CHAPTER II

LITERATURE REVIEW ON TAPIOCA WASTEWATER AND TREATMENT

2.1 Location and Manufacturing Process of Tapioca Starch Factories

Tapioca starch factories have been established in Thailand for more than 30 years. At that time all of them were the second grade or the old-type processing as a household industry with a low capital cost and low productive capacity. The manufacturing process is simple which utilizes more labour than mechanization. The first grade factories or the new-type have been introduced about 20 years with the producing process is more complicated, rapid, high capacity with better quality than the second grade. Although, the capital cost of the first grade factory is higher the production per unit is less.

There are 59 first grade and 86 second grade tapioca starch factories in Thailand. Most of the first grade factories are located in Nakornratchasima, Rayong and Chonburi Provinces but the second grade factories are concentrated only in Chonburi Province. The number of the factories is shown in Table 2.1.

2.1.1 First Grade Tapioca Starch Manufacturing Process

A first grade tapioca starch flow diagram is illustrated in Fig.2.1. Roots are transported by truck to the factory. The average percentage of starch is tested basically on the specific gravity before the cost of them are evaluated. Normally the roots must be processed within 24 hrs to avoid degradation of the starch. The belt conveyor will

Table 2.1 - The Number of Tapioca Starch Factories* in Thailand

Provinces	1st Grade	2nd Grade	Sub-Total
Chonburi	14	71	85
Rayong	17	8	25
Chanthaburi	1	-	1
Prachinburi	1	2	3
Ratchaburi	2	-	2
Kanchanaburi	2	-	2
Chainat	1	-	1
Nakornsawan	1	-	1
Kamphaengphet	3	1	4
Uttaradit	1	-	1
Nakornratchasima	11	-	11
Kalasin	2	-	2
Khonkaen	1	-	1
Udornthani	1	-	1
Songkhla	1	4	5
Total	59	86	145

*From Industrial Environmental Division
Department of Industrial Works.

