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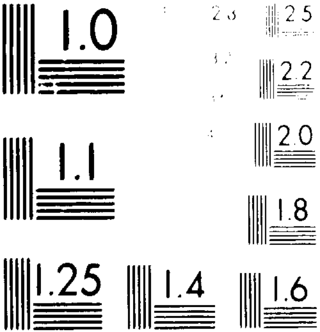
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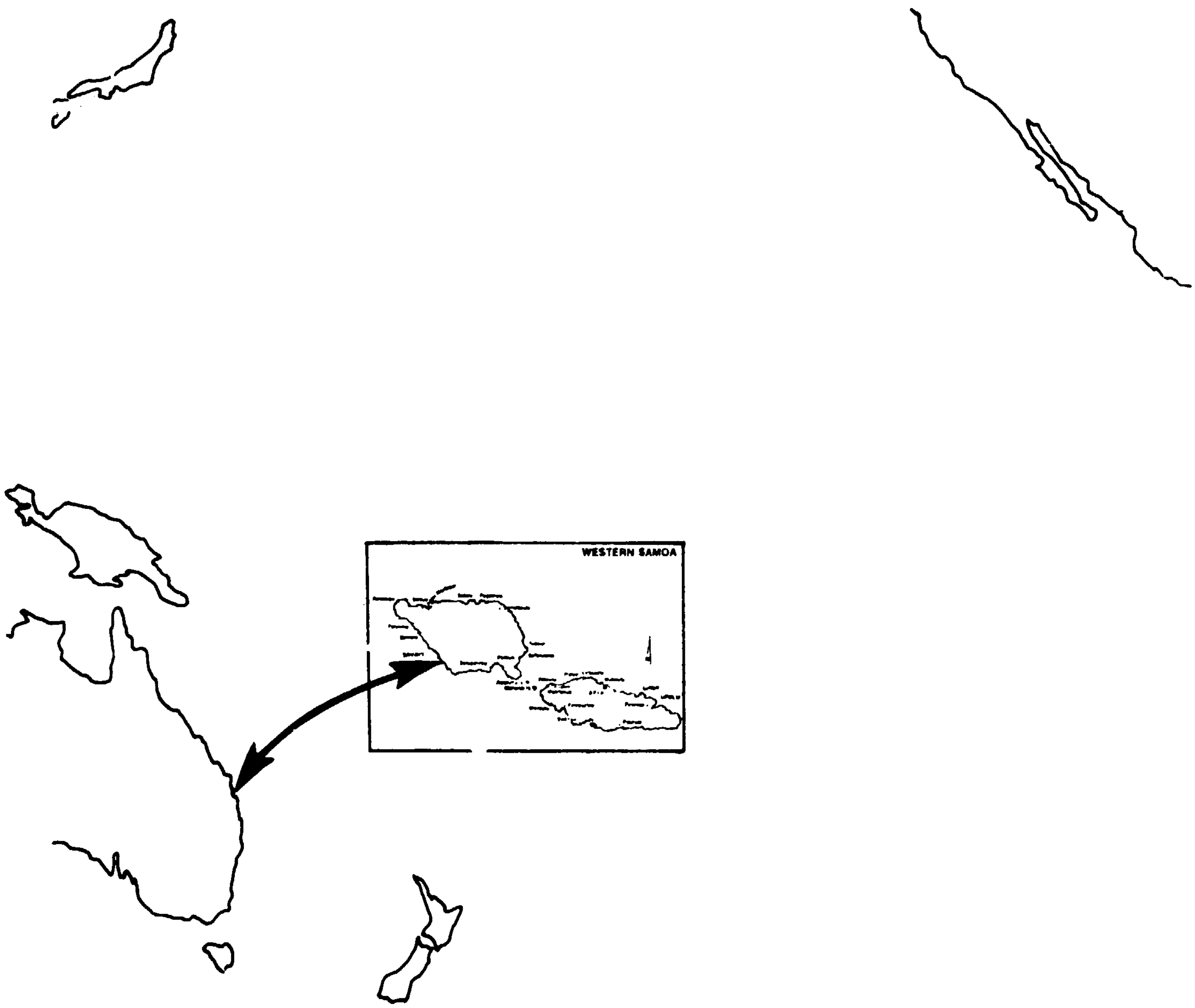
Government of Western Samoa

Western Samoan Starch Plant Study



Davy Agro

Davy

Final Report
June 1980

FEASIBILITY STUDY

ON

MANUFACTURE OF STARCH FROM TARO

Davy

Melbourne

JUNE, 1980

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COVERING LETTER

Davy

Davy Agro

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Tel: 26 6961
Telex: 30094

RBB/bg - DA9005

June, 1980

United Nations Industrial Development Organisation,
The Chief, Purchase and Contracts Services Section PAC/IOD,
P.O. Box 300, A-1400,
VIENNA, AUSTRIA

For the attention of Mr. D.F. Mant

Dear Sir,

COMMERCIAL STARCH FACTORY STUDY
FINAL REPORT

We have pleasure in enclosing 20 copies of our FINAL report in accordance with the terms of our Contract SI/SAM/79/803.

The study ranges wider than the initial terms of reference, both in crop choice and marketable products, in an attempt to find the most useful and viable alternatives to help the people of Western Samoa. The list of people this mission consulted is long and yet does not mention many of those, particularly in Western Samoa, who gave helpful advice.

This FINAL report follows closely to the DRAFT FINAL report, as comments on the DRAFT were so few. The financial section was extended to include cash flows and the cost data was both up dated and expanded. Factory layouts and mass balances have also been included for completeness.

We hope this report is sufficiently detailed and thorough for UNIDO and the Western Samoan Government to be encouraged to carry the project through to the next phase - of turning the various options into a practical reality. Our Company would be pleased to offer its services in this regard. The feasibility study is not an end in itself but a means to an end, that of establishing a factory, or factories, in Western Samoa.

As expressed in the DRAFT report, a number of other organisations have expressed a wish to receive a copy of the FINAL report, e.g., South Pacific Commission Library (New Caledonia), Department of Economics (Australian National University) and the School of Geography (Melbourne University) if you allow.

....2/

We would be willing to discuss this in detail with yourselves or the people of Western Samoa in person if the need arises, particularly the fuel ethanol alternative. We are responsible for the establishment, design, erection, commissioning and management of a farm and factory in the Highlands of Papua New Guinea which will produce fuel ethanol from cassava.

We hope the report meets with your approval.

Yours faithfully,
For DAVY AGRO

R B Brooks

R.B. Brooks
PROJECT MANAGER
WESTERN SAMOA STARCH STUDY

encs:

1

1.0 INTRODUCTION

This report is a feasibility study on the establishment of a commercial starch plant for Western Samoa and an investigation in detail of the food and industrial uses of starch, and products that can be made from starch. The Government of Western Samoa is particularly interested in the processing of taro.

Production of taro is one of the principal traditional agricultural occupations, it is consumed as a main staple food and has become a valuable export earner. The terms of reference, Appendix, for this report stated that the export markets for taro were showing signs of over-supply. This could result in village production having to be cut back, a step with potential grave repercussions. Alternative uses of taro are thus being sought.

I intend showing that taro is not a sufficiently cheap source of starch to compete on the world export markets against Australian wheat starch, Thailand cassava starch or any other starch.

The report describes Western Samoa, its background, climate, land tenure system, agriculture and economy because they deeply affect the nature of this or, indeed, any other agro-industrial venture in Western Samoa.

In the best interests of Western Samoa, and after appropriate consultation, the report was extended from taro and cassava to include breadfruit, bananas and other edible aroids.

Export of starch as crystal starch to Australia was believed to be the only starch that could compete on the world market because of the low wage structure offsetting the high raw material and shipping costs.

It was considered more appropriate to look at import substitution as a way of improving the trade imbalance where the disadvantage of the remote location from potential markets would work to the country's advantage. Also, there was doubt expressed in the long term that Western Samoa could feed its people, particularly if it exports agricultural products.

In particular, I consider starch as a flour substitute, glucose as a sugar substitute and ethanol as a fuel substitute.

The report describes in detail the way starch is hydrolysed to glucose syrups and then enzymically converted to ethanol. It shows the way this would be done on an industrial scale by describing in detail the equipment that is used.

The report assesses the yield, cost and analysis of the various available starch bearing crops.

A detailed market survey is described for Western Samoa on the quantity of starch, flour, glucose syrup and ethanol that can usefully be produced for internal use.

Sites are considered on both islands as possible factory locations, Asau and Salelologa (Savai'i) and Vaitele, Mulifanua and Lotofaga (Upolu). The availability of power, fuel, water and effluent disposal are reported.

A financial analysis is completed for five different finished products. Plant costs, running costs, chemical requirements for each option are calculated and the effect on the trade balance is considered briefly.

2

2.0 SUMMARY

It was found that TARO is too expensive a raw material for it to be used as a source of starch. However, because it has special non-allergenic properties, it should be processed in any factory set up for any other starch bearing crop and then used in special applications where price is of secondary importance.

Breadfruit, cassava, banana and other aroids were all considered as a source of starch but only breadfruit can be produced at a low enough price to be a feed for an agro-industrial complex. It has the added advantages that it is already said to be produced in sufficient quantities on both islands and that much is left to rot.

It was estimated that breadfruit could be grown and harvested for $7.00 per tonne. The factories producing starch, flour and dextrose syrup from this raw material have negative cash flows. The fuel ethanol factory producing enough ethanol to be used in petrol as a 20% replacement has a 1.43% I.R.R.

The Government of Western Samoa may consider investing in such ventures because all options improve the balance of payments situation, provide jobs in the factories and cash for the villagers who grow and harvest the crops.

If H.M.L. van Wissen agrees with the statements in this report on the price and availability of breadruit, then the following is recommended:

a) The first stage of an integrated starch/dextrose/flour factory is built at Vaitele consisting of a crystal starch facility with a large enough raw materials handling section to supply future expansion into flour and dextrose.

b) After the above facility is commissioned and experience gained on laboratory conversion of starch to glucose and ethanol, a 2.6 million litre/yr ethanol factory should be built at Asau.

3.0 WESTERN SAMOA

3.1 Geography

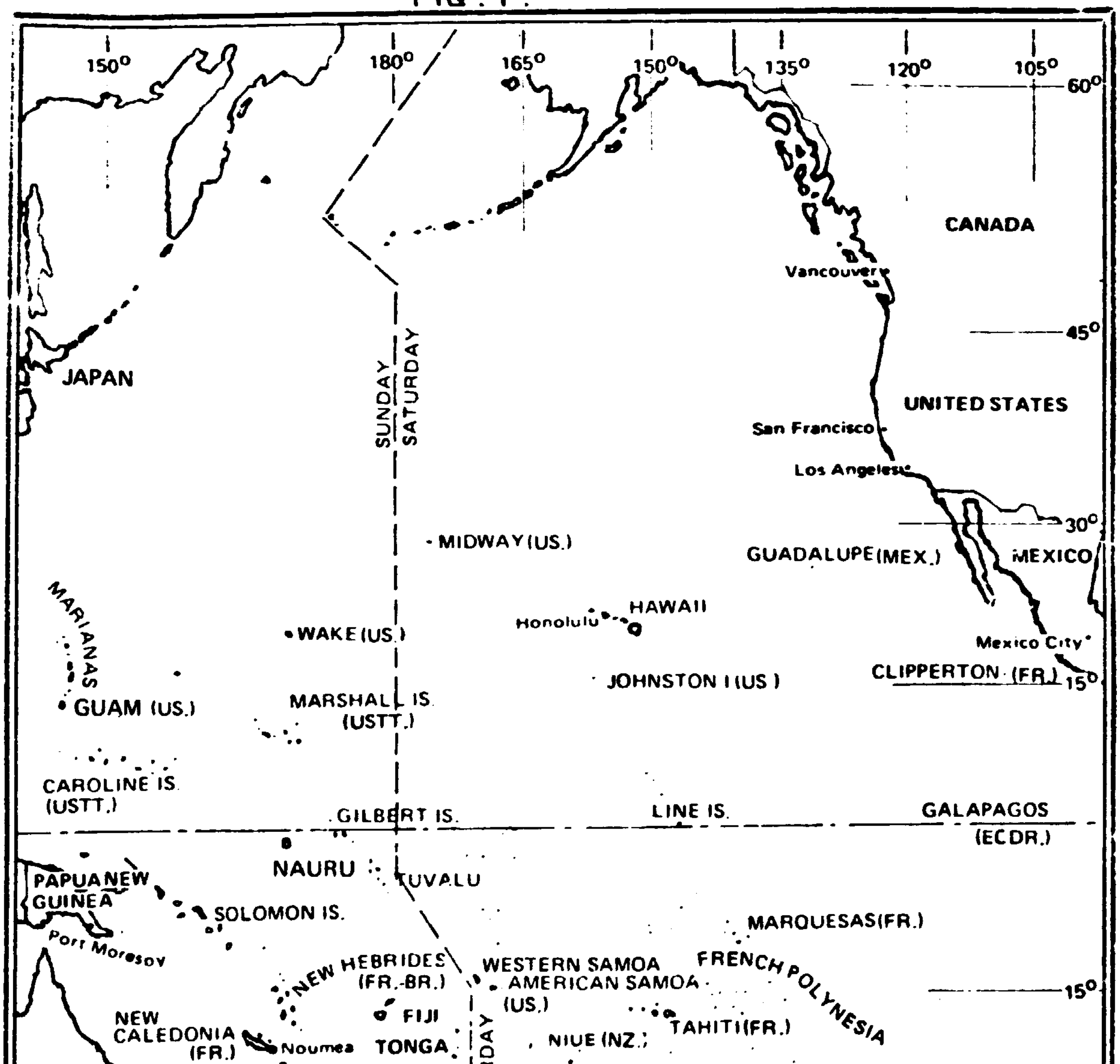
Western Samoa is the larger and westerly portion of the Samoa Archipelago, lying between latitudes 13° and 15° South and 171° and 183° West in the South Pacific. Within the South Pacific region, it lies 130 kms west of American Samoa, 1200 kms north of Tonga and 1260 kms east of Fiji. In world terms, it lies 4300 kms east of Australia, 2900 kms North-East of New Zealand and 4200 kms south of Hawaii, Fig.1.

It is geographically concentrated when compared to many of the countries of the South Pacific consisting of two main islands 22 kms apart. The island to the North-West, Savai'i, Fig. 2 has an area of 1714 km^2 (population density 25 per km^2) and Upolu has an area of 1122 km^2 (population density 100 per km^2), Fig. 3. There are a small number of very small islands.

Western Samoa has a population of 155,000 of whom 90% are pure Polynesian, the largest Polynesian population still living in authentic style. Over two-thirds of this population live on Upolu, of whom one-third live in the Apia urban area. The rate of natural increase is 3.0% (1977 estimate) though growth in recent years has only been 0.8%, because of substantial migration, particularly to New Zealand. Over half the population is under 15, a very high dependency rate. The projected population figures for Western Samoa are 260,000 (1991) and 350,000 (2000).

The climate is tropical with a temperature that varies from 22°C to 30°C and 2,500 hours of sunshine per year. It lies in the hurricane belt. In Apia, the capital and only urban community, average humidity is 80% and average rainfall is 2850 mm per

Fig. 1.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TUVALU
PAPUA NEW GUINEA
SOLOMON IS.
Port Moresby
MARQUESAS (FR.)
NEW HEBRIDES (FR.-BR.)
WESTERN SAMOA
AMERICAN SAMOA (US.)
FRENCH POLYNESIA
NEW CALEDONIA (FR.)
Noumea
FIJI
TONGA
TAHITI (FR.)
NIUE (NZ.)
COOK IS. (NZ.)
EASTER IS. (CHILE)
PITCAIRN (BR.)
NORFOLK I. (AUST.)
Brisbane
Sydney
Canberra
Auckland
Wellington
NEW ZEALAND
Christchurch

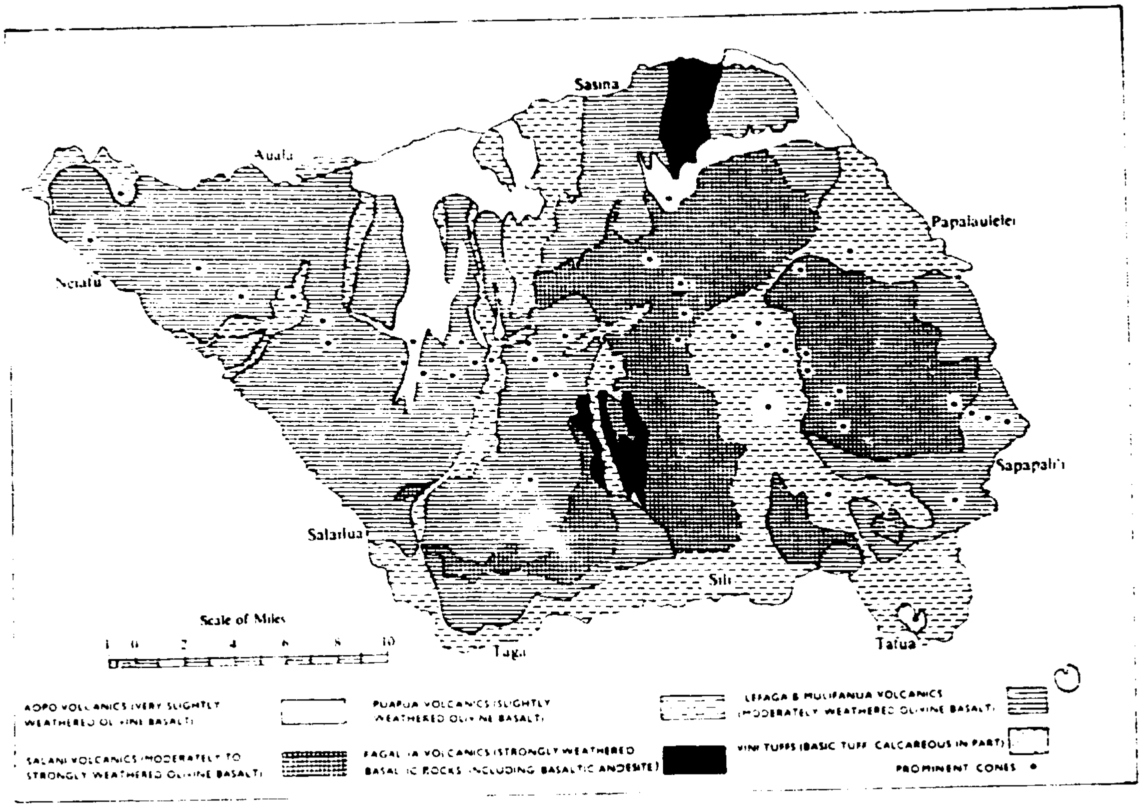


Fig. 2 : Geological map of Savai'i (after Kear and Wood, 1959).

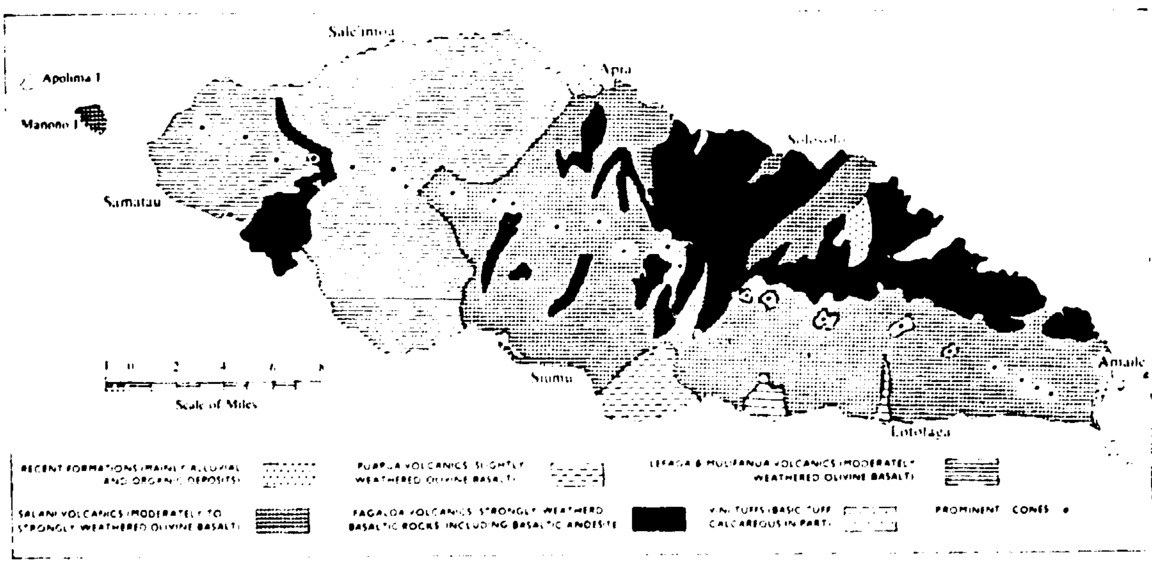


Fig. 3 : Geological map of Upolu (after Kear and Wood, 1959).

year of which 75% falls in the November/March period.

