eliminates the need for purification of the hydrolysate.

Ethanol

The fermentation of saccharified TFWR, as such or after concentration to contain 15% reducing sugars was explored[9,10]. Supplementation of the hydrolysate with nitrogen, phosphate and magnesium was found to be necessary for achieving optimal alcohol productivity. The data on comparative economics of the process with or without concentration of the hydrolysate is presented in table 2 and it indicates that concentration of the hydrolysate is not economical. The data on the fortification of the hydrolysate with molasses to raise sugar concentration to 15% is depicted in table 3. Though this approach is feasible, it has limitation such as non-availability of molasses in tapioca processing areas and high transportation cost of either molasses or saccharified TFWR. The present scarcity of molasses will also prove to be a major deterent. On the other hand, the fermentation of TFWR hydrolysate as such with its sugar concentration at 7% can be used but it will lead to a loss of 295 kg. of alcohol per day as compared to that obtained with the use of 15% initial sugar concentration[9].

The lower sugar concentration (7%) in TFWR hydrolysate is due to the use of 10% slurry of sun-dried TFWR in saccharification. The use of slurry at higher solid contents posed problems in mass transfer, agitation and handling of highly viscous mass. These problems were overcome recently by using 30% slurry in shallow layers[14]. The improved technology is under scale-up trials and showed potential commercial viability.

Confectioner's Syrup

Limited saccharification of TFWR with H_2SO_4 for production of confectioner's syrup of 42 DE was explored[12]. The process offers advantages over complete saccharification in its requirement of comparatively much less investment on plant machineries and operating costs. The commercial viability of the process is evident from the data on cost estimation given in table 4. The

TABLE 2
COMPARATIVE ECONOMIES OF ALCOHOL PRODUCTION WITH/WITHOUT CONCENTRATION OF SACCHARIFIED TFWR

Parameter	Value
Plant capacity/day	7500 kg. sun-dried TFWR
Yield of reducing sugars/day	5250 kg.
Concentration in reducing sugars in hydrolysate	7 kg/m³
Yield of ethanol/day without concentration of the hydrolysate	1728.45 kg.
Yield of ethanol/day after concentration of the hydrolysate to contain 15% sugar	2028.75 kg.
Additional expenses on steam/day for concentration of hydrolysate	Rs. 1600
Extra investment on evaporator and boiler	Rs. 0.6 millions
Expenditure based on steam alone for production of each additional kg. of ethanol possible due to concentration of the hydrolysate	Rs. 5.42

TABLE 3
COMMERCIAL FEASIBILITY OF FORTIFICATION OF HYDROLYSATE WITH MOLASSES TO RAISE SUGAR CONCENTRATION TO 15% FOR ALCOHOL PRODUCTION USING 7.5 TON TFWR/DAY

Parameter	Value
Requirement of molasses/day to raise sugar concentration to 15%	12 metric ton
Expenditure on molasses/day @ Rs. 60/ metric ton	Rs. 720
Expenditure on each additional kg. ethanol produced due to molasses fortification	Rs. 2.44

TABLE 5
MAGNITUDE OF VALUE-ADDED PRODUCTS FROM TFWR AVAILABLE IN AND AROUND SALEM

(No. of Starch & sago factories : 600
Combined capacity/day : 3000 tons chips/roots
Combined generation of TFWR/day : 600 ton

Product	Quantity/day	Sales value/day Rs. in millions
Glucose syrup	519 metric tons	4.152
Ethanol	174 m³	1.392
Single-cell protein	207 metric tons	2.070
High fructose syrup	519 metric tons	5.190
Confectioner's syrup	474 metric tons	2.844
Enzyme	600 m³	15.00
By-product ; bio-gas	33480 m³	—
By-product ; dry yeast (ethanol production)	4560 kg.	—

cost calculation is for a plant processing 7.5 metric tons of sun-dried TFWR/day in two shifts. The requirement of the land for the plant is 1200 m² with built up area of 275 m². The total investment qualifies for incentives available to small scale industry. Additional subsidy may also be available from appropriate agencies as the plant is based on waste utilization.

TABLE 4
COMMERCIAL FEASIBILITY OF THE PROCESS FOR CONFECTIONER'S SYRUP PRODUCTION FROM TFWR
(Capacity 8000 tons sun-dried TFWR/annum)

Parameter	Value Rs.
Land, Building, plant and equipment	4.294 millions
Tapioca waste	Free
Chemicals	2.482 millions
Utilities	1.742 "
Labour and plant overhead	0.283 "
Factory over-head	0.249 "
Administrative and sales expenses	1.065 "
Cost of production/kg	3.46
Selling price/kg.	6.00
Profit before taxes	2.876 millions
Profit after taxes	1.440 "
Return on investment, percentage	23.57 "
By-product (bio-gas)	129,600 m³

Enzyme Production by Solid State Fermentation

The use of TFWR as substrate in solid state fermentation for enzymes was investigated and it revealed the need for fortification with nitrogen for optimum productivity[13]. The substitution of wheat bran by nitrogen enriched TFWR for enzyme production offers economic advantages. The cost of sun-dried TFWR is Re 0.40-0.75/kg. against about Rs. 1.50/kg. of wheat bran. Among all the other products explored, the enzymes are costliest and also produced in larger quantity (Table 5). Moreover, there is no need for modification of or addition to the existing solid state fermentation plants for switching over from wheat bran to TFWR. Technology can be directly exploited by the industry as there is no need for scale up studies on this process.

Bio-Gas

The use of TFWR for bio-gas production will be a total wastage of valuable starch present in it. However, the spent residue obtained after saccharification or after extracting the enzyme produced by solid state fermentation can be utilized for bio-gas production, after necessary supplementation with nutrients.

Magnitude of Products from TFWR Available in and Around Salem

Based on the data of the R & D investigations, the magnitude and sales value of various products that could be obtained by utilizing TFWR available in and around Salem are calculated and presented in table 5. The values reported are based on the assumption that the waste is completely utilized for the manufacture of that particular product. In addition, the spent residue can also be used to produce 33480 cu.m. biogas per day as the by-product.

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