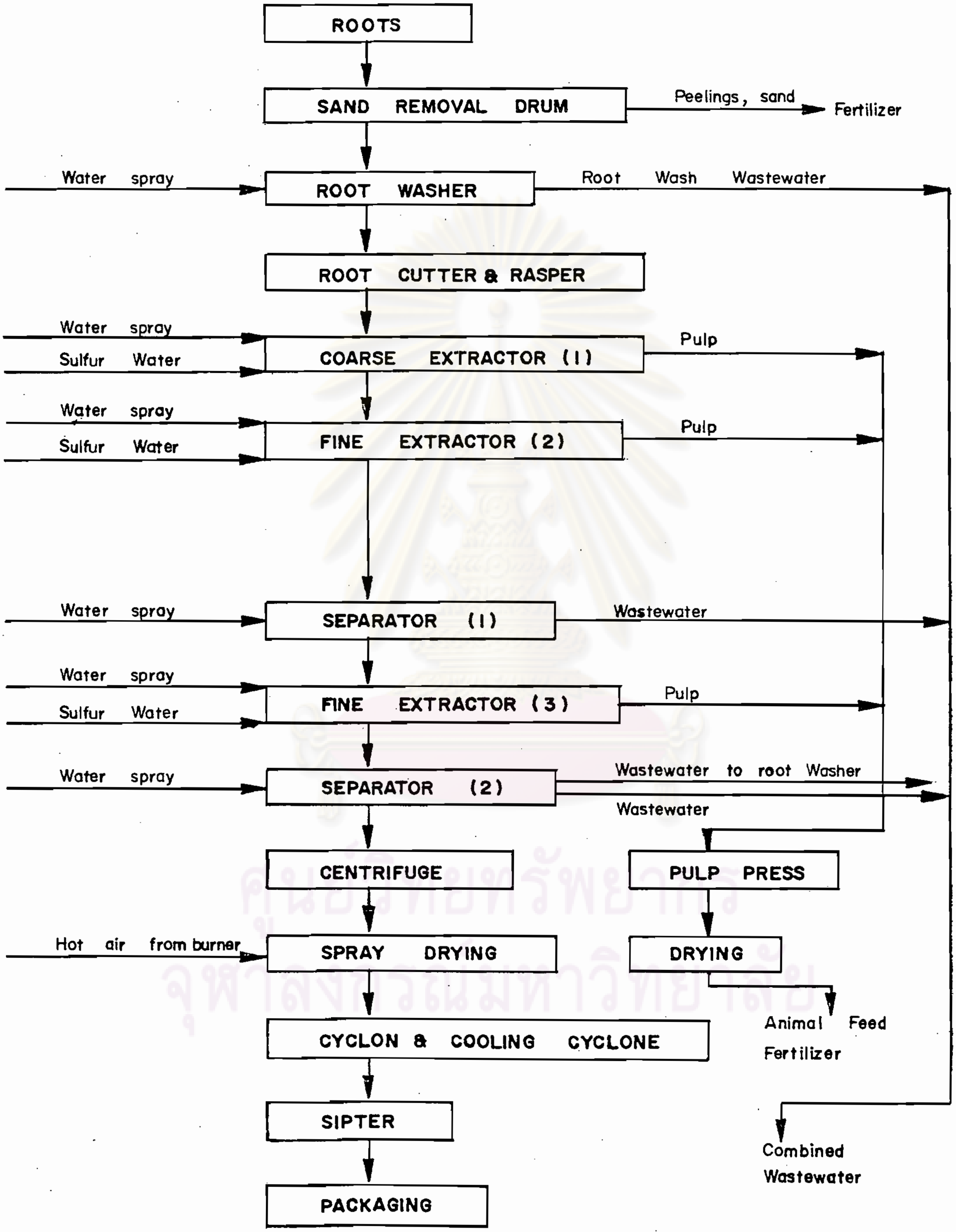

Fig. 2.1 First Grade Tapioca Starch Flow Diagram

transport the roots to sand removal drum, where peel and sand are removed and piled before finally disposal as fertilizer. The roots are then washed in a basin with spray water (sometime or some factories included wastewater from separator). Revolving paddles in this tank remove the remaining peels, sand and clay particles from the roots where the root wash wastewater is eventually discharged to combined with other factory wastewaters. Washed roots are conveyed to root cutter and rasper releasing the starch granules from their surrounding cellulose matrix or pulp. Most of the pulp is removed by centrifugal means firstly in the corase extractor where spray water and sulfer water are continuously feeded. Separated pulp is dewatered by pulp press and drying by sunlight on a large concrete slab before processing as animal feed or use as fertilizer. The starch milk after coarse extractor passes through the series of fine extractors and separators in order to remove fine particles of pulp and concentrate the starch milk respectively. The pulp is also discharged from the fine extractor and wastewater is come from separators. Every units of fine extractors is feeded with spray water and sulfur water but only spray water for separators. The concentrated starch milk after the last separator passes through a centrifuse to give a paste-like substance before spray drying by hot air from burner. The small amount of starch milk is released from the centrifuse and recycle to the primary fine extractor. After spray drying, the heated starch powder is decreased it temperature by cyclone and cooling cyclone before passing through a sipter to classify it quality and finally packaging.

The purpose of adding sulfur water at every units of the extractors is to increase the quality of starch in terms of colour and to prevent the growth of microorganisms because of its acidity of sulfur dioxide dissolved in water.

2.1.2 Second Grade Tapioca Starch Manufacturing Process

A second grade tapioca starch manufacturing process is illustrated in Fig.2.2. The initial stages of processing also include sand removal drum, root washer and rasper. Starch separation from the cellulosic pulp is made in only one step by screening it through fine nylon mesh supported by a large eylindrical drum. The starch is sprayed through and the pulp slowly drawn off to pulp press before drying by sunlight on concrete slab. The starch milk is then seived again and released into large 1.2 m deep settling basins. After 24 hrs settling, the supernatant is removed by decantation and discharged as wastewater. The surface of the starch caked on the bottom is washed, the wash water from which is discharged to an outdoor lagoon. The starch is then resuspended and pumped to the second-sedimentation basin of 1.2 m deep and 24 hrs detention time again. The supernatant is then decanted and discharged as wastewater and the surface is again washed. This surface washwater is stored in the same lagoon as the first one. The starch is then removed in large cakey chunks to the subsurface hot air heated concrete pad for spreading drying and finally packaging.