3.2 Government

Western Samoa is a fully independent state with a parliamentary system of Government. It became independent on 1 January, 1962, the first country in the South Pacific region to achieve this status which it was well prepared for by New Zealand.

The Head of State for life is His Higness Malietoa Tanumafili II, with the Legislative Assembly consisting of 47 members. The 45 Samoan members are elected by matais, and the remaining 2 members elected by part-Samoans and Europeans under universal suffrage. A recent special Committee of Cabinet found that most Samoans eventually wish for universal suffrage for over 21 year olds to apply to the election of all members. There are no political parties.

Western Samoa became a member of the United Nations in 1977, including ADb, ESCAP, UNDP, UNCTAD, UNIDO and FAO. It is a member of the World Bank, the Commonwealth and an associate member of the EEC. The IMF also has an adviser there. It is a member of a number of Regional Corporation Groups, including the South Pacific Commission.

3.3 Agriculture

3.3.1 Land

All customary land is administered according to the traditional practices of the Samoan people. Thus, no individual owns any particular land, control is under the extended family grouping, the "aiga" and is administered by the family head, the "matai".

Customary land cannot be alienated, though with Government approval it can be leased. The Alienation of Customary Land Act 1965 allows the Minister of Land to grant a lease or licence of customary land and to act as trustee for the owners. It may be leased for 20 years with a 20 year renewal.

Government, WSTEC and freehold lands cannot be purchased or leased for industrial or other development purposes without the consent of the Head of State. Land areas are shown in Table 1.

There are about 300 villages around the perimeters of Upolu and Savai'i. The villages traditionally have been on the coast but in recent times there has been some movement inland to the edge of the road which runs around the island. Each village land area commonly runs in a strip from the coast to the peak elevations near the centres of the islands. Most crops, e.g., taro,coconut, banana and breadfruit should be grown below an elevation of 300 m in Western Samoa. Division of land between villages and between aiga within the village is strictly controlled. It is meaningless to put a market price on village land as labour is the limiting resource with most families having more land than they can farm intensively.

There is little mechanisation apart from knapsack sprayers and chain saws. The terrain and rocky soil makes the use of tractors and implements difficult. The top of the taro, the "tiapula" is still usually planted with the long digging stick, the "oso".

TABLE 1

DISTRIBUTION OF LAND IN WESTERN SAMOA (Square kms)

	Savai'i	Upolu	Total
Customary Land	1,540	743	2,283
Public (Government) Land	150	170	320
WSTEC Land	8	121	129
Freehold Land, Including Missions	16	88	104
TOTAL:	1,714	1,122	2,836

Most families try to produce all the food crops they need with some surplus for cash. The surplus depends on the interest of the matai, the needs of the village and the land and labour at the matai's disposal. Hired labour is seldom employed by villages. The work force is the family which also must make time available for road and building construction, social and religious events.

Fisk considers that Western Samoa has limited agricultural resources in relation to population, in that there is adequate land to support the population with traditional staple foods, but the scope for exports is limited and diminishing.

3.3.2 Major Crops

There is a chain of substitution amongst the traditional staple foods. This chain is breadfruit, taro, banana, ta'amu. When a crop higher up the chain is available to eat, it is preferred. Breadfruit, the top of the chain, is the only seasonal crop. It might not be at the top of the chain if enough varieties were grown to produce an all year round crop. At the moment, there is little evidence of the chronic food shortage in Pacific countries like that which plagues many other emergent nations. However, there is some apprehen on that rapid development towards cash goals will further diminish the indigenous food supplies.

There are a number of crops important to Western Samoa which are briefly discussed below.

Coconuts: (Cocos *nucifera*) are the most widespread cash crop and are used for copra production. They are an important item in the local diet and are used as pig and poultry feed. They grow on the coastal plain extending inland and are generally grown below 250 m. Copra is the export staple of Western Samoa, as it is for all the South Pacific countries, though as in all of them the production per head of population has fallen in recent ,ears. In 1977, WSTEC, which has the largest coconut plantation in the Southern hemisphere, accounted for 16% of copra production, the rest being grown by villages. It is expected to produce 6,000 tonnes of its own copra meal from a new mill, of which 900 tonnes could be used in the local stock feed plant. Coconut stems are being used commercially for fence posts. It has been estimated that growing coconuts produces a revenue of $1 - $2 per man day.

Cacao: is the only cash crop grown which is not a staple food in Western Samoa. In 1977, WSTEC estates accounted for 14% of cacao production. Like coconuts, cacao is very labour intensive with harvesting and processing accounting for 40 - 50% of total production costs. The national average production is approximately 0.62 tonnes/ha (i.e., $1,170/ha return at 85 sene per lb.). It has been estimated that growing cacao produces $5 - $12 per man day in a fully mature plantation, though these costs do not reflect the time taken to reach maturity - 3 years for new hybrids and 6 years for more common varieties.

Taro: (Colcasia *esculenta*) is one of the edible aroid family. It is grown as a dry land crop in Western Samoa where it yields 15 t/ha in 9 - 10 months compared to the 75 t/ha that can be achieved using wet land culture in Hawaii. Taro does not store well either when left in the ground or when lifted. It is grown all over the islands with the main surplus in Upolu. All parts of the plant may be eaten, although many varieties contain high concentrations of calcium oxalate crystals (raphides) which can cause difficulties in the preparation of palatable food. The heart-shaped leaves and petioles are more acrid than the corms. When the taro corms are exported, a small amount of the petiole and the old base of the corm are left on to help it keep. It has been estimated that growing taro produces $5 - $6 per man day. It is the third biggest export earner for Western Samoa.

There are two other members of the aroid family which are of interest, Ta'amu (Alocasia *macrorrhiza*) and Taro palagi (Xanthosoma *saggitifolium*).

Ta'amu corms can grow up to 1 m long and weigh 20 kg each. They are woody cylinders. The crop takes 2 years or more to grow.

Taro palagi looks like coarse taro. The main corms are very acrid and often only the cormels, the small corms around the main corm, are harvested and eaten. The crop period is usually 9 - 12 months. A feature of this crop is that Haynes states it has good storage potential, a great advantage. A ratoon crop of cormels can be taken 5 - 6 months after the first.

<u>Bananas</u>: are grown all over the island and are eaten green as a boiled vegetable or as a ripe fruit. They only grow in Samoa below 300 m.

They were a much more valuable export earner in the past, but now rank as fourth in the edible crop exports. In 1978, a renewed effort was made to develop a good banana for the export trade. A new plantation of 250 acres has been set up. The crop averages over 32 tonnes/ha grossing $5,000/ha. When bananas are packed for export, as much as 50% may be rejected. This could be available for stock feed or other processing.

<u>Cassava</u>: (Manihot *esculenta*) is only grown to a small extent on Western Samoa for animal feed. It has been said to produce 70 tonnes/ha under very fertile soils, but its average yield in Oceania is only 11.4 tonnes/ha. Test plots grown at Alafua College, Upolu, produced 19 tonnes/acre, but when WSTEC planted 146 ha for the supply of cassava chips to the Western Samoa Feed Mill, they only averaged 7.5 tonne/ha. In the tropics, cassava accounts for more than half the total root crop production, indicating its strong competitiveness, although to be this

competitive it needs to be mechanised. The very rocky soils in Western Samoa make this difficult. A stone remover may be used to advantage on these soils. A simple device such as that designed in Australia towed by a tractor and driven by the P.T.O. could be useful, Fig.

Breadfruit: (Artocarpus *altilis*) grows on hills up to 300 m high. It is a tree which is competitive with coconuts. It is often grown as a second storey crop in village gardens. It is the only seasonal crop of the ones discussed in this report. Its two seasons vary slightly around Western Samoa being November to January and June to August. It is well known as a production crop, though its neglect as a means of import substitution is surprising. It has a key advantage that once planted, needs little fertiliser, and little labour input. The Department of Agriculture and Forestry in Western Samoa initiated a study into breadfruit as a crop for processing (Van Wissen, 1978). Van Wissen estimated that between 50,000 - 100,000 tonnes of breadfruit are already grown on Western Samoa, with 70% on Upolu. He further believed that there are enough cultivars known to ensure a non-seasonal crop. When fully ripe, the starch in some breadfruit is converted into sugar. It is estimated that half the breadfruit grown rots on the ground.

3.4 Economy

The Western Samoan decimal currency is based on the tala (dollar) equal to 100 sene (cent). The rates of exchange are given below.

Year	A$/WS$	US$/WS$	Baht/WS$	¥/WS$	£/WS$
1972	1.25	1.45			
1973	1.14	1.45			
1974	1.16	1.71			
1975	1.19	1.31		298	0.64
1976	1.15	1.25	25.8	366	0.73
1977	1.17	1.34	27.0	321	0.70
1978	1.22	1.43	18.5	260	0.69
1979	0.98	1.13	22.0		0.58
Now, May '80	0.96	1.07	21.9	259	0.48

3.4.1 Balance of Trade

The economy is based on agriculture which employs over 60% of the labour force and generates more than 95% of the exports. Manufacturing is at a fairly simple and small scale level, being mainly the processing of agricultural products and the production of a few consumer goods. The service sector (including commerce) employed more than 25% of the labour force in 1976, but more importantly it accounted for 57% of wage and salary employment. Government employment is a large part of this, and it would appear that the increase of over 100% in the number of Government employees accounts for most of the increased share of "services" in total employment between 1971 and 1976. Over the same period, agricultural employment fell both absolutely and relatively.

Export income is derived almost entirely from copra and cacao, with taro and timber making up most of the balance, Table 2 Banana exports, which were a major item in the 1950's and 60's, were only 0.4% of exports ($46,000) in 1977, though this is now the subject of a great deal of agricultural improvement and in the first three-quarters of 1979 it is up to $156,000.

The dependence of export income on only two products, both subject to severe fluctuations in domestic output and world prices, is a major problem. Export receipts more than doubled in 1977 due to good prices and high volumes of cacao and copra exports. The following year cacao price and volume dropped as did the export of copra (although its price rose by 20%). Total exports were 29% lower, but imports rose by one-third resulting in a very large trade deficit.

In 1978 and 1979, production of taro increased considerably as evidenced by the abundant domestic supply and a substantial increase in exports, reflecting output response to the rural

TABLE 2

TRADE STATISTICS

	('000's of tala)					
VALUE OF EXPORTS	1974	1975	1976	1977	1978	1979 *
Taro + Ta'amu **	318(2.2)	95(3.0)	363(3.0)	347(4.3)	1127(6.2)	940(8.5)
Copra	4658	2612	1894	4646	3614	6124
Cocoa	1872	1180	2229	5905	2645	1211
Timber	375	150	64	200	281	171
VALUE OF IMPORTS						
Flour						
Sugar						
Petroleum Products	1200			2500	3600	5500 Full Yr.
Food	3969	4946	6713			
Total Exports	7672	4540	5349	11651	8541	9628
Total Imports	15909	23160	23627	30198	40465	36263
Imports-Exports	8237	18620	18278	18547	31924	26635
C.P.I. December		158.2	180.4	196.2	201.6	231.8 (Sept)

*First threequarters of year only

**Price in s/kg in parenthesis

development programme, a relatively high buying price and the Government's drive in overseas markets. Exports of taro have increased from 51,000 cases* in 1977 to 114,300 cases in 1978 and an estimated 150,000 cases in 1979. At present, early 1980, Western Samoa is encountering increased demand in New Zealand for taro with demand now 12,000 cases per month. Additionally, they are air freighting about 40 tonnes of taro to the USA each week, i.e., a further 5,000 cases per month. This increase in taro exports, together with those of bananas and timber, offset some of the sharp decline in copra and cacao earnings.

Western Samoan exports receive preferential treatment in the markets of New Zealand, Australia, United States, the EEC and Japan.

Imports by commodity groups are shown in Table 3. It can be seen that the percentage of the various groups has remained static over the years 1975-1978. However, Western Samoa is greatly affected by the considerable increases in the price of petroleum products which have occurred. The total cost of importation of petroleum products during 1979 will be $5.5 million, and it is anticipated that this will rise to over $7.0 million in 1980. This was considered so important a problem that an Energy Committee has been formed and legislation was brought before the House in the 1980 budget to increase duty on some petroleum products.

The disturbing increases in the oil prices will have a depressive effect on growth in industrial and non-oil developing countries. This slow down in economic growth in industrial countries will then generate secondary effects on Western Samoa, as it exports more than 90% of its goods to industrialised countries.

* 70 lb. = 1 case

TABLE 3

IMPORTS BY COMMODITY GROUPS, 1974-78

(In thousands of tala and in per cent)

	1974	1975	1976	1977	1978[1]
Food and Live Animals	4,947 (31)	6,714 (29)	6,616 (28)	8,455 (28)	11,735 (29)
Beverages and Tobacco	1,184 (7)	1,242 (5)	1,890 (8)	1,563 (5)	2,023 (5)
Crude Materials: Inedible except Fuel	105 (1)	123 (1)	225 (1)	604 (2)	809 (2)
Minerals, Fuel, Lubricants and Related Materials	480 (3)	1,913 (8)	1,914 (8)	2,718 (9)	3,642 (9)
Animal and Vegetable Oils and Fats	49 (-)	93 (-)	239 (1)	302 (1)	405 (1)
Chemicals	1,095 (7)	1,128 (5)	1,418 (6)	1,510 (5)	1,023 (5)
Manufactured Goods Classified Chiefly by Materials	3,858 (24)	4,996 (22)	4,725 (20)	6,342 (21)	8,093 (20)
Machinery and Transport Equipment	2,696 (17)	5,160 (22)	4,750 (20)	6,946 (23)	9,307 (23)
Miscellaneous Manufactured Articles	1,495	1,791	1,850	1,758	2,428
	15,910 (100)	23,160 (100)	23,627 (100)	30,198 (100)	40,465 (100)

Sources: The Department of Customs and the Department of Statistics.

1 - Preliminary Estimates.

3.4.2 Exchange Controls

The Monetary Authority of Western Samoa was established in 1975 to control banking operations. Each year, local companies must apply to the Monetary Board for a yearly allocation of imports which is granted in two 6 monthly lots depending on the country's needs. Items mainly affected are vehicles, building materials and luxuries.

There is no restriction on the importation of capital. Remittance and repatriation of capital, profits, interest and dividends is controlled by Exchange Control Regulations (1961) which at present allows repatriation of dividends, interest and capital.

Overseas investment most favoured by Western Samoa is that which makes most use of indigenous raw materials, contributes to export income, encourages import substitution and brings with it technical knowledge and skills.

3.4.3 Wages and Taxes

The average income of the Western Samoans is low, though there is little evidence of deprivation or a general shortage of food. Judging by the total lack of any local preservation techniques, there has never been any chronic food shortages. Relative levels of national income cannot be established unambiguously because of the extent of non-cash production. However, incomes are low by the industrialised nations' standards with an average of $A254 per head for Western Samoa compared to $4000 for American Samoa and New Caledonia, though only $230 for the Solomons.

The rates of pay generally applicable at present (1980) are shown in Table 4.

TABLE 4

RATES OF PAY

Minimum Wage (over 16 years old) = T2.50/day

1.	**GOVERNMENT**	**Tala**
	Labourers	NOT DIVULGED
	Tradesmen	
	- Unqualified	
	- Locally Qualified Grade II	
	- Locally Qualified Grade I	
	Overtime Rate (40 hrs/wk):-	
	Weekdays x 1½, Sunday x 2, Public Holidays x 2, Commission Holidays x 2.	
2.	**PRIVATE INDUSTRY**	**Taia**
	Accountants	4,000 - 6,500
	Stenographer-Secretary	1,600 - 2,500
	Book-keeping Clerks	800 - 1,800
	Typists	800 - 2,000
	Electricians (Qualified)	1,000 - 2,600
	Carpenters/Mechanics	1,800 - 2,600
	Factory Sewing	800 - 1,800
	General Labourers	2.50/day

The Income Tax Rate Act (1974) describes the Regulations in detail.

Resident Company Tax is 42% and non-resident Company Tax 48%. Individual Income Tax varies from 5% for incomes below $1,000 per year up to 50% for incomes of $10,000 per year, though there are various personal allowances.

Buildings may be depreciated at a flat rate of 1, 1½ or 2½% per year depending on whether the building is reinforced concrete, brick (with or without wood frame) or all wood.

Motor vehicles, machinery equipment can be depreciated at 20% on the diminishing value.

3.5 Development

3.5.1 Transport

Faleolo Airport runway is 1700 m long and 150 m wide with 275 m over-runs at each end, suitable for BAC111 and DC9 aircraft, all weather, 24 hours operation. There are regular flights to Fiji and American Samoa and recently a 737 direct service to New Zealand.

Apia harbour has wharfage for two vessels of 36 feet draught with tug facilities and container storage. The Pacific Forum Line, established in 1977 is in operation serving the whole of the South Pacific region, including New Zealand and Australia with very competitive, subsidised freight rates (Appendix A).

The "Forum Samoa", a 4,500 tonne container vessel, has now made its maiden voyage from Europe and will be used on a regional route taking 18 days to Australia and calling into Apia every 26 days. Its sister ship the "Fua Kavenga" will be owned by the Tongan Government when it comes into service on the same route.

The Polish Ocean Lines regularly sail between Europe and Western Samoa.

The main routes on Upolu are good all-weather roads. The Asau-Salelologa Road (Savai'i) is the subject of an extensive programme of development, up-grading and sealing under a $20.6 million Savai'i

Agricultural Development project financed by the World Bank, Australian Development Aid Programme, UNDP, Japanese Aid Programme and the European Special Action Fund. By 1982, a 40 km/hour sealed road will link Asau with Salelologa.

3.5.2 Investment Incentives

As part of the first Five Year Plan following Independence, the Government enacted legislation to encourage a climate for economic growth.

The Enterprises Incentives Act was passed in 1965 which has the following allowances for projects which establish or expand the processing of agricultural products, factories of any type, any research and development.

(a) Loans at 10% for agricultural and 12% for industrial enterprises.

(b) A five year tax holiday (with a possible further five year extension) and an overall pay back of 15 years.

(c) Purchase or import free of customs duty any approved items, including raw materials, building materials, vehicles, plant and machinery.

(d) No duty on exports and a protection tariff on competing imports.

(e) A Company Tax of 42% following the tax holiday.

(f) Dividends or profits paid to shareholders tax free for two years following the end of the tax holiday.

(g) The Government will guarantee all loans.

The Act is administered by the Department of Economic Development. So far, 30 totally locally-owned and 36 partly foreign-owned enterprises have benefited.

In 1974, an Industrial Free Zone was established giving very favourable terms to new companies registered in Western Samoa which export at least 95% of their production.

The New Zealand Government has provided a Pacific Islands Industrial Development Scheme which, among other incentives, will give special access of goods to the New Zealand market and will give loans of up to $60,000 covering up to 30% of plant, equipment and buildings which are interest-free and are converted to grants if the venture is still operating after five years.

3.5.3 Development Bank

The Development Bank was incorporated in October 1974 to promote the expansion of the economy by making loans and giving financial, technical and advisory assistance to enterprises in Western Samoa. The bank will lend 20% of the total capital provided the sum is no greater than WS$700,000, usually at 8-10% for agricultural and 10-12% for industrial ventures with a three year holiday period and a 15 year pay back period from the date of securing the loan. They have a bias towards financing the small farmer. This is demonstrated in the composite table of loan patterns, Table 5 indicating that the Development Bank gave one loan to every six households for staples.