2.2 Characteristics of the Wastewater

First grade tapioca combined wastewater characteristics studied by previous investigators are shown on Table 2.2.

Table2.3shows the second grade tapioca wastewater characteristics

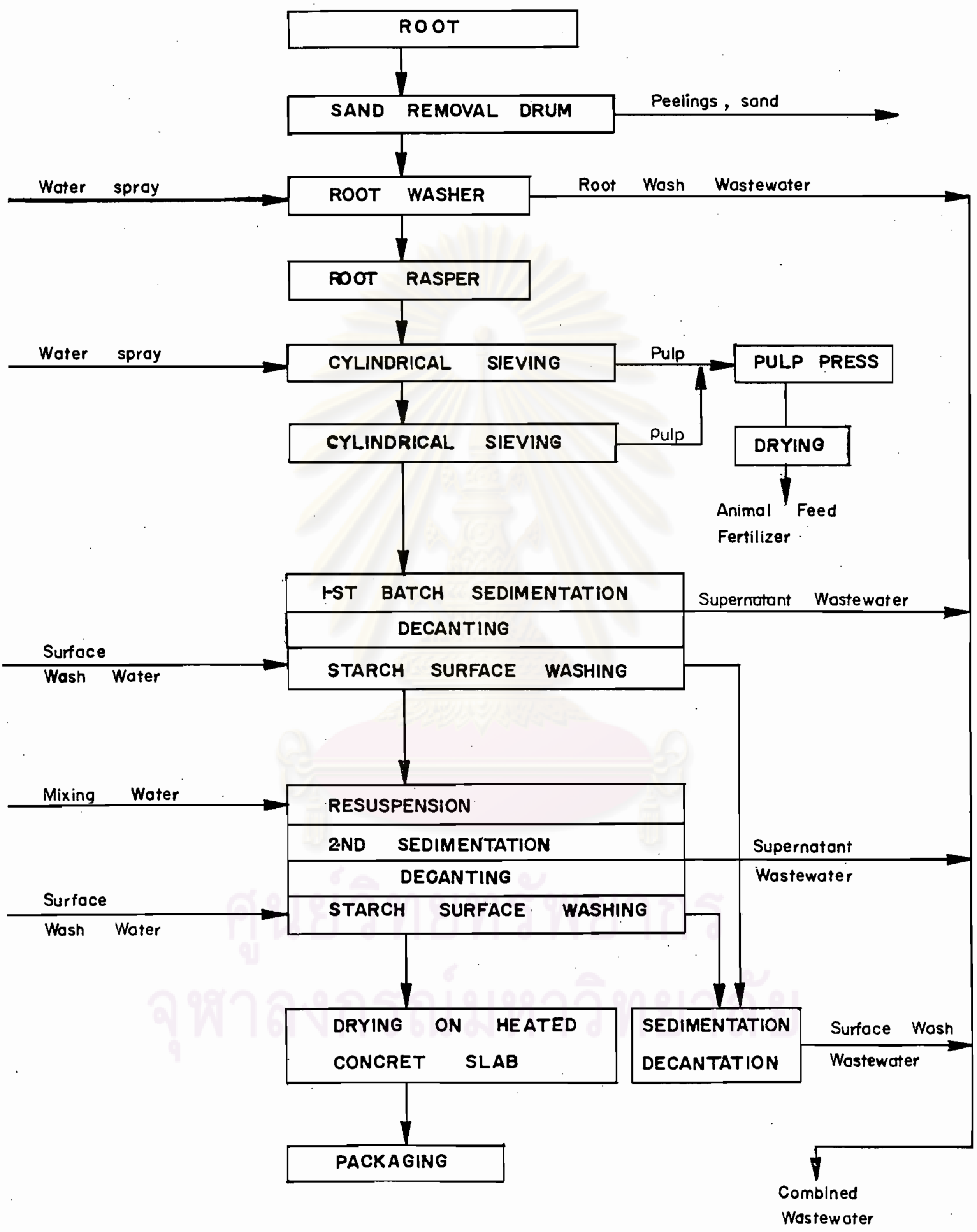

Fig. 2.2 Second Grade Tapioca Starch Flow Diagram

Table 2.2 First Grade Tapioca Combined Wastewater Characteristics

Item	Units	JESUITAS (1966)	THONGKASAME (1968)	UDDIN (1970)	USUK (1975)	SAIPHANICH (1975)
Temperature	^{o}C	28.5-33.0	30-31	29.5-32.1	23-26	26-30
pH	-	3.4-4.2	3.8-5.2	4.1-4.4	3.5-3.9	3.9-5.2
Alkalinity	mg/ℓ as $CaCO_3$	0	0	0	-	0
Acidity	mg/ℓ as $CaCO_3$	667.5-860.2	135-1010	550-900	-	-
Suspended Solids	mg/ℓ	1480-8400	1970-3850	2160-3450	3200-4000	1700-3920
Settleable Solids	mg/ℓ	60-200	48-115	42-115	30-70	30-100
Total Solids	%	0.56-0.93	0.60-0.80	5480-6820	1500-2500	3840-6800
Volatile Solids	% of T.S.	92.0-98.6	80.2-86.8	78.3-89.1	0.80-0.88	-
Dissolved Oxygen	mg/ℓ	0	0	-	-	-
BOD	mg/ℓ	3000-4400	5550-7400	5060-6590	4500-6000	4000-6650
COD	mg/ℓ	3100-13900	13800-19500	7500-15200	5500-6700	5100-7760
Ammonia - N	mg/ℓ	0-4.70	0	5.0-10.2	0-4.5	2-22
Organic - N	mg/ℓ	19.0-38.9	86-115	0.75-145	100-180	95-220
Nitrite - N	mg/ℓ	0	0	-	-	-
Nitrate - N	mg/ℓ	0	0	-	-	-
Phosphorus	mg/ℓ $PO_4^{\equiv}$	5.6-8.5	0	5.0-10.0	7-14	3-14

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Table 2.3 Second-Grade Tapioca Wastewater Characteristics (McGARRY et al., 1972)

Characteristics	Units	Amphur Sriracha Plant				Amphur Muang Plant I				Amphur Muang Plant II				