TABLE 5

DEVELOPMENT BANK LOANS

	1972	1973	1974	1975	1976
		(Value in $'000's)			
Taro	27	85	82	179	138
Total Farming	58	216	328	613	828
Other	18	62	129	419	839
TOTAL:	76	278	475	1,032	1,717
		(Number of Loans)			
Taro	98	321	305	585	622
Total Farming	165	617	967	1,330	1,929
Other	71	181	249	235	522
TOTAL:	237	798	1,216	1,565	2,448
		(Loan Patterns)			
Proportion of Staples Loans on Taro (%)	59	52	31	44	32
Average Loan for Staples ($)	349	351	339	461	430
Average Loan for non-Staples ($)	258	341	519	1,782	1,703

3.5.4 Education

Nearly 85% of primary school age children attend school, so the literary level is high. In recent years, there has been an emphasis of Government activity on secondary and vocational education with the Trades Training Institute providing full-time two-year courses.

At the tertiary level, the emphasis is on agriculture. The South Pacific Regional College of Tropical Agriculture was established in 1966 offering a three year course to diploma level in Tropical Agriculture. It recently became a part of the University of the South Pacific, which will offer a four year university degree.

Western Samoa has students in Lae, PNG, doing degrees in Food Technology.

3.5.5 Development Programmes

Between 1947 and 1970, the national and per capita income of Western Samoans fell continuously in real terms. Growth in income and employment was almost all in the primary and tertiary (Commerce and Government) sectors with secondary industry almost static. In 1970, the per capita income was $165 - $175/year.

In the first Five Year Plan, 1965 - 1970, a number of new industrial developments were encouraged, including soft drinks, biscuits and ice cream. The second Five Year Plan was devoted more to rural sector productivity and to provide incentives to mobilise domestic resources. Most of the resources were used in promoting commercial activities associated with the production of export crops. This orientation arose from the need to accelerate from subsistence to commercial activites and to earn foreign exchange. It was most important to motivate Village Agriculture, thus reducing food imports, improving agricultural productivity and increasing farm incomes. There was an expressed wish to use expatriates as little as possible.

The third Five Year Plan focussed mainly on increased production and economic growth. This period saw the establishment of a brewery, a cigarette making factory and a match factory, plus a great investment in a rural roads programme to promote agriculture.

The fourth Five Year Plan (1980-84) will emphasise those projects capable of enhancing the productive base of the economy, strengthening exports, promoting import replacement activities, creating employment and greater economic diversification. Among other things, high priority will be given to agriculture, industry and related infrastructure. Rural development will remain a major element, using traditional village institutions. This plan will be published early in 1980.

The Government of Western Samoa sees itself as having a number of advantages in terms of investment potential and future development, including abundant land, available man/woman power, no Government ideological obsession, no unions,and political stability. Overall, it sees agriculture as the mainstay of the country's economy, which has adsorbed a large share of available funds. There is an increasing drive to establish agro-industrial operations,and infrastructure to provide sound transportation and communication

Fisk thought the scope for agricultural exports as limited and tending to diminish, although there is adequate land to support the population. Generally, the small countries of the South Pacific are situated in the humid tropics and their agricultural potential is in most respects similar to that of most other countries in the humid tropics as regards the types of crops that can be grown. Thus the high costs of collection and transport, to the point of export, and then to the world markets, places them at a disadvantage with their competitors in other regions.

The recent South Pacific Agricultural Survey (February-June, 1979) states that in the absence of migration, the natural resources of Western Samoa will not be sufficient to support the future population at the standards of living to which they currently aspire. It sees the rate of growth in agriculture as the most important way Western Samoa can increase export earnings.

Fairbairn stated that isolated agricultural development can become an economic failure if it is not properly combined with the establishment of suitable processing industries for the production of semi and/or fully processed agricultural goods with an added value. An essential prerequisite for this is a thorough analysis of both the domestic and export market potential.

Thus agro-industrial projects appear to be the area in which Western Samoa should be concentrating either for export, if there is a large add on value, or for import substitution where remoteness from markets becomes an advantage rather than a disadvantage.

3.5.6 Industrial Development

A brewery began production in late 1978 and has already begun exports to Tonga. It has total reliance on imported raw materials.

A national computer facility started in January 1979 and is already servicing the public and private sector. In February 1979, a livestock feedmill financed by the New Zealand Aid Programme was opened. At the present time it has almost total reliance on imported raw materials. In April 1979, a cigarette factory began, though at present it uses all imported material. In May 1979, a match factory started operation. These last two factories have immediately provided employment for 110 people and saved valuable foreign exchange.

3.5.7 Constraints

In 1968, Trauth said that Samoa was not willing to compromise its deep rooted culture for purely economic gain.

Wai said that it has been shown that Western Samoa's labour and land resources are adequate for the production of both traditional food staples and export crops to support a viable economy which would supply the basic needs of its rapidly expanding population. However, the same studies also stated that this is possible provided traditional methods of production are adapted or replaced with the appropriate modern technological practices, and provided certain social and institutional constraints to economic development are modified or removed. (Fox and Cumberland, 1962; Lauterbach and Stace, 1963; Lockwood, 1965).

Radical social reform is unacceptable, but adaptations are occurring within the traditional social system. Whilst some aspects of the traditional Samoan social system limit economic development, the traditional matai system based on the aiga and the village unit has many welfare advantages.

3.6 Electricity Generation

At present, Western Samoa generates 88.3% of its installed electrical capacity of 11,099 kW by diesel and the balance by hydropower. There are two more hydroelectric power schemes underway, the Samasoni and Fale-ole-Fe Schemes both in Upolu. Through hydro and steam generation by wood waste, the plan is to eliminate the production of electricity from diesel within five years with a potential saving of 2 million gallons of diesel.

The timber mill at Asau has 2.5 MW of generating capacity from its timberwaste and there is a proposed wood-fired (coconut log) power station near Mulifanua. Electricity is 12 s per unit with a proposed increase to 14 s per unit in early 1980.

4.0 STARCH AND ITS DERIVATIVES

4.1 Starch

4.1.1 Occurence

Starch can be found in all parts of most higher plants, including the leaves, stems, seeds and tubers. Starch is stored in the form of granules and is an excellent source of energy, metabolically much more accessible than cellulose, and playing a similar role that glycogen does in animals. Starch in leaves is often transitory, breaking down to sugars during the night. However, it is the reserve organ starch that is of major interest, that which is deposited in the tubers, bulbs, rhizomes, stems and unripe fruit.

Starch granules can generally be identified simply by microscopic examination. Some typical examples are shown in Appendix B. They are typically spherical, ovoid, or irregular in shape, some being of a single size range and others twin distributions.

The starches of most importance in food and industrial use are those from corn (maize), sorghum (milo), wheat, rice, potato, cassava, sago and arrowroot. Each has its own particular special properties, but for most uses the most important property is price, particularly with modern technology when starch behaviour can be changed chemically.

Most of the world's starch derives from corn with the rest of the supply made up by potatoes, wheat, cassava then rice in order of magnitude.

The corn starch is mainly manufactured in the USA, whereas most of the potato starch is from Europe, wheat starch from Australia with cassava and rice starch coming from Asia.

4.1.2 Chemistry

Starch is a high molecular weight polymer of D-glucose. Most starches consist of a mixture of two types of polymer, amylose and amylopectin. They have considerably different chemical and physical properties. The molecules are shown in Fig. 4. The linear polymer is called amylose in which glucose units are joined by α D (1:4) links of several hundred glucose units. The branched polymer of starch is called amylopectin in which glucose units are joined by α D 1:4 links and α D 1:6 links, the latter link causing a branch point. There may be many thousands of glucose units in amylopectin. Generally, there is 20-25% amylose in starch and 75-80% in amylopectin.

Starch is insoluble in cold water and the granules settle out at a speed dependent on their particle size. When a suspension of starch in water is heated, the granules retain their shape until a particular temperature is reached at which they begin to swell. This gelatinisation temperature varies with each type of starch and generally occurs over a range of about 10^{o}C. The granules will continue to swell until the viscosity of the suspension begins to rise (as recorded by a Brabender amylograph under standard conditions). This viscosity normally rises to a peak and then drops off. The point at which the viscosity starts to rise is called the pasting temperature. When the solution cools, the viscosity may rise again reflecting the tendency to retrograde. Amylopectin stays in solution but amylose is never truly soluble in water, and it is the amylose that retrogrades.

All of these various behaviours and characteristics are different depending on the type of starch. The mechanical and thermal properties can also be altered by producing chemical derivations of the various starches.

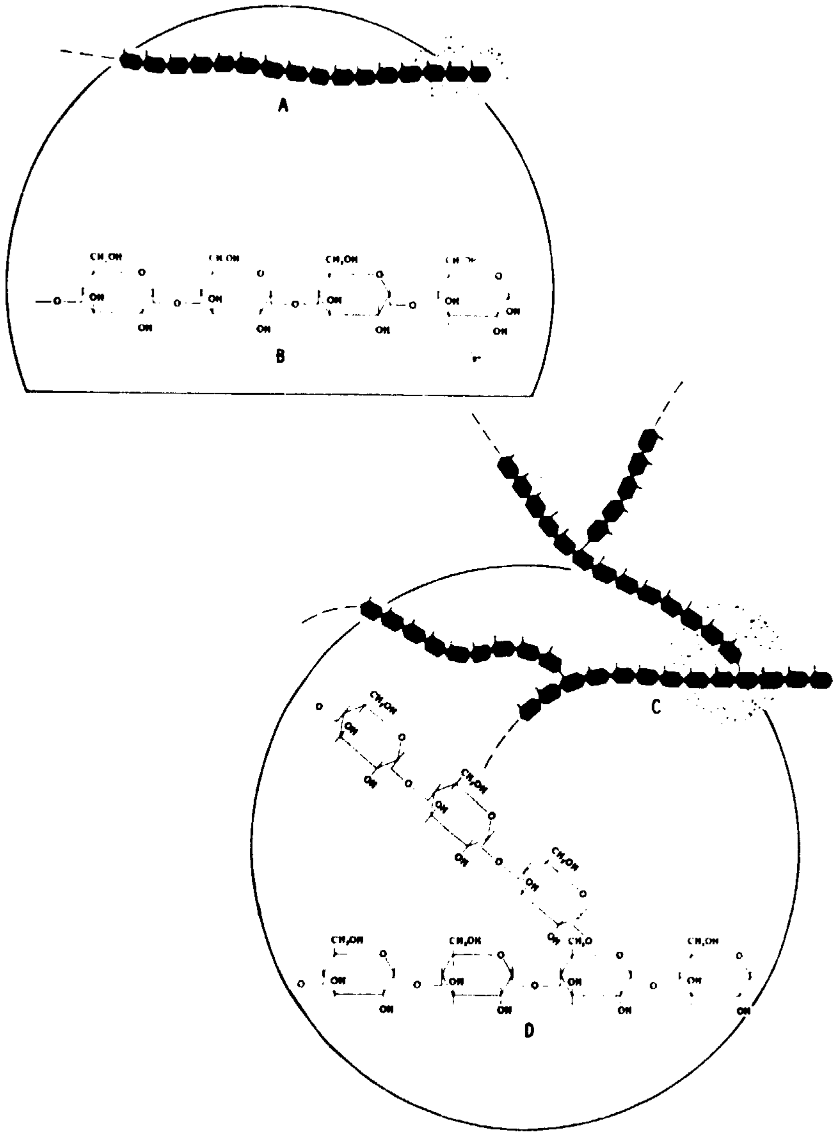


FIG. 4—Structure of the amylose and amylopectin components of starch. A: diagram of a portion of an amylose molecule; B: enlarged view of the shaded section showing chemical formula; C: diagram of a portion of an amylopectin molecule; D: enlarged view of shaded area showing chemical formula.

4.1.3 Manufacture

The basic process of starch manufacture is much simpler from fruit and root materials compared to grains. The manufacture of starch from corn, sorghum and wheat involves a major process to remove the gluten (protein). In fact, the gluten is often the primary product, and the starch is the factory by-product. It is difficult to remove all the gluten from grain starch despite numerous washing stages.

Roots, tubers and unripe fruits (banana and breadfruit) contain very little protein. They are first washed then diced and disintegrated. The pulp is then sieved to remove fibre, dewatered, then the starch is washed and dried. Starch can be centrifuged to 55-65% solids depending on its particle size, or the starch slurry can be vacuum filtered. Finally, the starch may be solar dried, tray dried artificially, or flash dried.

4.1.4 Uses

The paper industry is the largest single industrial consumer of starch products. Starches used are primarily potato, cassava, sorghum and corn in both their natural and modified state. The industry uses them in pulping, sizing and surface coating.

Starch is used in the textile industry for strengthening yarns, finishing, printing and glazing cloth. Corn starch is most commonly used in the USA, the main reason being economic.

The food industry uses both natural and modified starches. As with other industries, economics plays the major role in determining which source the starch may come from. Cassava starch has a bland flavour and paste clarity typical of root starches, potato starch has a long body and clarity; arrowroot is said to be very digestible; sago starch gives high strength, high fluidity gels; wheat starch has tender gels of low viscosity;

rice starch has tender opaque gels and is used in some premium beers; corn and sorghum starches form viscous, short opaque gels with a cereal flavour. However, although some of these specific properties are useful, chemical derivatisation allows interchange of starches so that economics plays the major part in any choice. Starch is starch is starch.

Taro starch has the smallest particles of any true starch, generally<1-4 microns, which gives it easy digestibility and some special potential as a dusting powder and in cosmetics. It is thought to have good non-allergenic properties because of it its low protein content.

There has been no commercial production of breadfruit starch, but testwork has been done showing it has a particle size of 0.6-10 microns and it can be used in many applications that other tuber starches may be used, e.g., breadmaking. It is similar in size to rice starch.
Other industrial uses of starch include adhesives, abrasives, binders in ceramics and the production of dextrins and laundry starch.

4.2 Glucose Syrups

4.2.1 Manufacture

Starch is made up of glucose units linked together in long chains. These chains can be broken back down by severing the links using enzymes.

Enzymes are proteins which act as catalysts in biological reactions. Their reactivity is closely related to temperature, pH and metal ion concentration,particularly calcium. Enzymes catalyse both the synthesis of starch from simple sugars and its hydrolysis back to simple sugars, but being proteins they can be denatured irreversibly if exposed to unfavourable conditions. Enzymes that catalyse the hydrolysis of starch are widely distributed in nature.

Alpha-amylase attacks 1:4 links between glucose units at random and produces rapid fragmentation of large starch molecules, but because it cannot attack 1:6 links, a high molecular weight limit dextrin will remain. The α amylose of microbial and plant origin cannot hydrolyse the 1:4 link of maltose (the dimer of glucose), hence hydrolysis of amylose gives a mixture of glucose and maltose and hydrolysis of amylopectin gives glucose, maltose and limit dextrins.

Beta-amylase is slightly different in its action as it hydrolyses glucose units off in two's from the non-reducing end of a starch molecule but it is unable to cross a branch point. It therefore produces maltose and much higher molecular weight dextrins.

Amyloglucosidase can hydrolyse 1:4, 1:6 and 1:3 links, but it also acts only from the non-reducing end of the chains and in this case, it cleaves the glucose units off individually.

These enzymes all occur naturally. For instance, when ripe, dry, starch containing,cereal grain is moistened, the inactive enzymes in the grain become active. They break down the storage starch in the grain to sugars such as glucose, maltose, maltotriose and limit dextrins. These sugars provide the energy for the grain seed to grow. This moistening can happen when seed is planted in soil, it also happens when barley is converted to malt in the brewing industry - the sugars of course are then fermented to alcohol.

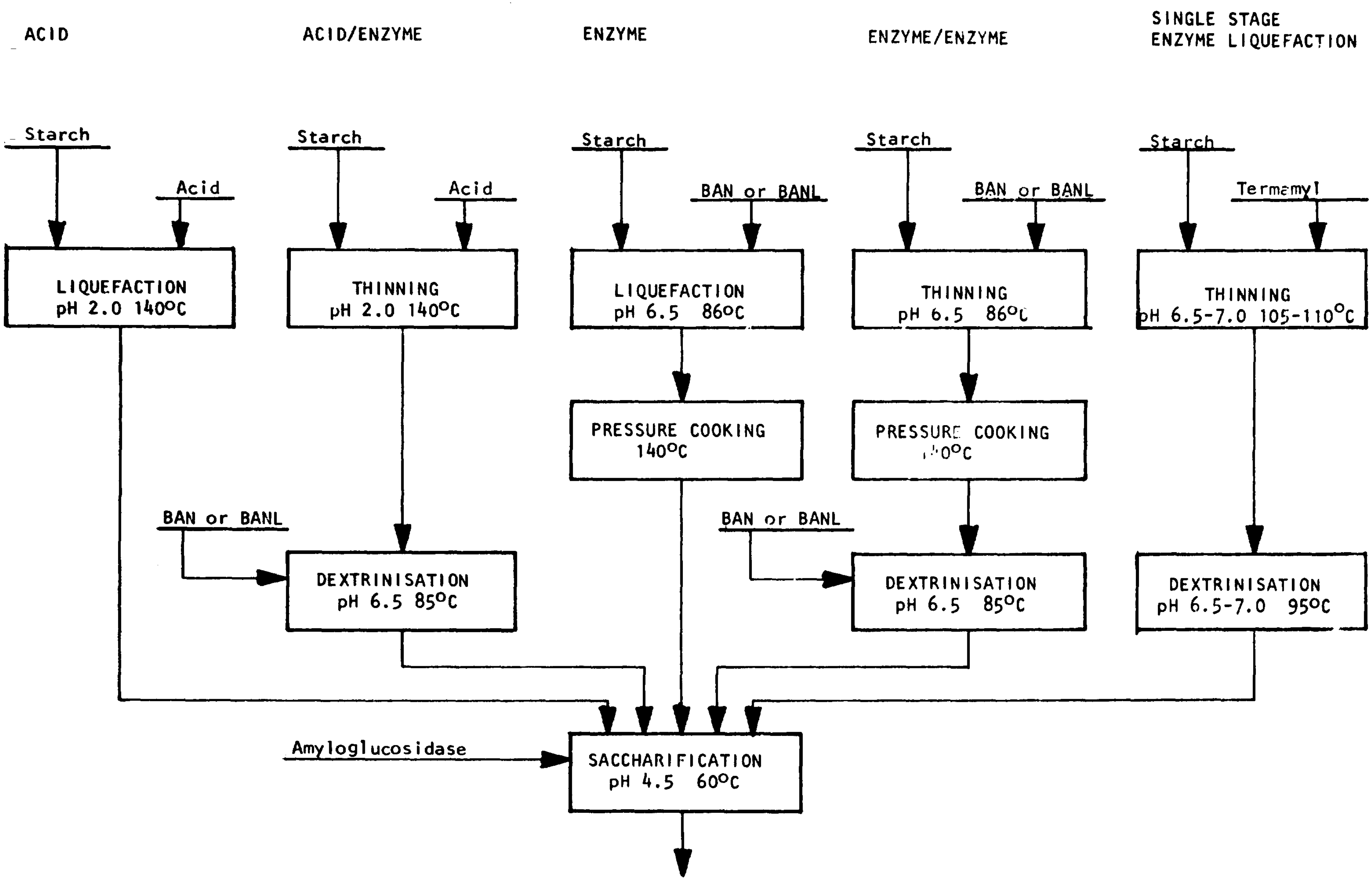
In the 1920's in Brazil, this activated malted barley was added to cassava starch. The enzymes converted the cassava starch to sugars which were then fermented to alcohol.

In recent years, a number of companies have developed methods using fungi and bacteria (Aspergillus *niger*, Bacillus *subtilis* and Bacillus *licheniformis*) to make concentrated preparations of the appropriate Alpha-amylase and Amyloglucosidase.

Acids can also hydrolyse starch to sugars. They have been and still are being used on large scale plants to make glucose syrups. However, compared to using enzyme systems they generate more side products which results in lower conversion efficiencies. Since the early 1960's when enzyme preparations became available on a large scale, they have gradually phased out acid usage in a number of applications. However, corn and wheat starch processing is still a slight problem for all enzyme systems because there are filtration problems. The range of methods using acid/enzyme/enzyme combinations is shown in Fig. 5.

Typically, an alpha amylase is added to a slurry of starch in water. The temperature is raised to the optimum that the enzyme can tolerate,above this temperature the protein denatures. The heat causes the starch to gel but simultaneously the alpha amylase breaks down the long chain molecules to shorter ones. This break down drastically reduces the viscosity before it has the opportunity to rise, as the reaction rate of the alpha amylase catalysed starch hydrolosis reaction is very high. This temperature optimum can be as high as 105°C with one particular commercial preparation (Termamyl 60L) and only 85°C with others (Ban 120L, BAL 1200). Starch concentrations of 30-40% dry solids (17-23 Be) and pH of 6.5-7.0 are typical processing conditions. Without this liquefying enzyme viscosity could peak at more than

FIGURE 5. VARIOUS STARCH HYDROLYSIS SYSTEMS



10,000 cps whereas less than 100 cps is normal with added enzyme.

After an hour, the liquefying enzyme has produced a syrup of 10-20 D.E. i.e., 10-20% of the starch has been converted to glucose. There is a limit to how much starch can be broken down to glucose by alpha amylase as explained earlier.

The 10-20 D.E. material can then be treated with amyloglucosidase, the saccharifying enzyme. This will further convert the solution to the desired finished product. This second reaction is much slower as it only splits off glucose one unit at a time from the ends of the long chains of starch and and it also takes much longer to split 1:6 branched links. Typically, it takes 40 to 50 hours at 60^{o}C and pH 5 to complete the saccharification depending on the degree of conversion required.

The product is generally produced at 30-40% dry solids. It must then be filtered to remove material that could later produce opacity in marketed products. The liquid may then be decolourised by activated carbon and/or ion exchange resins if the final product is affected by colour, e.g., soft drink but not beer or bakery products.

The material must then be evaporated to a high solids syrup, usually 75-80% dry solids (40 Be). This is necessary to stop any microbiological action and to reduce the amount of water that otherwise may be added to a food, e.g., baking.

There is also trade in crystallised dextrose and dry powered dextrose.

There is considerable art as well as scientific skill in producing the very wide range of products used on the world market.

4.2.2 Properties and Uses

Both acid, acid/enzyme, and dual enzyme systems can be used to make low and high D.E. converted syrups. The very highest converted syrups for fermentation (97-98 D.E.) are better made using the dual enzyme system.

The low conversion syrups have better mouth feel, higher viscosity and are used in frozen dairy products whereas the higher conversion syrups are used where a sweeter product is required. The very highest conversions are needed for fermentation to ethanol.

The food uses range from jams, fruit juices, carbonated drinks, beer, spirits, bread, cakes and biscuits to cured meats, sausages, pickles, cough medicines and mayonnaise.

As mentioned in Section 4.1.2, partially hydrolysed starches are used in the non-food industry, but they are mostly very much larger molecular weight gels.

4.3 Flour

4.3.1 Manufacture

Flour is typically dry milled, fractionated cereal grain. However, this discussion is devoted to the production of "flour" from raw materials such as cassava and other tropical products. The term 'flour' is often used interchangeably with starch. A number of exporting and importing countries and individual end users have standards relating to starch, ash, fibre, moisture,bacterial count,and viscosity considerations for flour and starch - which are different, Table 6.

TABLE 6

GENERAL SPECIFICATIONS FOR STARCH AND FLOUR

TYPICAL SPECIFICATIONS FOR COMMERCIAL CASSAVA PRODUCTS FOLLOWING OFFICIAL STANDARDS					
		Chips	Flour	Pellets	Starch
Moisture %	Max.	14	14	14	14
Fibre %	Max.	5	5	5	0.8
Ash %	Max.	3	3	3	1
Starch %	Min.	70	70	62	80

The world's main exporter of cassava chips, pellets and flour (starch?) is Thailand, although it only ranks 4th or 5th as a producer behind countries such as Brazil, Indonesia and India. In 1978, Thailand exported 420,000 tonnes of flour/starch mainly to Japan and the U.S.A., though this was only 7% of its total export of cassava products.

Flour has often been considered as simply dried, chipped, finely ground raw material. However, this method of preparation raises a number of problems. For human consumption, the product would have to be made from washed, peeled raw material which could not be solar dried because of contamination problems. The fibre content and inorganic salts content would still all be present to the possible detriment of bread, biscuit, cake or other products. The reducing sugars would still all be present which could produce very much more browning of the finished products. One other problem is the presence of hydrogen cyanide in cassava, and calcium oxalate crystals in taro, ta'amu and taro palagi. These compounds would be largely retained in the making of the flour. For instance, Meuser quotes HCN levels of only 0 and 1.8 ppm in cassava starch from Colombia and Berlin and yet 436 ppm in cassava flour. The HCN being in the water phase it was eliminated in the mashing/washing, centrifuging of the starch.

For human consumption, it is considered better to manufacture starch and use this as a substitute for flour rather than use milled, dry material.

4.3.2 Properties and Uses

The main raw materials of concern are taro, breadfruit and cassava. Numerous studies have been done using cassava flour and starch as partial substitutes for cereal. Generally, about 15% can be tolerated before the bread shows signs of adulteration. However, in many of the tests, the protein content of the original flour was not considered. One of the major considerations in the mixing of very low protein root flours with cereal flour is the dilution effect on the gluten. The gluten matrix becomes too weak to support the structure of the bread. Recently, work has been done on putting fresh cassava in bread to eliminate the drying stage. There is some small promise that future work is worthwhile. The HCN content must be particularly monitored if using fresh cassava. Only 30% of the HCN was lost from the loaves during baking with fresh cassava addition.

Taro flour has been produced on laboratory scale both in Western Samoa and Hawaii. In Western Samoa, the taro had been hand trimmed and peeled, sliced into 0.5 mm slices and dried for 12 hours at 63^{o}C. The material was then coarse ground and fine ground to yield a flour.

In Hawaii, the taro was peeled (25% loss), cubed, ground in a meat mincer (0.318 cm dia), dried and passed through a Fitz mill. The first pass was at 0.16 cm and the second at 0.069 cm.

The Food Processing Laboratory in Western Samoa have done some baking trials using up to 63% substitution and adding gluten or calcium -2 steroyl lactate to bind the starch. They saw no major problems in introducing taro flour at the 10-20% level in bread.

In similar work with breadfruit, they found that it gave a more wholemeal type bread which was more acceptable than the wheat flour on its own.

Tests were done in Lagos on blending taro, yam, cassava and breadfruit flours with wheat at 10-30% levels. The flours were prepared by hand peeling, washing, dicing and air drying for 24 hours at 65°C. The meal was then milled and sieved through 80 mesh. No extra gluten was added in the baking trials. They found 10% addition of all flours gave very good bread and 20% blends gave acceptable bread.

4.4 Ethanol

4.4.1 Manufacture

Most of the world's supply of industrial ethanol comes from petrochemical sources via ethylene. However, there are a number of major countries of the world that only allow potable ethanol and vinegar to be derived by fermentation. It is this latter method of manufacture that will be described.

The manufacture of high D.E. glucose syrup, which is used as feedstock for fermentation, has already been described in Section 4.2.1. However, if glucose syrup is a feedstock for ethanol which is distilled, rather than drunk in dilute form (e.g., beer), then a number of short cuts in glucose syrup processing are allowable. Any particular agricultural crop, after washing and pulping with the skin still on, need not be filtered nor need the resultant glucose be decolourised, it may simply go to fermentation.

The resultant glucose solution should be diluted down to 15% dry solids and some nitrogen and phosphorus added as nutrients so the yeast can efficiently ferment the glucose to ethanol. Fermentation may be continuous or batch. In the batch operation, the ferment is put in a tank with an inoculum of Sacchromyces *cerevisiae* which is allowed to metabolise the sugar for 24 hours. In a continuous system, the ferment is continuously added to and taken from the fermenting tank. The batch system is cheaper, simpler to operate, more flexible and has higher conversion efficiencies. The continuous system uses smaller tank space. Yeast may be recycled in both the batch and continuous process to speed up the fermentation.

The fermented wash is then centrifuged and the ethanol then distilled off. In the first distillation stage, the fermented liquor, at 7-10% ethanol, is boiled and a 50% ethanol vapour is formed. This is then fractionated in a second distillation column to produce 96% ethanol. There are a number of ways in which this may be treated if absolute ethanol (99.9%) is required. The water may be distilled off with another solvent or the water may be adsorbed chemically.

The resultant stillage and waste yeast, the so-called spent wash, is highly polluting, though also very useful as a plant nutrient. It still contains all the phosphorus and nitrogen added in the process and considerable potash. If used intelligently, it is a good fertilizer. The carbon dioxide is also a very useful by-product. Carbon dioxide produced by fermentation is the purest form in which it can be made (99.9% pure) and it needs very little further purification.

4.4.2 Uses

Fermentation ethanol is traditionally drunk or made into vinegar. The emphasis in this proposal is in the making of a fuel additive. Ethanol has been used as a 20% additive in petrol since the 1930's.

In Sweden, Brazil and Australia, it was used for many years. Queensland (Australia) used ethanol in petrol by law up to 1956, and the law is still on the Statute books. Brazil, of course, has the most ambitious fuel ethanol programme. They were producing 60 Ml/year during the 1939-45 War from cane and cassava. When the fuel crisis re-emerged, Brazil set a goal of 20% ethanol in petrol by 1980. Most of the distilleries they have built recently are cane-based though they have one 18 Ml/year cassava plant operating in Curvelo, Minas Gerias, and a number of other larger ones planned.

Ethanol can be blended into petrol at up to 20% with no need for any alterations to be made to the Otto engine. It improves the anti-knock properties to the point that no lead tetraethyl need be used. High blends can be used, but it is then advisable to alter the carburettor and increase the compression ratio. Spark ignition engines run satisfactorily on 95% ethanol/5% water with alterations to the carburettor.

Ethanol can also be used up to 10% in diesel fuel in compression ignition engines. Tractors are even running in Australia on 40% blends. The common approach with diesel engines is to use two separate fuel tanks and to spray the alcohol in with the air which is then ignited by the diesel spray as ethanol is less miscible with diesel than it is with petrol.

A number of petrol stations in the U.S.A. now sell 'gasohol', a blend of corn alcohol and petrol and Thailand is in the middle of a countrywide feasibility study to make fuel ethanol.

5.0 AGRICULTURAL CONSIDERATIONS

5.1 Crop Choice

The major crops of Western Samoa were dealt with in Section 3.3.2. In terms of this study on a commercial starch plant, there is a special need for about 50 tonnes per year of taro starch (or perhaps flour) for use in the baby weaning food programme. Apart from this requirements, the main criterion for choosing one crop over any other is the price it can be grown or bought for. This implies optimising the yield/ha (of starch rather than total weight), the cost of fertiliser, cost of planting and amount of labour required to produce the crop.

There are secondary important criteria which should be considered, however. These include ease of factory processing, ability to store the raw material, type of land available and the wish of the Government to support the price of a crop in the market place by taking the surplus into a factory for processing.

Breadfruit, taro, ta'amu, taro palagi, green bananas and cassava should all be considered.

5.2 Source

The crop can be grown commercially on leased land, grown by villages and/or grown by WSTEC.

WSTEC were adamant that the only crops worth growing in Western Samoa were cocoa, coconuts and coffee. They will grow breadfruit trees in a ring around the plantations, but it was not really considered a commercial crop. WSTEC would not grow taro (or other aroids), cassava or bananas. Though this decision was said to be taken on economic grounds, we were not able to see the returns that the various crops actually were producing. WSTEC decisions may not be inflexible in the long term.

There is still no International Cocoa Agreement, the Ivory Coast (the world's second largest producer) has 40,000 tonnes stockpiled compared to a Western Samoan production of 1,000-1,500 tonnes/year, and there is talk of a synthetic cocoa just as good as the natural. Western Samoa sells cocoa at $3 per lb compared to $1 per lb on the world market (December, 1979).

Coconuts only produce $1-2 per man day (R. Burgess) compared to $2.50 per day minimum wage.

Fisk considers that agricultural land is limited in relation to the population and that land may have to be used to grow food rather than cash cropping for exports.

The obvious source of crops for a factory are the villages. However, it may not be easy to persuade enough villages to grow produce for a factory when the village has enough cash to satisfy its needs. Also, the guarantee of supply in times of food shortage would be doubtful. This may not be the case with breadfruit, as the factory could take breadfruit long before it was ripe or ready for eating.

The crops could be grown on a plantation dedicated to a factory. However, the availability of sufficient land was placed in doubt by a number of people in Western Samoa, the crop would obviously still not be available in times of national food shortage and in the case of breadfruit, there is very little experience in the world in growing it on a plantation basis, e.g. the disease problem and effect on land.

In general, land below 300 m is required for any of the crops being considered. However, there are differences in land requirements. Cassava needs relatively rock-free soil as the rocks interfere with root development and harvesting. Taro can be grown in more stony ground, as the traditional method of growing simply requires a hole to be worked into the soil in which the root will then grow. Breadfruit and bananas, being trees, can grow in very stony ground. Bananas need a high level of fertiliser to grow well, whereas breadfruit, as far as is known, requires none.

5.3 Yield

5.3.1 Breadfruit

There is very little information on yields of breadfruit, particularly in a plantation environment. Van Wissen (1978) did a detailed study and arrived at a figure of 27 tonnes/ha per year (in two seasons). He arrived at this by calculation, estimating 41 trees/acre on 35 ft. centres with 250 fruit per tree of 2 lbs each, twice per year. Despite a computer search of the world literature on breadfruit, the only other yield quoted was R. Burgess (Western Samoa) of 25 tonnes/ha per year. Trimming loss for skin would be less than 5%.

5.3.2 Taro

There are two different ways of growing taro, "wet land" culture and "dry land" culture. In Western Samoa it is grown under "dry land" culture. Dry yields are usually one half to one-third wet yield. There are a number of authorities who would agree that taro should yield in the range 15-20 tonnes/ha per year. R. Burgess - Western Samoa (16 tonne), Lockwood - Western

Samoa (15 tonne), Dr. Basil Williams (15-20 tonne), Fiji (15.5 tonne). There is an excellent review due to be published in 1980 (MAB Technical Note No. 13 Paris UNESCO Press) which in Appendix 2 gives yields of as low as 2.59 tonne to as high as 32 tonne for dry cultivation. The FAO Year Book quotes yields for Asia (11.5 tonne), Africa (5.1 tonne) and Oceania (8 tonne). Trimming loss would be at least 30% as the crop would normally be weighed with both the top and bottom still on and the skin, being rough,would take more with it in peeling

5.3.3 Ta'amu

There is much less known of ta'amu. It grows much larger but takes comparatively longer to mature. R. Burgess quotes, 10 tonne/ha per year. Trimming would take 20%.

5.3.4 Banana

Banana responds well to fertiliser. R. Burgess estimates village production in Western Samoa at 6 tonne/ha per year, whereas B. Fitzpatrick on 250 acres being developed for growing bananas for export yields 34 tonnes/ha per year. Trimming we did in Western Samoa gave an estimate of 54% skin (which gave a negative starch iodine spot test).

5.3.5 Cassava

There is great variability on cassava yields. The literature quotes figures from 5-70 tonnes/ha per year. The FAO Year Book quotes Asia (9.9 tonne), Africa (7.3 tonne) and Oceania (11.4 tonne). Nigeria yields 6-7 tonne/ha and say the potential is 36 tonne/ha - but they later admit it would be a 2 year crop. The Philippines average is 3.6 tonne/ha and Fiji 10 tonne/ha. Trials at Alafua College, Western Samoa, gave 35-47 tonnes/ha, but WSTEC claimed they could grow no more than 5-10 tonnes/ha on a large scale.

It has been estimated that about 15% of this would be lost by peeling and trimming.

5.4 Analysis

There are detailed analyses of many starch bearing crops and these are quoted in Appendix C for completeness.

5.4.1 Breadfruit

Breadfruit, like bananas, ripens such that the starch turns to soluble sugars as the skin changes from green to brown/yellow. For starch, it must be picked when starch is maximised, but there is no conversion to sugar. Yields of the unripe fruit may be lower in total weight of fruit, but the season could be lengthened by being able to take unripe fruit. Generally, figures range in the 20.2% to 26.2% range. Two references refer to the fact that it has a higher starch than potato (normally, say, 19%) and that it is more akin to sweet potato and cassava. An average of 22% would, therefore, not seem unreasonable.

5.4.2 Taro

There has been considerably more analyses of taro perhaps because of its known non-allergenic properties. Starch ranges from 23-35.5% with the moisture content for the tubers ranging from 85% down to 53.5% respectively. A reasonable figure for moisture content would be 73%, and 23% starch.

5.4.3 Ta'amu

A computer literature search revealed no analyses for ta'amu. However, it is more fibrous and appears slightly drier. It could have a starch level close to taro, but less would be extractable.

5.4.4 Bananas

No comprehensive work was done with bananas but the literature yields levels of starch in the 20-22% range.

5.4.5 Cassava

This crop is most certainly the highest starch yielding crop growing in any abundance. Literature figures range from 19% to 37% starch. The higher levels generally in the older crop which would be harder to extract and be associated with more fibre. It is certainly not unrealistic to expect 25% starch in cassava, and an extra 5% fermentables for the alcohol application.

5.5 Costs

There were very few definite costs available for growing crops in Western Samoa. WSTEC were unable to give any costs.

5.5.1 Breadfruit

Breadfruit is not often seen on the local market because so many people grow their own, and when there is a surplus for sale, it is the height of the season when everyone has enough of their own.

It sold at 3.7 sene/lb on the Apia market (February, 1979). Van Wissen estimated it can be grown for 3.5 sene/lb dry chips (equivalent to, say, 1.08 sene/lb "as is") as there is little fertiliser required, no tending and planting only has to be done every 30-35 years. He used a figure of 62 man days/ha per year to gather 27 tonne fruit or $5.74 per tonne (0.26 sene/lb).

5.5.2 Taro

R. Burgess has estimated some costs for taro. He estimates taro at 272 man days/ha per year for growing and double this for marketing, i.e., 816 man days/ha for producing taro in the market place, $112/ha for weed killer, and 11,000 taro plants/ha. Planting material would cost $3 per 100 in the market place, though the village would produce its own tiapulas from previous crops. Without charging for land, plant material or transport to the market and using the minimum wage of $2.50 per day, then the cost of growing taro can be estimated at:

$$\frac{(816 \times 2.50) + 112}{16} = \$134.50\text{/tonne (6.1 sene/lb)}$$

The price in the market place at Apia has varied recently from 7.1 sene/lb (February, 1979) to 12 sene/lb. The farmer was getting 10 sene/lb for export taro in December, 1979. Many farmers expanded their taro acreage in 1977 when prices were high. The result was a glut of taro in early 1978. The Apia market was flooded but the price still did not drop below 7 sene/lb, the sellers took it home and ate the surplus themselves. It could be that if an arrangement was made to pick up taro at a centralised point in a village with a guaranteed sale, then a price of

$$\frac{(272 \times 2.5) + 112}{16} = \$49.50\text{/tonne (2.25 sene/lb)}$$

would be comparable recompense as the villagers would not have costs of transport,or marketing labour to "pay" for.

5.5.3 Ta'amu

There is no information at all on the cost of growing, but it was selling in the market place at 5 sene/lb when taro was 7.1 sene/lb and R. Burgess values it at 10 sene/lb compared to 14 sene/lb for taro.

5.5.4 Bananas

Bananas grown for export sell for 10 sene/lb FOB Apia, which gives a profit of $500-600 per acre. B. Fitzpatrick calculates that he grows the bananas for 7.5 sene/lb. These are highly industrialised and export quality grown with a great deal of fertiliser.

Village produced bananas appear in the market place at $1.50 to $1.80 per hand. A hand would have about 45 lbs of bananas. Thus the Apia cost is a minimum of $73.33/tonne (3.3 sene/lb). Neither Burgess nor B. Fitzpatrick believed bananas could be bought at the village for less than 2.5 sene/lb.

5.5.5 Cassava

There was no data available in Western Samoa on the cultivation costs of cassava. Villages take little note of it as it is only grown for animal feed and not sold in the market. WSTEC have 150 ha under cassava for supply to the feed mill, but have no associated costs. It is grown using manual labour as the soil is too stony for mechanisation. WSTEC (Ai'i Pili) were offered cassava chips from Malaysia at $50/tonne we were told, but on later checking with their office we were told that it was $78/tonne FOB Tonga (equivalent to $24.20/tonne fresh roots).

They had no written quote nor had they ordered any.

Thailand grow most of their cassava using manual labour, on small farms of average size, 16 ha. Their average yield is 12-21 tonnes/ha and the average farmer's selling price in 1979 was $46.20 /tonne (2.1 sene/lb). Their labour cost is marginally lower than Western Samoa.

The feed mill Manager said he could afford to offer $180/tonne for dry cassava chips, as it competes with maize from New Zealand at NZ$220/tonne CIF Apia. The feed mill offer $56/tonne fresh roots (2.55 sene/lb), but get little response from Villagers. Clive Pedrana thinks it could be grown for $33/tonne (1.5 sene/lb) but only if yields could be increased substantially from present WSTEC levels.