		A	B	C	Total	A	B	C	Total	A	B	C	Total	
Flow	l/kg root	1.43	6.8	0.5	8.7	0.379	4.22	0.525	5.1	0.372	4.27	0.508	5.2	6.3
BOD	mg/ℓ	1,290	6,600	4,200	5,140	1,790	6.830	1,970	5,990	2,460	6,600	2,450	5,835	5,655
Total Solids	mg/ℓ	2,913	15,012	4,460	12,468	4,408	11,004	3,712	9,815	7,012	10,292	3,742	9,320	10,534
T. Susp. Solids	mg/ℓ	2,185	12,280	1,152	10,023	2,496	2,650	2,540	2,640	1,762	2,650	2,540	2,550	5,071
T. Vol. Solids	mg/ℓ	1,823	11,276	2,992	9,285	2,243	6,008	1,529	5,295	3,148	5,856	2,069	5,240	6,606
pH	-	-	-	-	-	6.2	6.7	4.8	6.5	5.6	5.2	4.1	5.1	5.8

after McGARRY et al. (1972).

The comparisons of first grade and second grade tapioca factory are shown in Table 2.4.

2.3 Treatment of Tapioca Wastewater

JESUITAS (1966) carried out an investigation of tapioca wastewater from the S.R. Tapioca Co., Ltd. Chonburi. He studied flow and characteristics of the wastewaters and technical feasibility of the treatment using methods such as plain sedimentation, chemical coagulation, wedge-wire filtration, and aerobic treatment. The results showed that plain sedimentation could remove 94% of suspended solids, 67% of BOD_5, and 72% of COD. It was also feasible to treat settled separator wastes by a biological method. Wedge-wire filtration produced a poor quality effluent. Chemical coagulation also produces poor quality effluent at high operation cost. The recommended that primary sedimentation followed by a biological process be necessary for treatment of this particular wastes.