The following table associates the Yields (Section 5.3), Analysis (Section 5.4) and Costs (Section 5.5).

TABLE 7

COST OF STARCH FROM VARIOUS CROPS

	Breadfruit	Cassava	Taro	Banana
Yield/ha-tonne	27	10	16	6
Trimming %	5	15	30	54
Starch %	22	25	23	21
Available Starch/ha t	5.64	2.13	2.58	0.58
Apia Market Selling Price $/tonne	81.40	-	220	73
Villane Selling Price $/tonne	23	56	156	55
Cost of Production* $/tonne	21	33	50	44
Starch Cost $/tonne (based on production cost)	100.53	154.93	310	455

It is quite clear from the above table that bananas are not worth considering as a source of starch, and taro should only be considered under the special circumstances where its non-allergenic properties are valuable. Cassava and breadfruit appear to be the most worthwhile sources. It must also be remembered that whereas breadfruit can be produced from the same area of land for 30-35 years, cassava (and taro) must be allowed to fallow, or at least rotate so that the crop is only grown one year in five.

5.6 Project Experimental Work

Root and fruit starches are generally much easier to process than grain starches because unlike corn, sorghum and wheat they do not have large amounts of gluten to interfere in the starch extraction.

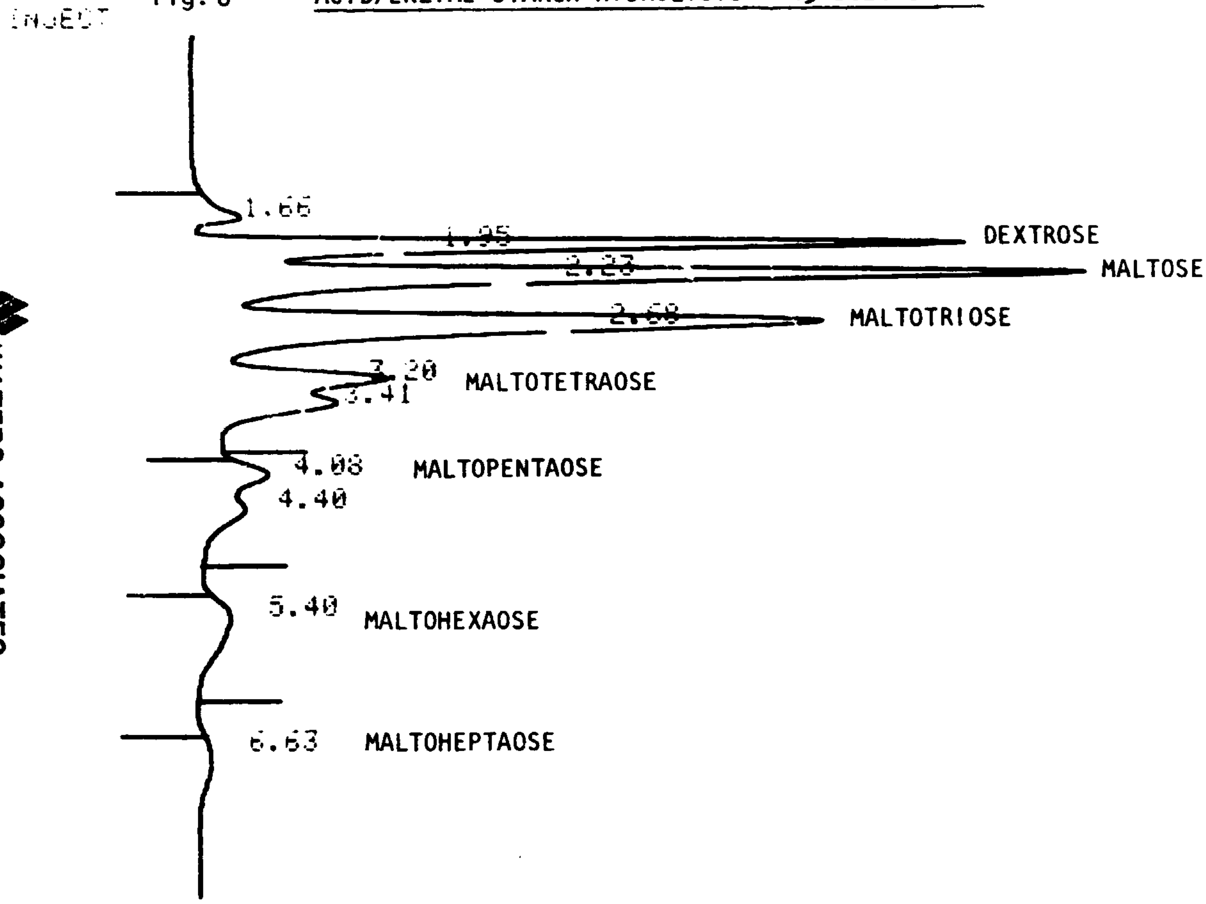
5.6.1 Breadfruit

In the literature, breadfruit starch was said to have a particle size range of 0.6-10 microns. It was confirmed that all granules were spherical and certainly less than 10 microns, but no very small particles were observed. The starch spun down, washed and filtered quite well. A small amount was brought back to Australia for testing as it seemed to have some potential. It was enzymically converted to low and high D.E. syrups with little difficulty. High pressure liquid chromatographic analyses are shown in Figs. 6, 7 and 8.

5.6.2 Taro

There is little information in the literature on the processing of taro starch apart from recording that it is the smallest of all known starches, 0.5-2 microns. We found no manufacturer who would guarentee equipment performance of centrifuges or filters on such small particles. Some taro was bought in Australia for preliminary experimental work.

Fig. 6 ACID/ENZYME STARCH HYDROLYSIS - 43 D.E. SYRUP

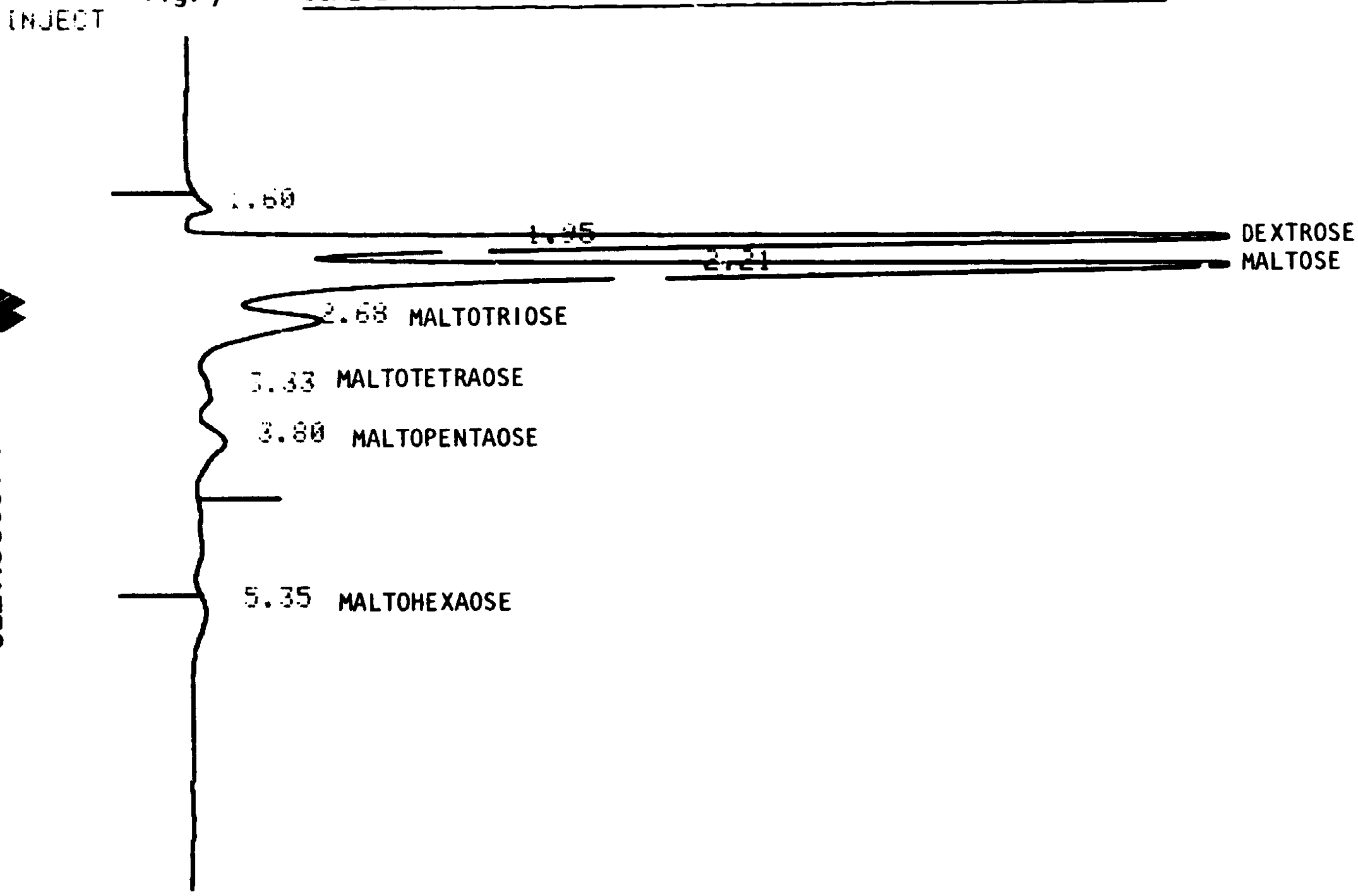


JUN. 9, 1980 17:10:30 CHART 1.50 CM/MIN
RUN #28 CALC #0
COLUMN SOLVENT OPR ID: 4

EXTERNAL STANDARD QUANTITATION

PEAK#	AMOUNT	RT	%
	3257.11000	1.66	1.44
	44816.60000	1.95	19.82
	66959.80000	2.23	29.61
	64028.30000	2.68	28.32
	16445.30000	3.20	7.27
	12473.90000	3.41	5.51
	6209.70000	4.08	2.74
	4281.59000	4.40	1.89
	7614.64000	5.40	3.36
TOTAL	226087.00000		99.99

Fig. 7 DUAL ENZYME STARCH HYDROLYSIS - HIGH MALTOSE SYRUP (65 D.E.)



JUN. 9, 1980 17:42:53 CHART 1.50 CM/MIN

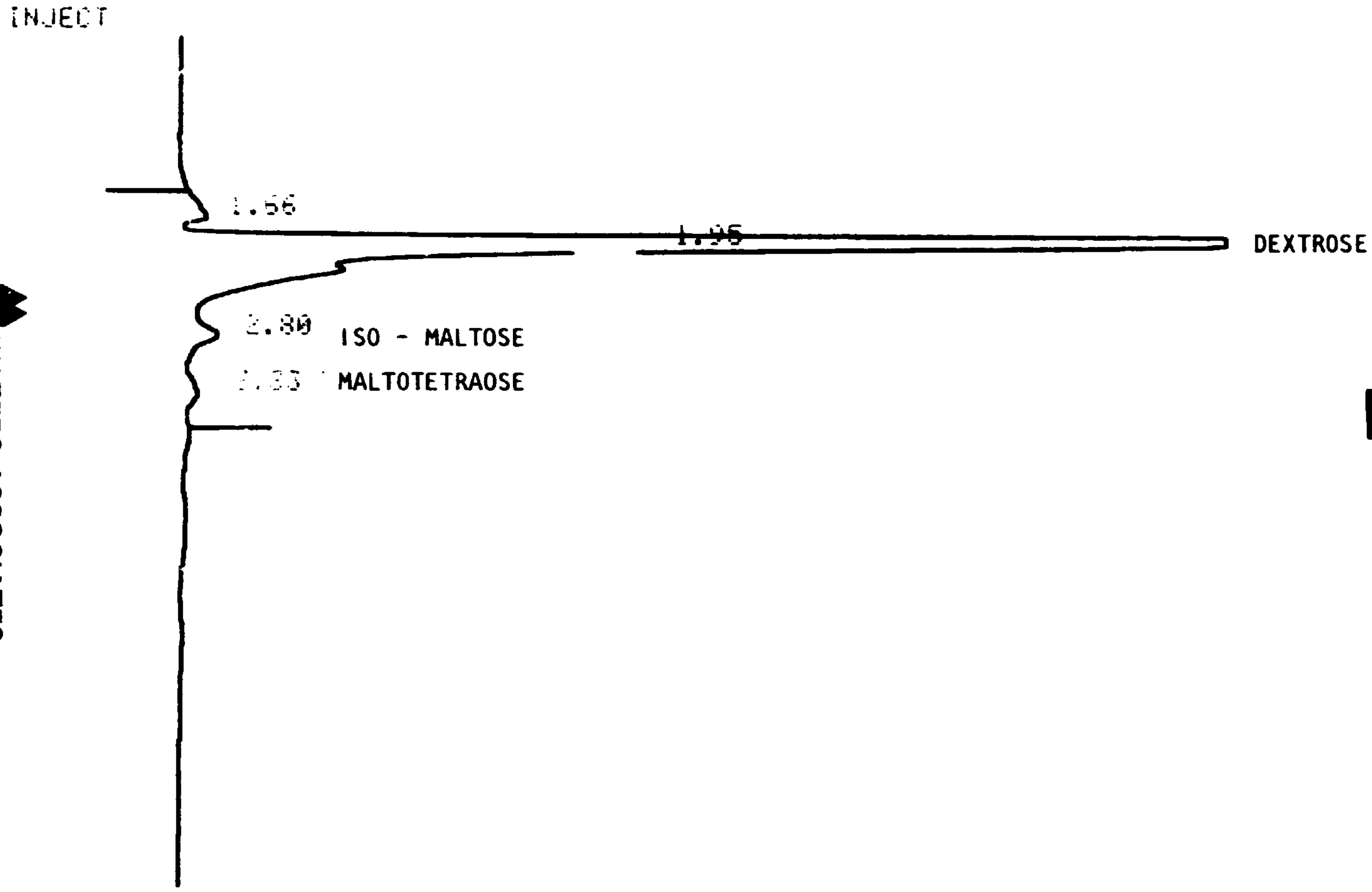
RUN #31 CALC #0

COLUMN SOLVENT OPR ID: 4

EXTERNAL STANDARD QUANTITATION

PEAK#	AMOUNT	RT	%
	1670.05000	1.60	0.89
	70474.10000	1.95	37.96
	88698.50000	2.21	47.77
	17718.30000	2.68	9.54
	2595.57000	3.33	1.39
	4487.38000	3.80	2.41
TOTAL	185643.00000		100.00

Fig. 8 ACID/ENZYME STARCH HYDROLYSIS - 88 D.E. SYRUP



JUN. 9, 1980 17:22:25 CHART 1.50 CM/MIN
RUN #29 CALC #0
COLUMN SOLVENT OPR ID:

EXTERNAL STANDARD QUANTITATION

PEAK#	AMOUNT	RT	%
	2630.58000	1.66	1.98
	125627.00000	1.95	94.62
	3650.71000	2.80	2.74
	857.61100	3.33	0.64
TOTAL	132767.00000		99.99

The taro was 28.1% starch and 6% fibre which when compared with the literature suggests that the taro may have been drier than average either because of distance of transport or because of the time of year it was picked (cassava moisture content varies during the year).

The starch had a natural pH of 6.03. It could not be recovered by No. 4 Whatmen filter paper because of its fine particle size but it spun down well be centrifuge (2,000 g for 3 mins. was adequate with 30 mins. giving substantially complete recovery).

The starch had a gel temperature of 78-79°C and a peak of 1100 Brabender Units. The starch and high stability strength being 1030 B.U.'s between 92°C and 60°C. It could be used in pies, custard fillings, cakes, vanilla slices and sizing of textiles. A starch slurry converted well using amylase and amyloglucosidase.

The fruit water spun off the starch contained soluble protein which coagulated easily at 60°C and pH = 2.5 similarly to breadfruit. Although considerably more experimental work would be needed to assess its value, digestibility and amino acid spectrum, it certainly was easier to recover than grain proteins. Of course, the protein level is substantially lower in root and fruit crops than in grains.

High pressure liquid chromatographic analyses are shown in Figs. 6, 7 and 8 of three different DE syrups made from the starch.

5.6.3 Bananas

Some laboratory tests were tried on banana starch extraction from green bananas while in Western Samoa. The starch was difficult to sieve off the pulp because of frothing problems. However, it did spin down and wash easily. As can be seen from the photomicrograph in Appendix B, the starch granules are large and irregular in shape. As they are larger, even than potato starch granules, they would centrifuge easily.

5.6.4 Cassava

No work was done on cassava as the literature abounds with information.

5.7 Post-Harvest Storage/Preservation

There is considerable concern over post-harvest deterioration of the crops generally considered as staples in the South Pacific. A major part of the recent Conference on "Small Scale Processing and Storage of Tropical Root Crops" (now published as a book edited by D.L. Plucknett) is devoted to the subject. Up to 30% of taro, cassava, etc., can be lost due to prolonged storage.

Mobil have supplied some surface coatings to Western Samoa for trialling with taro, but this will only reduce transpiration and surface mould growth. It cannot stop internal changes that produce sofening when the starch breaks down to sugar.

Cassava will keep in the ground until ready for harvest, though this stops the land being used for other crops. It is said that if the tops (leaves and stems) are removed two weeks before harvesting the roots, the roots dessicate slightly and this improves storage slightly. Cassava would normally have to be processed within 24 hours for making the best starch, though in Thailand the crop is left on the ground for more than a week - with obvious signs of deterioration.

We did trials with gamma radiation, as it is used very successfully with potatoes both to sterilize microbiologically and to stop sprouting. In fact, irradiated potatoes are commonly stored for 10-11 months after harvesting. The trials with cassava were not successful, as the irradiation level, although lower than that used on potatoes, caused massive breakdown of the cell tissue.

A simple gamma radiation system is shown in Fig. 9. The cobalt source costs about $1 per curie. To give, say, 1 million rads exposure in, say, 6 hours, requires 250,000 curie source which would have a capital outlay of at least $500,000 and a running cost of $25,000 per year for cobalt alone.

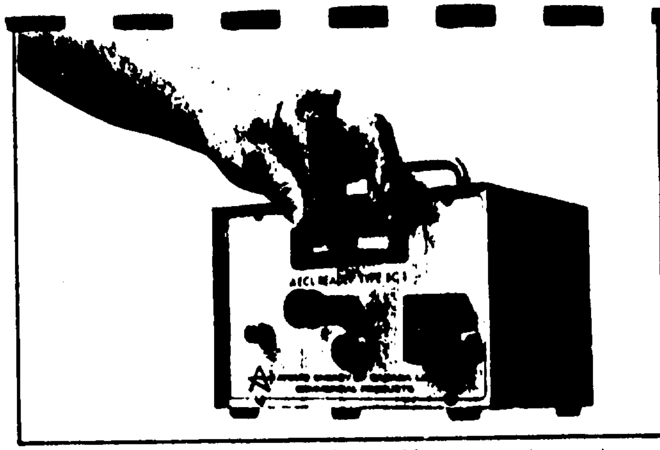
Under high radiation (15 million rads.), there is degradation of starch and if the radiation continues, eventual breakdown to the individual sugars. Radiation of starch up to 0.5 million rads is considered safe in food products. At 15 million, there is enhanced cold water solubility and at 100 million, total breakdown.

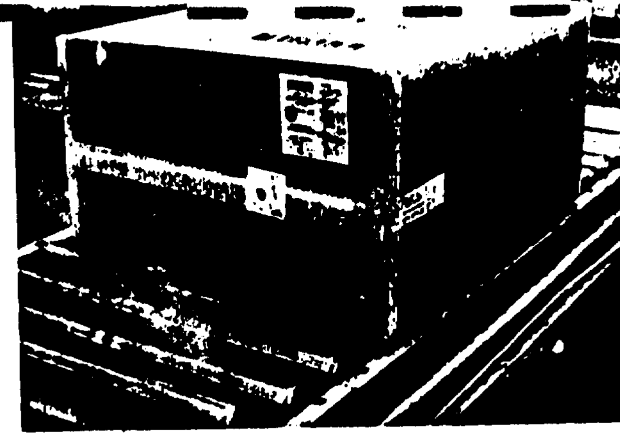
Radiation could not be recommended for taro or cassava because of the expense. A radiation source must be used 24 hours/day continuously throughout the year for economic benefits.

Breadfruit has been stored successfully both under water, a typical Jamaican method, and chilled to not less than 12.5°C. It did not [illegible] yellow dot. The effect of gamma radiation changes the colour of the indicators from yellow to red. Thus a carton carrying this red sticker is an assurance of sterile contents.

The Economies of Gamma Sterilization
Sterilization by gamma irradiation is not expensive, and the savings it makes possible are most significant. Manufacturers are saved the cost of sterile packing areas; orders can be made up and bulk packaged prior to sterilization by gamma irradiation; shelf life is indefinite; costly internal sterilization measures are made redundant.
To the user, gamma irradiation means greater convenience; more reliable, longer-lasting sterilization; less time wasted by skilled staff on sterilization measures; greater patient safety through reduced risk of cross-infection; smaller inventories through greater use of disposables. (In the case of rubber gloves, for instance, many hospitals are finding it more economical to buy them in individual packs gamma sterilized and discard after use, than to reconstitute them and re-use — all cost factors taken into consideration.)
Manufacturers seeking to offer better products are using gamma sterilization.

Summary
Gamma sterilization of medical supplies is already widely adopted throughout the world, and is likely to be the most significant development in technique of the next decade. The convenience, reliability, long-life and economy of gamma sterilization offers benefits in greater depth to the whole profession than any other foreseeable development.





(Top left) When not in use the Cobalt 60 source is lowered to the bottom of a 26 foot pool of water. Here the radiation is safely contained, and the viewer can marvel at the eerie beauty of the blue glow given off — known as the Cerenkov effect.

[illegible]

[illegible] sterilization.

(Above) This acrylic dosimeter is used as a check on radiation dose.

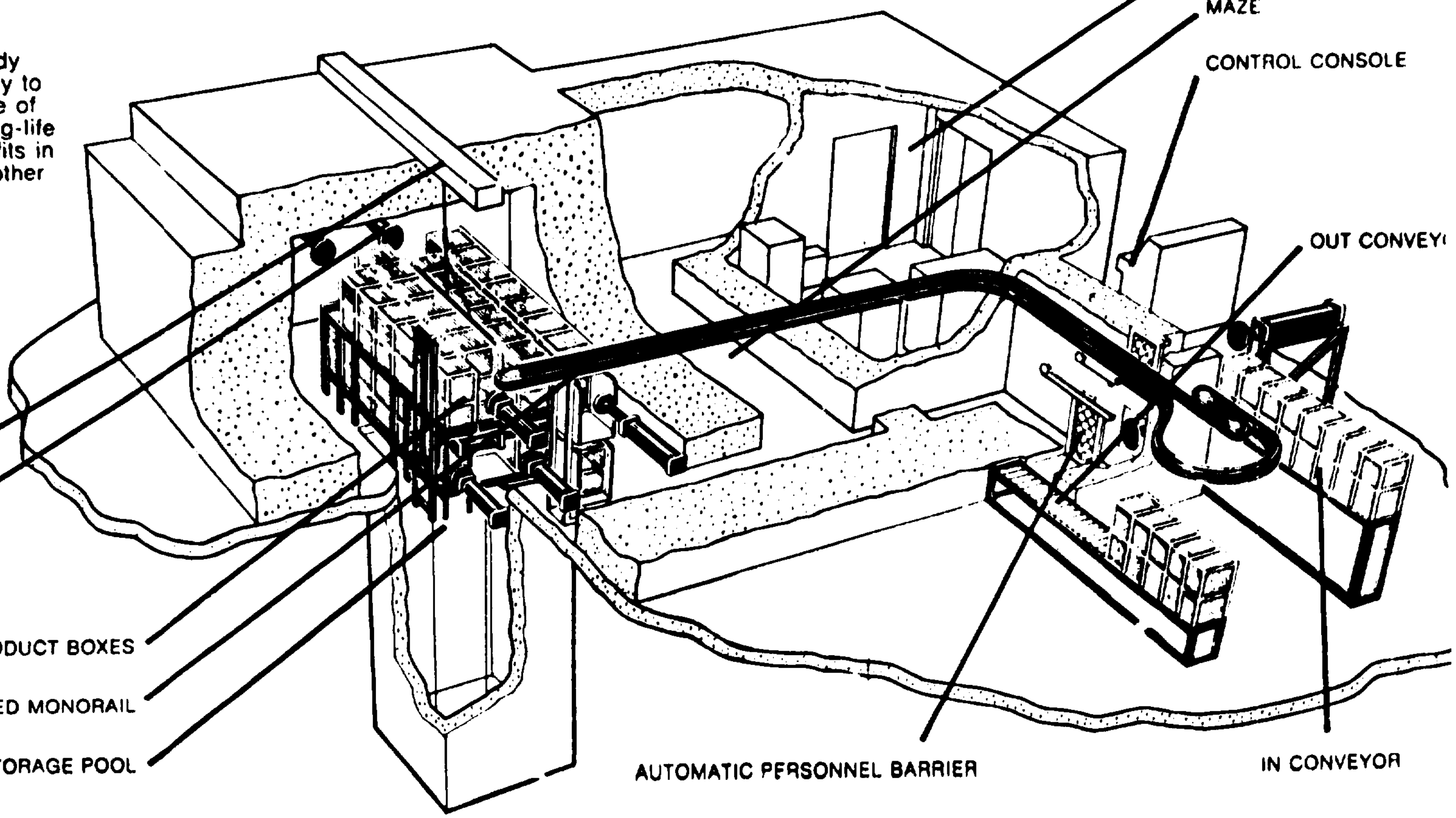


FIG. 9

matter whether on harvesting, the breadfruit were caught or allowed to be dropped on the ground. The fruit kept well for 5 days chilled to 12.5°C, and up to 15 days when stored under water.

Taro will not keep in the ground like cassava, or ta'amu. If harvested with both top (petiole) and bottom left on, it will keep well enough to be transported to New Zealand by ship, (12-14 days) and the few more days necessary to market the product.

6

6.0 MARKET SURVEY

6.1 Starch

6.1.1 Domestic Use

There are seven bakeries of various sizes in Upolu and about five small ones in Savai'i. A UNIDO report stated that there were adequate bakeries in Apia, but there was considerable untapped demand in rural districts.

We visited the largest, R.V. Meredith Enterprises, and also Drews Bakery, Ah Kuoi Bakery and Boon Chan Bakery. They accounted for 2,700 tonnes of wheat flours out of the 4,000 tonnes shipped into Western Samoa. However, 800 tonnes of that 4,000 tonnes is Australian aid flour supplied to appropriate recipients directly.

All flour is imported in 50 kg bags. Some is sold to villages, some is broken down and sold loose in Apia. It is assumed that only the flour used by bakeries could be diluted with locally produced starch which has been made to 10% gluten before being supplied to the bakeries.

There is an estimated 3,000 tonnes of flour used by bakeries. Starch from taro, breadfruit or cassava could be blended into this imported wheat flour at 10% immediately and at 20% if the gluten level in the locally produced starch is corrected to 10%. Gluten can be imported from Australia.

Gluten = 70% Protein
Flour = 11.5% Protein
Starch = 1.5% Protein

To add 20%,gluten enriched, starch requires replacing 600 tonnes flour

To make 600 tonnes, gluten enriched, starch to a 10% average protein requires

adding 74.5 tonnes gluten
to 525.5 tonnes starch

The four latest prices for flour in Apia were (per tonne) $374, $319, $328 and $344, giving an average $341 per tonne.

Gluten in Australia varies from $200 to $900/tonne and generally never greater than $475 per tonne.

Freight to Apia = $1560 per 18 tonne container + 7.5% bunkers
+ $0.75 per tonne + insurance
say = $100 per tonne
Gluten in Apia = $575 per tonne, therefore.

Thus, if 600 tonnes starch can be made at $311.37 per tonne, it will provide an import saving of 600 tonnes of flour at $341, per tonne less the gluten value, that is, an import saving of $161,762.

Clive Pedrana of the Food Processing Laboratory estimates that there is a market for 50 tonnes per year of taro starch in a baby weaning food. An amount of work has been done on the production of baby weaning food formulations in Western Samoa and Hawaii. Two formulations have been produced as shown below.

Ingredient %	I	II
Taro Flour	17	34
Rice Flour	34	17
Sugar	4	4
Skim Milk Powder	30	30
Coconut Cream (DB)	15	15

The Health Department inWestern Samoa is using this food at the hospital as a rehabilitative food. It is also being distributed by the district nurses to children in villages who have been diagnosed as having sub-clinical malnutrition. One of the aims of the food is that it should reinforce a child's taste for traditional food.

Bate Ewart (WFP Regional Adviser) UN/FAO World Food Programme, South Pacific Regional Office also expressed his desire that this baby weaning food is produced.

The need for this product is such that it is not considered as a potential profit earner but a community service.

6.1.2 Export

In considering the export of starch from Western Samoa, it is worthwhile taking account of two other countries in this area of the world that have an excess of starch, Thailand and Australia. The major customers would be Japan, U.S.A., and the EEC. Western Samoa would have no special freight advantage over either of these other countries.

The present export price of Thailand cassava starch is $164.77 per tonne F.O.B., and Australian wheat starch, which cannot be exported because of its price, is $310 per tonne F.O.B (1980)

Thailand cassava starch (bone dry)	=	$187.24/tonne
Breadfruit or Taro @ 25% starch	=	$ 46.81/tonne raw material
Assume 20% total losses	=	$ 58.51/tonne
	=	2.66 sene/lb.

Thus, for Western Samoan starch to compete on the export market only 2.66 sene/lb is allowed for the price of taro or breadfruit, which must include its transport to the factory and all its processing cost. Therefore, unless there are special circumstances it could not compete with Thai or Australian starch. However, there is a specialised form of starch known as crystal starch which demands a premium price in Australia. It is too labour intensive to be made in Australia.

There is a demand for 250 tonnes/year of crystal starch if it can be landed in Australia at below $470/tonne.

Apia/Australia (subsidised freight) = $800/18 t container + 7.5% bunker + $0.75/tonne + insurance + wharfage, say, $50/tonne. Therefore, if 250 tonnes of crystal starch can be made at less than $420 per tonne of 88% solids starch, there will be export earnings of $105,000.

The price of starch on the world market fluctuates considerably as is typical of many agriculturally based products. There is a belief that if the EEC adjusts the import duty of cassava starch upwards from 6% to nearer the 60% applied to cereal starch, then there will be a surplus of cassava starch which will depress world prices. The trends of Thai cassava products is shown below.

CASSAVA A$/TONNE

	1975	1976	1977	1978	1979
Farmers Selling Price of Tubers	17.60	22.92	22.94	15.37	19.75
Wholesale Price of Pellets (Thailand)	60.62	77.94	68.81	63.67	90.78
Export Price of Pellets FOB	71.70	89.40	82.87	66.60	92.30
EEC Price of Pellets	88.00	109.27	95.45	87.83	122.82
Wholesale Price of Flour (Thailand)	121.87	167.34	145.76	140.52	198.34
Export Price of Flour FOB	120.59	150.53	145.02	125.15	164.77

6.2 Glucose Syrups

The world market price for sugar was $100/tonne in early 1971 and by late 1979 it had risen to $175/tonne (L.D.P). The recent ratification of the International Sugar Agreement by the U.S.A. should further increase price levels before they stabilise at a price considered to be satisfactory to both producer and consumer nations. The London Daily Price (L.D.P) refers to raw sugar but generally white sugar follows this price within $15 to $20. The latest delivered price in Western Samoa for white (refined) sugar is $483 CIF Apia. White sugar will be in excess of $500/tonne in Apia in the immediate future.

Glucose sweeteners can be used as a replacement for sugar in many applications. As a sweetener it has a sweetness 0.8 that of sucrose, as a fermentation substrate it is worth 10% more than the equivalent weight of sucrose.

6.2.1 Brewery

The brewery import 150 tonnes/year of white sugar at the moment and would be very happy to use Brewers Liquid Glucose as a replacement. 150 tonnes of sugar is equivalent to 157.9 tonnes of glucose (dry) which is equivalent to 179 tonnes of starch at 88% solids and an import saving of $72,450.

6.2.2 Soft Drink

There are three producers of soft drink using white sugar as follows:

	Tonnes/year
Apia Bottling Co.	185
Curry's Cordials	168
Western Samoan Brewing Co.	74
Total:	427

Glucose has a sweetness only 0.8 that of sucrose. Therefore, the soft drink sugar equivalent = 533.75 tonnes/year. Curry's Cordials also buy 5 tonne/year of dry glucose at $280/tonne. So the total soft drink requirement is 539 tonnes/year.

A sugar quotation was received on 21/12/79 of CIF $483 per tonne, i.e., 539 tonnes of dry glucose = 609 tonnes starch at 88% solid. This will result in an import saving of $206,241.

6.2.3 Ice Cream

There are two ice cream manufacturers, Supreme Ice Cream and Apia Bottling Co. They only use 20 tonnes sugar and 15 tonnes glucose per year. This is equivalent to 45 tonnes of starch at 88% solids and an import saving of $21,735.

6.2.4 Bakery Products

Bakeries could use glucose syrup as a sugar replacement in bread, but not for some of the dusting and sprinkling applications. Their total use is estimated as 50 tonnes/year of white sugar replacement which is equal to 60 tonnes of starch at 88% solids and an import saving of $24,150.

6.2.5 Food Processing Laboratory

The Food Processing Laboratory uses about 100 tonnes/year of white sugar for sweetening drinks, making baby foods and jams. These are all related to its sweetness. Thus their 100 tonnes/year of sugar is equivalent to 125 tonnes glucose/year, i.e., 117 tonnes of starch at 88% solids, an import saving of $48,300.

In total, replacing all the industrial white sugar use would amount to 1,034 tonnes of starch at 88% solids or

1,102 tonnes/year of glucose at 83% solids.

This gives an import saving of $370,461.

The glucose has to be made at $336.17/tonne to compete with the imported sugar.

6.3 Flour

This has been dealt with under Section 6.1.1.

6.4 Ethanol

The weighted average official dollar price for crude oil almost doubled during the year 1979 and is 17 times what it was 10 years ago. For the first quarter of 1980, the moderates will be selling at US$24-27 per barrel and the weighted average will rise to $27 per barrel (45% more than the 1979 average). However, some spot prices have been as high as US$45 per barrel. Each US$1.00 per barrel for crude oil could add another 3¢ per imperial gallon to the price of motor spirit in Western Samoa. The spot market has become less volatile now because of larger world stocks, large volumes in the spot market, the higher official prices and the slower economic growth in the consuming countries. At the end of December motor spirit had reached 89¢/imperial gallon ex Singapore. The price trends for super and diesel are shown in the following Table 8. The price is expected to rise by at least 10%/year in real terms in Western Samoa. Crude oil will be over $40/barrel before 1981.

TABLE 8

REFINED FUEL EX SINGAPORE

Year	Petrol (97 Octane)		Tala/US$	Diesel	
	US$/US Gal	WS$/Imp Gal		US$/US Gal	WS$/Imp Gal
October 1970	0.115	0.100	0.7211	0.079	0.068
1971	0.126	0.100	0.6641	0.092	0.073
1972	0.129	0.103	0.6641	0.095	0.076
1973	0.175	0.125	0.5962	0.128	0.092
1974	0.400	0.291	0.6066	0.326	0.336
1975	0.445	0.409	0.7652	0.366	0.336
1976	0.445	0.452	0.8452	0.366	0.371
1977	0.473	0.439	0.7729	0.389	0.361
1978	0.473	0.396	0.6967	0.389	0.325
October 1979	0.736	0.782	0.8853	0.657	0.699
21 Dec. 1979	0.804	0.887	0.919	0.748	0.826
June 1980	0.954.	1.06	0.928	0.894	0.996

6.4.1 Motor Spirit

Only supergrade petrol is sold in Western Samoa. There are three suppliers bringing refined petrol into Apia and Asau. In total, 2.66 million gallons of petrol were imported in 1979 (11.95 Ml).

Ethanol can be used as a 20% substitute in fuel, that is 2.39 Ml of ethanol. At an estimated yield of 550 litres/tonne starch, it requires an input of 4,300 tonnes of starch (dry) or 4,900 tonnes of starch at 88% moisture. Petrol was selling for $1.60/gallon retail in December, 1979 with the CIF price of the last Singapore shipment (December, 1979) at $1.3111/Imperial gallon so substituting ethanol at 20% would give a saving of $0.7 million of imports. This cost saving was confirmed by a member of the Western Samoan Energy Committee. The price of light Arabian crude has already increased by $6 per barrel since December. The target price for ethanol as a petrol extender will be taken as $0.35/litre (Dec. 1979 price).

6.4.2 Diesel

Diesel imports into Western Samoa were in excess of $2 million in 1979 with a retail price at the pump of $1.36 per gallon. In the short term, it could be suggested that ethanol also be blended with diesel in fixed installation diesel generators for electricity. However, the Government has made a commitment to phase out diesel generation within 5 years. No consideration will be given to diesel substitution, therefore, because of the future uncertainty, though with fixed installations a 30-40% replacement could be used, i.e., another 2.65 Ml ethanol could be used to save a further $0.77 million.

6.5 Biodegradable Plastics

Starch can be used as a "filler" or "extender" in making plastics, particularly low density polyethylene, and in a variety of other thermoplastics. The great advantage of starch rather than an inert filler is that it is biologically degradable. Thus, when plastics extended by starch are buried in soil, the filler is degraded away leaving a very high surface area of plastic matrix which then falls apart. There is a company in the U.K. (Colorall Ltd) making over one million shopping bags per day using this type of biodegradable plastic.

Tests have been done with rice, maize, wheat, cassava and potato starches as fillers. They were all successful. Griffin, who has done considerable work in this area, reported in the Sago '76 Conference in Kuala Lumpur that sago deserves serious consideration as a biodegradable filler/extender for plastic materials because of its competitive price. The particle size of sago is mainly in the 0-45 micron range, although there are some particles up to 70 microns. Plastic sheet is generally in the range 25-100 microns.

It has been said that taro starch would be ideal because of its small particle size. C. Brewer and Co. (Hawaii) have considered taro starch in this application, but say that the market would have to be much larger,as a starch making plant from taro would cost too much. The Colorall factory have not tested taro on full-scale. They only use 50 t/year of starch in total[1].

As in all industrial applications where 'starch is starch' basically, the cheapest form of starch is that which will be used. Certainly, if taro starch is made on a large scale in Western Samoa a trial shipment cculd be sent for testing, but it would not be good economic sense to base any factory on this application as a guaranteed outlet.

In conclusion, the following Table 9 gives the potential markets for starch and its derivatives, the target price to produce substitutes and the potential savings in imports or export earnings.

TABLE 9

	FLOUR	CRYSTAL STARCH	SUGAR SUBSTITUTE	FUEL SUBSTITUTE
SECTION	6.1.1	6.1.2	6.2	6.4
Quantity	600 tonnes	250 tonnes	1,102 tonnes	2.6 Ml
Starch @ 88% Solids	525.5 tonnes	250 tonnes	1,034 tonnes	4,900 tonnes
Target Price	$311.37/tonne of 88% Starch	$420/tonne of 88% Starch	$336.17/tonne Glucose	$0.35/litre Ethanol
Import/Export $	$161,762	$105,000	$370,461	$700,000

Results of market survey in Western Samoa, December, 1979

7.0 FACTORY DESIGN

7.1 Starch Manufacture

7.1.1 Process Description

The breadfruit/taro are weighed on collection by the truck. They are dumped at the factory for washing and inspection. The crop is then stored at 12.5°C until required for processing, which may be immediately or up to 5 days later.

The raw material is then diced and some water added. It is then pumped by a grating pump into a disc mill. The milled puree is fed to a factory supply tank.

The diluted puree is coarse screened and the oversize returned for further milling. The undersize is screened for removal of fibre. The starch milk is then fed to a batch-operated basket centrifuge which spins off the fruit water. The coarse starch at 50-55% solid is then ploughed out into a tank and re-slurried with clean water to produce a 30% solids slurry. This is continuously run through a washing centrifuge,in the case of breadfruit,and back through the basket centrifuge in the case of taro. The washed starch slurry then gets dewatered to 55% solids in a second batch centrifuge. The starch is then filled into plastic trays and loaded into a solar drier. After two days, the trays are removed, the layer of impurities which have risen to the top of the trays is scraped off and the trays returned for further drying down to 13% moisture.