TONGKASAME (1968) studied unheated anaerobic treatment of tapioca starch wastes in closed digesters and in stabilization ponds. He found that the efficiency of the digestion process increased with the increase in liquid detention time. An optimum detention period was found to be about 16 days resulting in volatile solids removal of 71.8% or 305 lb/acre-day and BOD removal of 71.5% or 362 lb/acre-day. However, the effluents released from the ponds or digesters were still too high in BOD and suspended solids to be discharged which should be further treated

Table 2.4 The Comparisons of First Grade and Second Grade Tapioca Starch Factory

Parameters	Units	First Grade	Second Grade
Raw materials	-	Tapioca roots	Tapioca roots
Product	-	First grade	Second grade
Processing	-	Equipment	Labour
Working hours	hrs	24	14
Average capacity	ton-starch/day	60	6
Average Consumption (1)	ton-root/day	300	30
Wastewater (2) flow rate	m^3/ton-starch	30-50	20-40
Total flow rate	m^3/day	2,400	180
Average BOD_5	mg/ℓ	4,000-6,000	4,000-6,000
Pollution loading	kg-BOD_5/day	12,000	900
Population equivalent (3)	person	180,000	14,000

(1) Based on 20% starch in the root

(2) Combined wastewater

(3) Based on 66 g/cap-day

using series of ponds, including aerobic stabilization ponds, prior to final disposal.

UDDIN (1970), his investigation of the performance of 3 ft deep experimental units anaerobic pond treating tapioca wastewater showed that BOD loading was the most significant variable compare to pH and detention time. The optimum BOD loading on single-stage anaerobic pond was found to be 6,000 lb/acre-day and maximum detention period of 5 days covered in the studies which gave 3,680 lb/acre-day of BOD removal. Areal BOD removals in the second and third-stage ponds were less than that obtained in the first-stage anaerobic ponds with equal detention time. The three stages of anaerobic ponds in series gave an average total BOD removal of 84.0% at an average BOD loading of 2,270 lb/acre-day based on the total area. In first-stage anaerobic ponds, the pH of the pond contents increased to within the range 6.4-7.1 at a BOD loading of about 4,000 lb/acre-day for all detention times, and not fall below 5.90 at 6,000 lb/acre-day and gradually increased in passing through second and third-stage anaerobic ponds.

McGARRY and PESCOD (1970) collected and analysed the data for anaerobic ponds treatment by previous investigators at the Asian Institute of Technology. The result showed that very high areal BOD removals could be achieved under controlled operating conditions. He believed that at any particular detention period high BOD loadings would give higher areal BOD removals than low BOD loadings.

USUK (1975) conducted a feasibility study of tapioca wastewater treatment using a laboratory-scale activated sludge unit. He found that more than 90% of BOD removal was possible at F/M ratio as high as 1.0. The value of growth yield coefficient of 0.6481 and microorganism-decay coefficient of 0.0223 day^{-1} were presented.

SAIPHANICH (1975) studied on anaerobic filter treating tapioca wastswater. His results showed that anaerobic filter could be loaded up to 4.0 kg COD/m^3-day (250 lb COD/1,000 ft^3-day) with 92% removal if pH and nutrient of the influent were controlled at optimum levels. The loading and the associated efficiency were equal to or higher than those of an activated sludge process or a trickling filter. If the pH and the nutrient control were neglected, the anaerobic filter could still remove 94% of the input COD at an organic loading of 1.4 kg COD/m^3-day (87.4 lb/1,000 ft^3-day). In addition to high percentage COD removal the anaerobic filter also had high stability to shock loading and could withstand a 15 day period of starvation without any significant drop in efficiency. The greatest COD removal occurred in the first 30-cm of the filter column. An optimum height recommended for full-scale filter would be about 1.5 to 2.0 meters as the result of process stability. Although the treatment process gave high efficiency, the effluent COD and SS still high which subsequent treatment of any conventional aerobic process have been proposed.