The crystal starch, which it has now become, is emptied out of the trays on to a perforated metal screen. All the less than 10 mm size pieces fall through and the rest are broken by hand with a wooden roller and also pushed through. The crystal starch is bagged and weighed. This is shown diagrammatically in Fig. 10 with an Equipment List, Appendix D, and a plant layout.

7.1.2 Process Calculations

It is assumed that the breadfruit is produced in two seasons each year and taro/taro palagi/ta'amu is processed during the non-breadfruit season.

Both materials are assumed to have the following analysis:

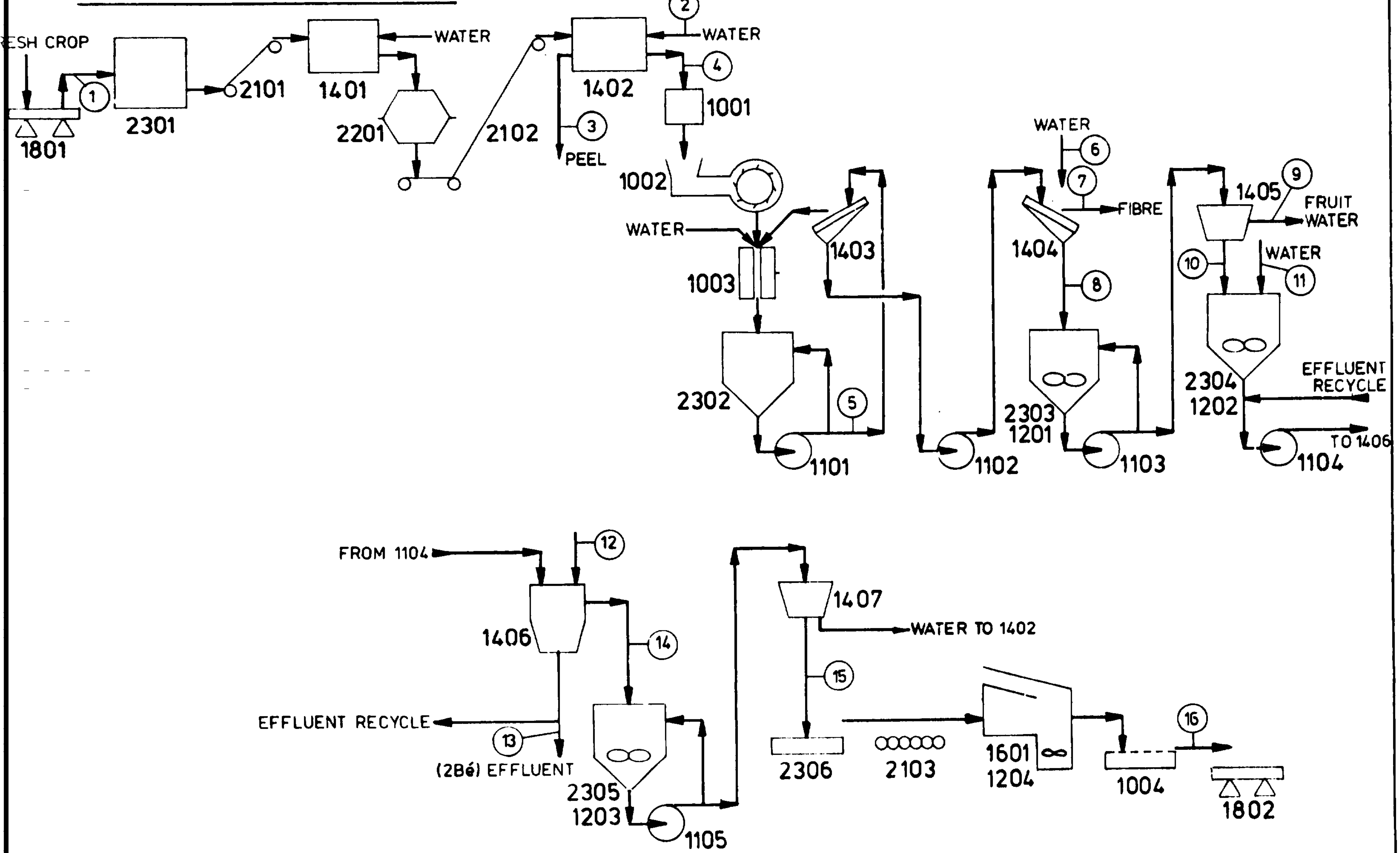
Starch	=	20%
Ash/Protein	=	2.3%
Fibre	=	4.0%
Sugars	=	2.0%
Water	=	71.7%

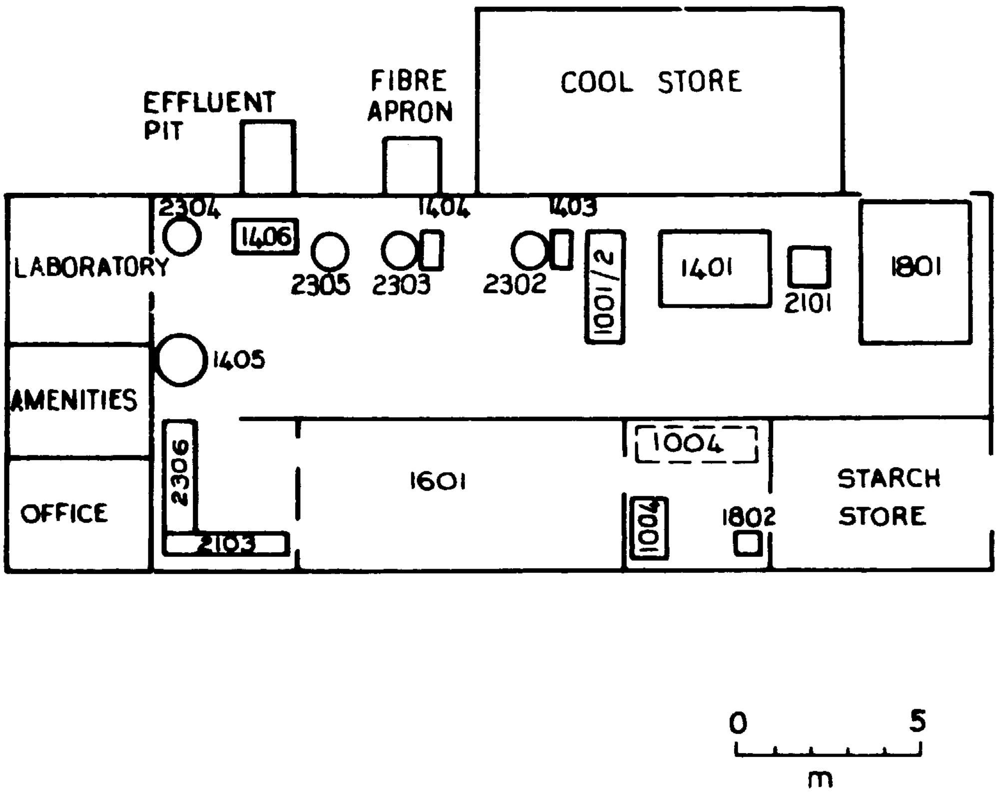
The seasons are such that in the 7 weeks lead up and tail off, the plant will work 5 days/week; 16 hours/day. In the 6 week height of the season, the plant will work 7 days/week; 24 hours/day.
i.e., Total Hours = 3136 for 250 tonnes of breadfruit starch
Thus, Starch Produced = 79.7 kg/hr
Raw Material needs = 398.5 kg/hr
with 20% losses = 498 kg/hr
Say, 500 kg/hr of raw breadfruit (1568 tonnes total).
The 50 tonnes of taro starch can be produced during the off season at this rate. So total plant running hours = 3,763 hours. A mass balance describing the numbered streams in Fig.10 are detailed in Table 10.

7.1.3 Plant Services

Power requirement for such a plant is estimated as follows:-

[G].10 CRYSTAL STARCH PRODUCTION





DAVY McKEE PACIFIC PTY. LTD. MELBOURNE MEMBER OF THE DAVY GROUP		CLIENT UNIDO	DATE
LAYOUT-9005		TITLE CRYSTAL STARCH/ F[illegible]OUR PRODUCTION	DES./DR R.B.B.

TABLE 10. CRYSTAL STARCH PRODUCTION - MASS BALANCE (kgs/hr)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
STARCH	99.6		3.1	96.5	96.5		5.8	90.7	0.7	90			4.3	85.7	85.7	79.7
WATER	357.0	477.1	15.2	818.9	818.9	20	107.0	731.9	641.9	90	120	45	120	135	85.7	13.3
FIBRE	19.9		1.7	18.2	18.2		17.4	0.8	0	0.8			0	0.8	0.8	0.8
ASH/PROTEIN	11.5		0.5	11.0	11.0		3.4	7.6	6.7	0.9			0.3	0.6	0.6	0.6
SUGARS	10.0		0.4	9.6	9.6		2.3	7.3	6.4	0.9			0.3	0.6	0.6	0.6
TOTAL:	498	477.1	20.9	954.2	954.2	20	135.9	838.3	655.7	182.6	120	45	124.9	222.7	173.4	94.9

ANALYSES (%)

	1 Crop		3 Peel				7 Fibre									16 Product
STARCH	20		15				4.3									84
WATER	71.7		72.7				78.7									14
FIBRE	4		8				12.8									0.8
ASH/PROTEIN	2.3		2.3				2.5									0.6
SUGARS	2.0		2				1.7									0.6
TOTAL:	100		100				100									100

TABLE 10. CRYSTAL STARCH PRODUCTION - MASS BALANCE (kgs/hr)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
STARCH	99.6		3.1	96.5	96.5		5.8	90.7	0.7	90			4.3	85.7	85.7	79.7
WATER	357.0	477.1	15.2	818.9	818.9	20	107.0	731.9	641.9	90	120	45	120	135	85.7	13.3
FIBRE	19.9		1.7	18.2	18.2		17.4	0.8	0	0.8			0	0.8	0.8	0.8
ASH/PROTEIN	11.5		0.5	11.0	11.0		3.4	7.6	6.7	0.9			0.3	0.6	0.6	0.6
SUGARS	10.0		0.4	9.6	9.6		2.3	7.3	6.4	0.9			0.3	0.6	0.6	0.6
TOTAL:	498	477.1	20.9	954.2	954.2	20	135.9	838.3	655.7	182.6	120	45	124.9	222.7	173.4	94.9

ANALYSES (%)

	1 Crop		3 Peel				7 Fibre									16 Product
STARCH	20		15				4.3									84
WATER	71.7		72.7				78.7									14
FIBRE	4		8				12.8									0.8
ASH/PROTEIN	2.3		2.3				2.5									0.6
SUGARS	2.0		2				1.7									0.6
TOTAL:	100		100				100									100

Macerating Equipment	=	18.7 kW
Centrifugation Equipment	=	12.3 kW
Other Moving Machinery	=	4.5 kW
Lighting and Cool Room	=	3.0 kW
		38.5 kW

@ $0.14/kW = $20,284/year or $67.61/tonne starch

No steam required.

Water usage and effluent = 2.5 m^3/hr

7.2 Glucose Syrup Manufacture

7.2.1 Process Description

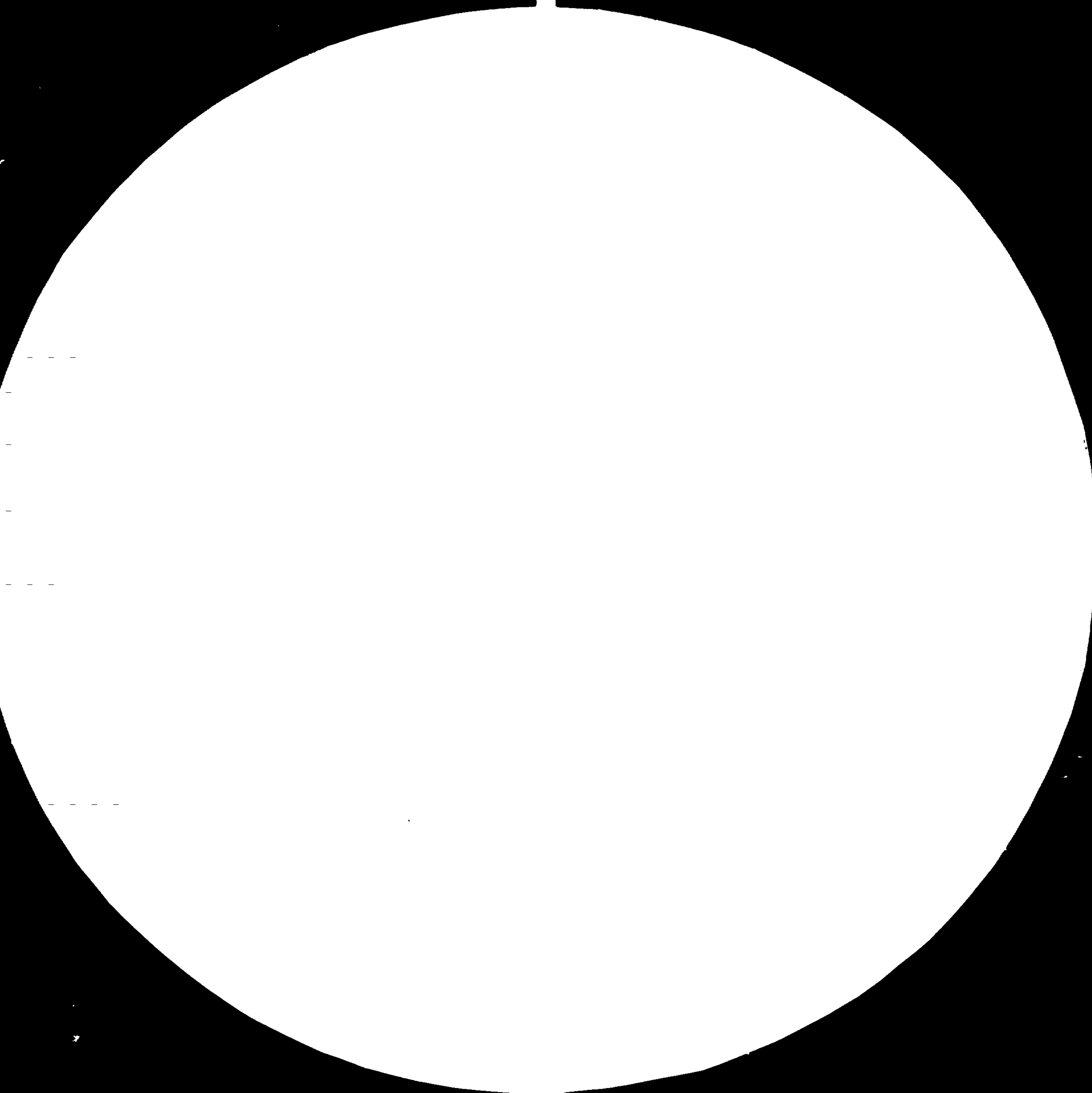
The process is similar to starch making until the washing centrifuge. At this point, the starch slurry at 30-35% solids is pH adjusted to 6.5 to 7.0 and alpha amylase enzyme is added. The slurry is then pumped through a jet cooker where steam raises its temperature to 105°C. The liquid is retained in a reactor coil for two minutes and then discharged into a tank where more alpha amylase liquefying enzyme is added. The starch completes its liquefaction/gelatinisation here. The pH is then adjusted to 4.5 - 5.5 depending on the type of D.E. syrup required and an amyloglucosidase enzyme added.

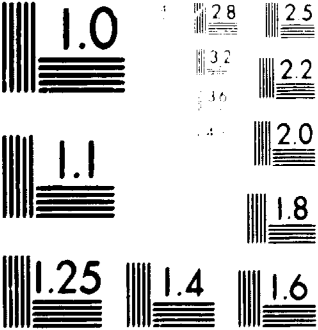
The liquefied starch is then pumped to one of a number of batch holding vessels, where the saccharification reaction turns the liquefied starch into glucose syrup. This will take between 40 and 50 hours. The intention is to produce two different finished products. The brewery syrup will have a very high D.E. to give a syrup that ferments completely. The Ice Cream, Soft Drink and Bakeries will want a lower D.E. syrup. These can all be simply tailor made to individual requirements.

The syrups at 35% solids are filtered in a batch operated leaf filter. The brewery syrup is then evaporated to 75% solids and stored until required. The other syrups are decolourised first, by a one hour contact with activated carbon. The carbon is filtered off using the same filter as before, and this syrup is then also evaporated to 75% solids for storage.

This process flowsheet is illustrated in Fig. 11 with an Equipment List, Appendix E, and a plant layout.

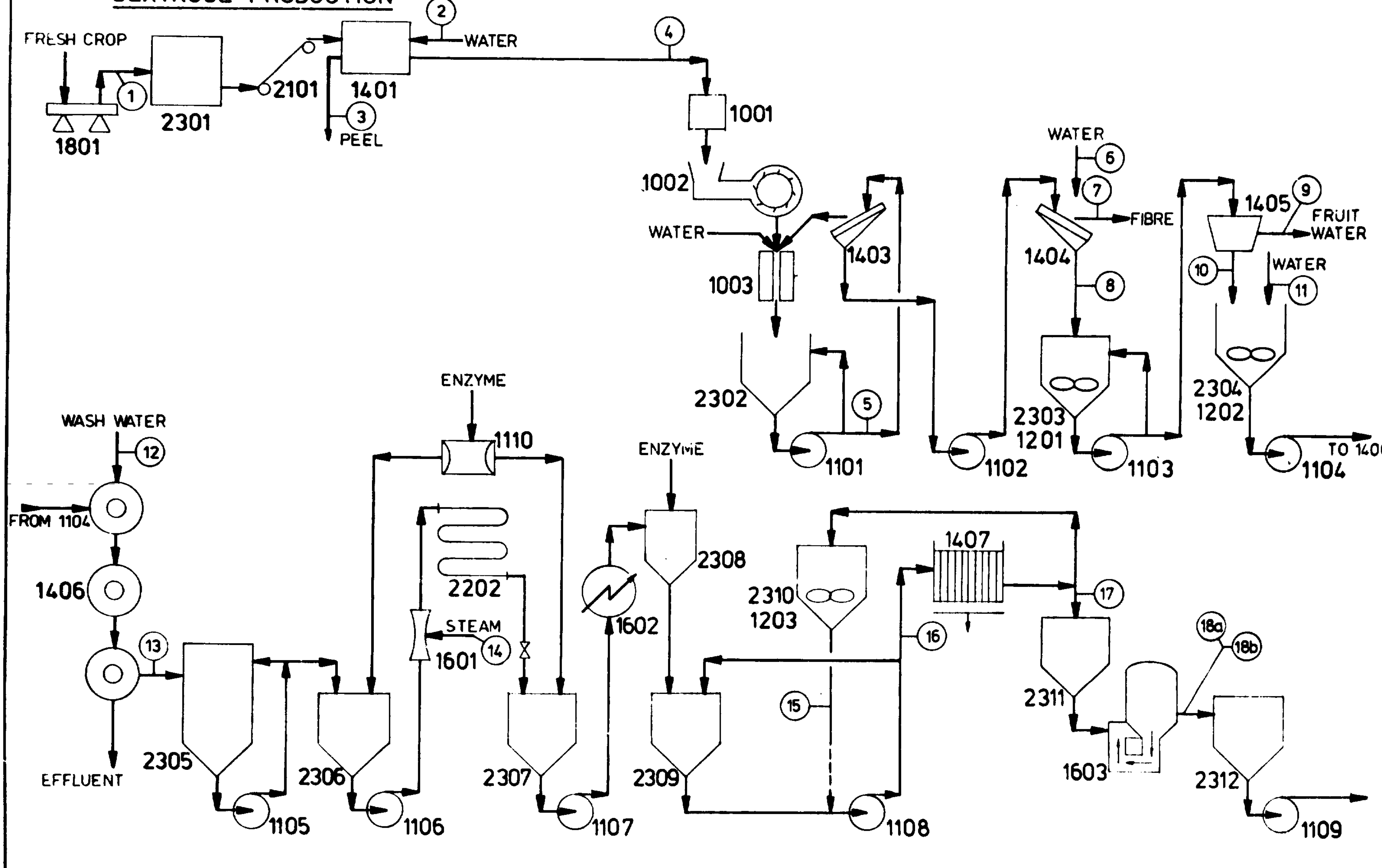
80 12 09

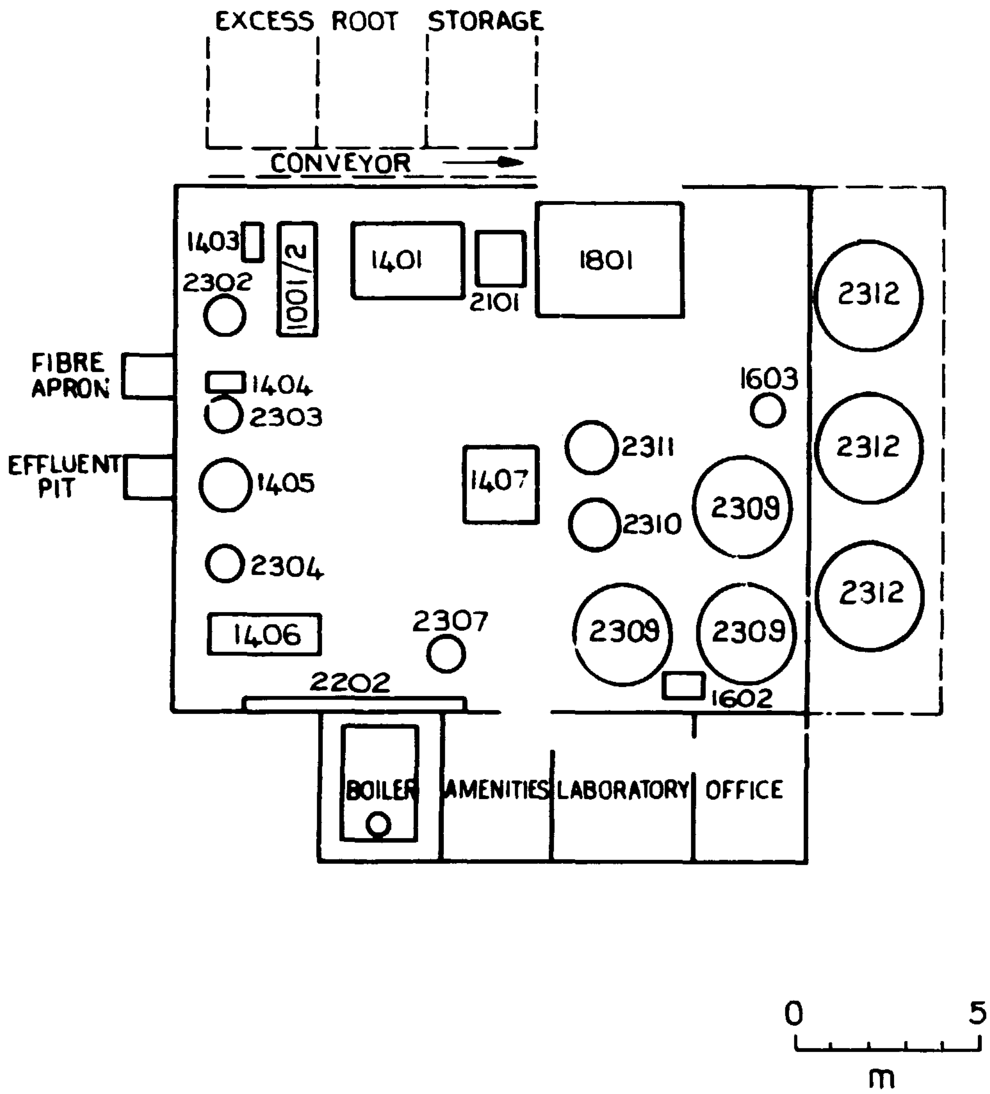




MICROCOPY RESOLUTION TEST CHART

FIG. 11 DEXTROSE PRODUCTION





DAVY McKEE PACIFIC PTY. LTD. MELBOURNE MEMBER OF THE DAVY GROUP	CLIENT UNIDO	DATE
LAYOUT–9005	TITLE DEXTROSE PRODUCTION	DES/DR

7.2.2 Process Calculations

Dextrose cannot easily be produced on a stop/start basis during a working week. Processing has thus been arranged on a 5½ day week/24 hours per day for 7 weeks with a 7 day week/24 hours per day during the height of the six week season. During the two periods, starch required = 1,034 tonnes at 88% water (910 tonnes dry weight) so the raw material required = 5,986 tonnes/year.

A mass balance is shown in Table 11 which describes the numbered streams in Fig. 11.

During the 5½ day working week, the following system will be operated:

Raw Material → Saccharification will run 8 a.m. Tuesday to 8 a.m. Friday

Filtering → Glucose storage will run midnight Tuesday to midnight Saturday.

During the 7 day working week, the plant will close for one shift of 8 hours each week for cleaning out.

Processing hours	=	3,264 hours/year
	@	1,834 kg/hour

7.2.3 Plant Services

Power requirements for such a plant is estimated as follows:

Macerating Equipment	=	18.7 kW
Centrifugal Equipment	=	29.8 kW
Other Moving Machinery	=	13.8 kW
Lighting	=	1.5 kW
		63.8 kW

TABLE 11 DEXTROSE PRODUCTION - MASS BALANCE (kgs/hr)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18a	18b
STARCH	366.8		11.6	355.2	355.2		21.5	333.7	2.6	331.1	0	0	320.8			0	0	0	0
WATER	1315	1757	55.9	3016.1	3016.1	70	393.9	2692.2	2361.1	331.1	441.5	111.4	496.7	72		533.1	533.1	68.3	278.5
FIBRE	73.4		6.2	67.2	67.2		64.1	3.1	0	3.1		0	1.5			1.5	0	0	0
ASH/PROTEIN	42.2		1.8	40.4	40.4		12.5	27.9	24.5	3.4		0	1.8			1.8	1.8	1.8	1.8
SUGARS	36.6		1.5	35.1	35.1		8.5	26.6		3.3			1.7			358.1	358.1	280.2	280.2
TOTAL:	1834	1757	77	3514	3514	70	500.5	3013.5	2908.2	672	441.5	111.4	822.5	72		894.5	893	350.3	560.4

(a) Icecream 65DE (b) Drawing, Sweetening 85 + DE

ANALYSES (%)

	Crop		Peel				Fibre											65DE	85 + DE
STARCH	20		15.1				4.3											0	0
WATER	71.7		72.6				78.7											19.5	49.7
FIBRE	4		8				12.8											0	0
ASH/PROTEIN	2.3		2.3				2.5											0.5	0.3
SUGARS	2.0		2.0				1.7											80	50
TOTAL:	100		100				100											100	100

This will be used as follows:

63.8 kW for 1,920 hours
61.2 kW for 1,334 hours
4.1 kW for 1,334 hours
to produce 1,102 tonnes glucose
Cost @ $0.14/kw is $26.71 per tonne of glucose

Steam required:

Jet Cooker	= 158.5	lbs/hr
Evaporator	= 1,142	lbs/hr
Steam Tracing	= 200	lbs/hr

A nominal 2000 lbs/hr boiler would use an average of 1351 lbs/hr for the 3,824 hrs/year.

Fuel use is estimated at $17.8 \times 3824 \times \frac{1351}{2000} = 45,979$ galls/yr.

Fuel @ $1.16/gall is $48.40/tonne glucose

The total fuel cost = $75.11/tonne glucose

Water usage and effluent = 10 m^3/hr.

7.3 Flour Manufacture

7.3.1 Process Description

The process is similar to crystal starch manufacture. However, the trays need not be removed from the dryer at the intermediate stage for removal of impurities. The lumps must also be ground in a pin mill. Flour can tolerate a proportion of fibre. Initial trial work in bakeries will establish the level of fibre that can be usefully added to the flour starch. The screen sizes would be changed accordingly.

7.4 Ethanol Manufacture

7.4.1 Process Description

The process of making ethanol from a starch bearing crop is illustrated in Fig. 12 with an Equipment List, Appendix F. The washed raw material need not be stored in a cool room, as it does not matter if some of the starch is hydrolysed to sugars during respiration.

The raw material is then diced and milled to a puree as before. However, the material need not be fine screened for removal of the fibre, nor is it centrifuged.

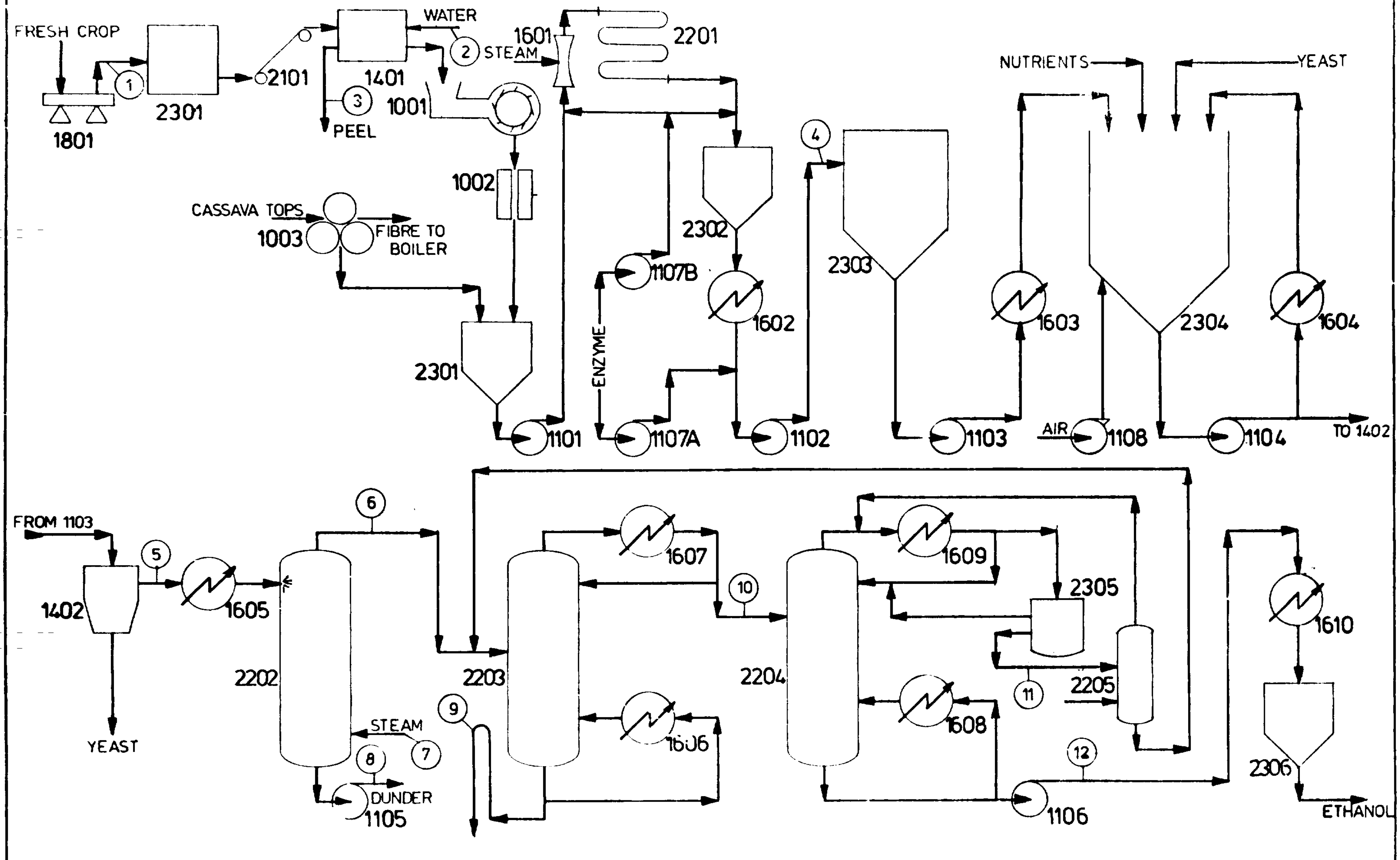
The diluted puree at 20-25% solids is then jet cooked as before with added alpha amylase. The liquefied starch is then saccharified to produce a brewery type syrup of very high D.E. It is then diluted down to 15-20% fermentable soluble solids and put in a batch fermenter with extra nutrients such as nitrogen and phosphorus (ammonia and superphosphate).

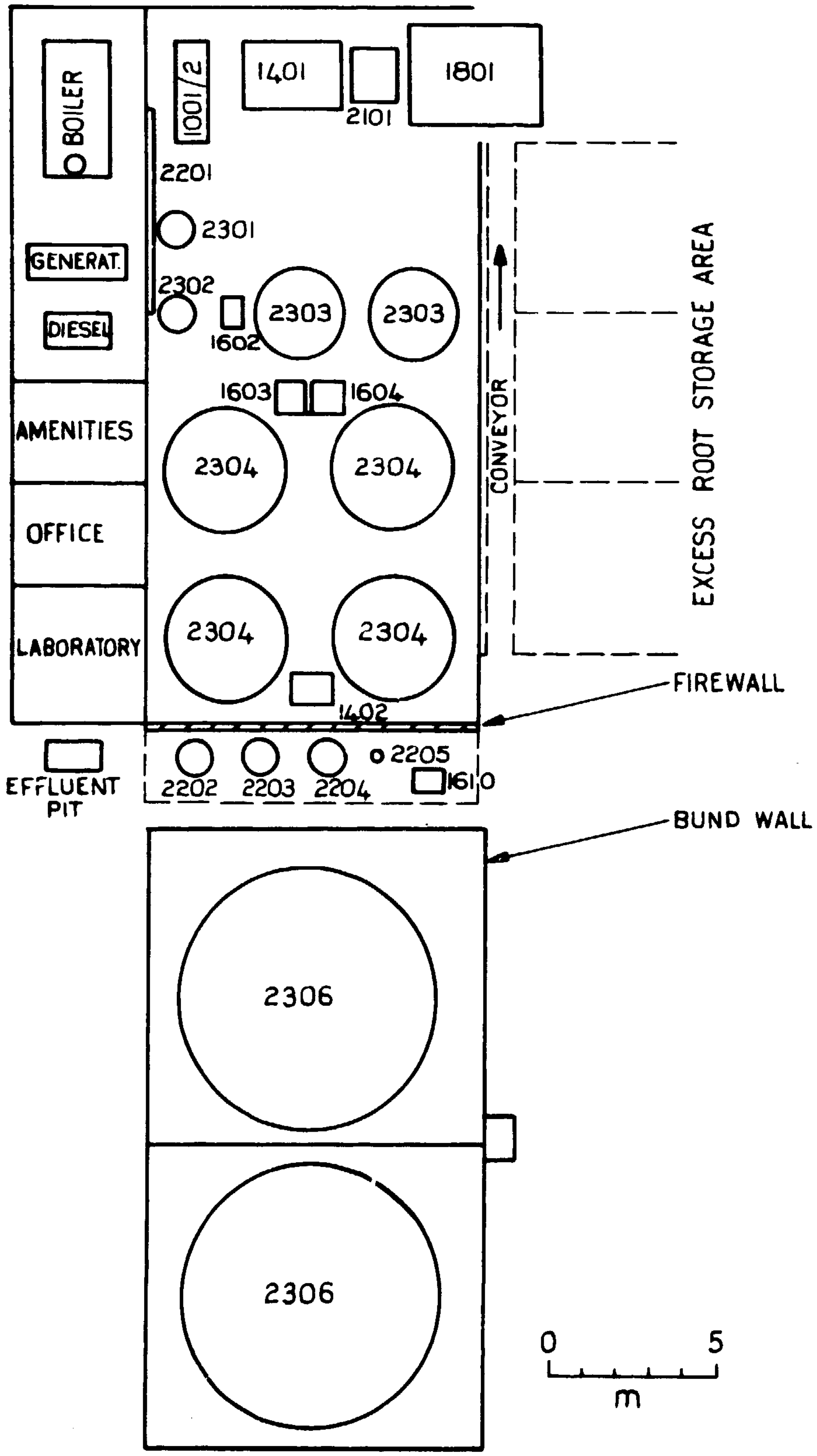
Yeast is then added which metabolises the sugar to produce ethanol. The diluted ethanolic solution then has the yeast and any other proteinaceous solids centrifuged off.

This clean ethanol solution is fed to a wash column which strips out all the alcohol producing a 50% ethanol/50% water vapour. This vapour goes to a second column where all the alcohol is stripped off as a 95% ethanol vapour. A chemical entrainer is then added to remove the remainder of the water and produce anhydrous ethanol which can be added to petrol or diesel.

The yeast is produced for the factory in a separate small yeast propagator. The equipment is all shown in the layout of the factory.

FIG. 12 FUEL ETHANOL PRODUCTION





DAVY McKEE PACIFIC PTY. LTD. MELBOURNE MEMBER OF THE DAVY GROUP	CLIENT UNIDO	DATE
LAYOUT-9005	TITLE FUEL ETHANOL PRODUCT	DES/DR R.B.B.

7.4.2 Process Calculations

Table 12 fully describes the mass balance of the factory by calculating the magnitude of the streams numbered in Fig. 12.

In total, an estimated 21,950 tonnes of raw material will make 2.6×10^6 litres/year of ethanol.

7.4.3 Plant Services

The options are for the ethanol plant to be fuelled by wood waste/sawdust from the Asau sawmill and to generate its own electricity or to buy in electricity and/or steam from the sawmill.

The plant cannot be economically fuelled with diesel or buying in electricity from the E.P.C.

A plant to produce 2.6×10^6 litres of ethanol would require:

175.3 kW
1250 kg/hour steam

Normally, 25 kg steam will be exhausted generating 1 kW of generated electrical power. Thus 4383 kg steam will be required for 175.3 kW. As this is greater than 1250 kg, process steam will be available in excess.

TABLE 12 FUEL ETHANOL PRODUCTION - MASS BALANCE (kgs/hr)

	1	2	3		4		5	6	7	8	9	10	11	12
STARCH	609.7		9.6	STARCH	0	ETHANOL	275.6	261.3	-	14.3	1.5	259.8	34.7	259.8
WATER	2185.8		46.5	WATER	3145.8	WATER	3145.8	319.3	593	3419.5	468.5	16.6	23.6	1.3
FIBRE	121.9		5.1	FIBRE	116.8	FIBRE		0	0	-	0	0		0
ASH/PROTEIN	70.1		1.5	ASH/PROTEIN	68.6	ASH/PROTEIN	68.6	0	-	68.6	0	0		0
SUGARS	61.0		1.3	SUGARS	599.2	SUGARS	59.9	0	-	59.9	0	0		0
						BENZENE	0		-	-	-	-	7.2	0.1
TOTAL	3048.6		64	TOTAL	3930.4	TOTAL	3549.9	580.6		3562.3	470.0	276.4	65.5	261.1

ANALYSIS (%)

	CROP		PEEL											PRODUCT
STARCH	20		15			ETHANOL								99.5
WATER	71.7		72.7			WATER								0.5
FIBRE	4		8			FIBRE								0
ASH/PROTEIN	2.3		2.3			ASH/PROTEIN								0
SUGARS	2.0		2.0			SUGARS								0
						BENZENE								
TOTAL	100		100			TOTAL								100

At a calorific value of 14,000 KJ/kg and 65% boiler efficiency, an estimated 25.7 tonnes/day of sawdust fuel would be needed.

A quotation of $15 per tonne has been received for the sawdust at Asau. It would cost an estimated $40 per tonne if shipping it to Vaitele.

Cooling Water Requirements	=	40 m^3/hr
Effluent (still bottoms)	=	5 m^3/hr of 25,000 ppm BOD
Other Effluent	=	9 m^3/hr of 5,000 ppm BOD

8.0 SITE CONSIDERATIONS

In general, five sites were investigated on both the islands. They are indicated on Figs 13 and 14.

(1) Asua is a deep water harbour, adjacent to Samoa Forest Products.

(2) Salelologa is the nearest shipping point to Upolu.

(3) Vaitele is the site of the Industrial Estate.

(4) S.E. Coast, Upolu is an area in the heart of suitable agricultural land.

(5) Mulifanua is the closest shipping point from Savai'i.

8.1 Industrial Incentives

From a National Development point of view, the Department of Economic Development prefer a factory site on Savai'i rather than Upolu. Roads and water could be developed as a separate venture if necessary. The road between Asau and Salelologa is at present being up-graded to a 40 kph sealed road, see Section 3.5.1.

There is an Industrial Estate at Vaitele on Upolu where land would be made available at $360 per acre.

If at least 95% of a company's products are sold for export, then the company could be set up in the Industrial Free Zone. This would allow complete exemption from payment of import/export duties and excise,exemption from tax for 5 years and then only 25% thereafter. A site can be leased for 30 years

FIG. 13

SAVAI'I ISLAND

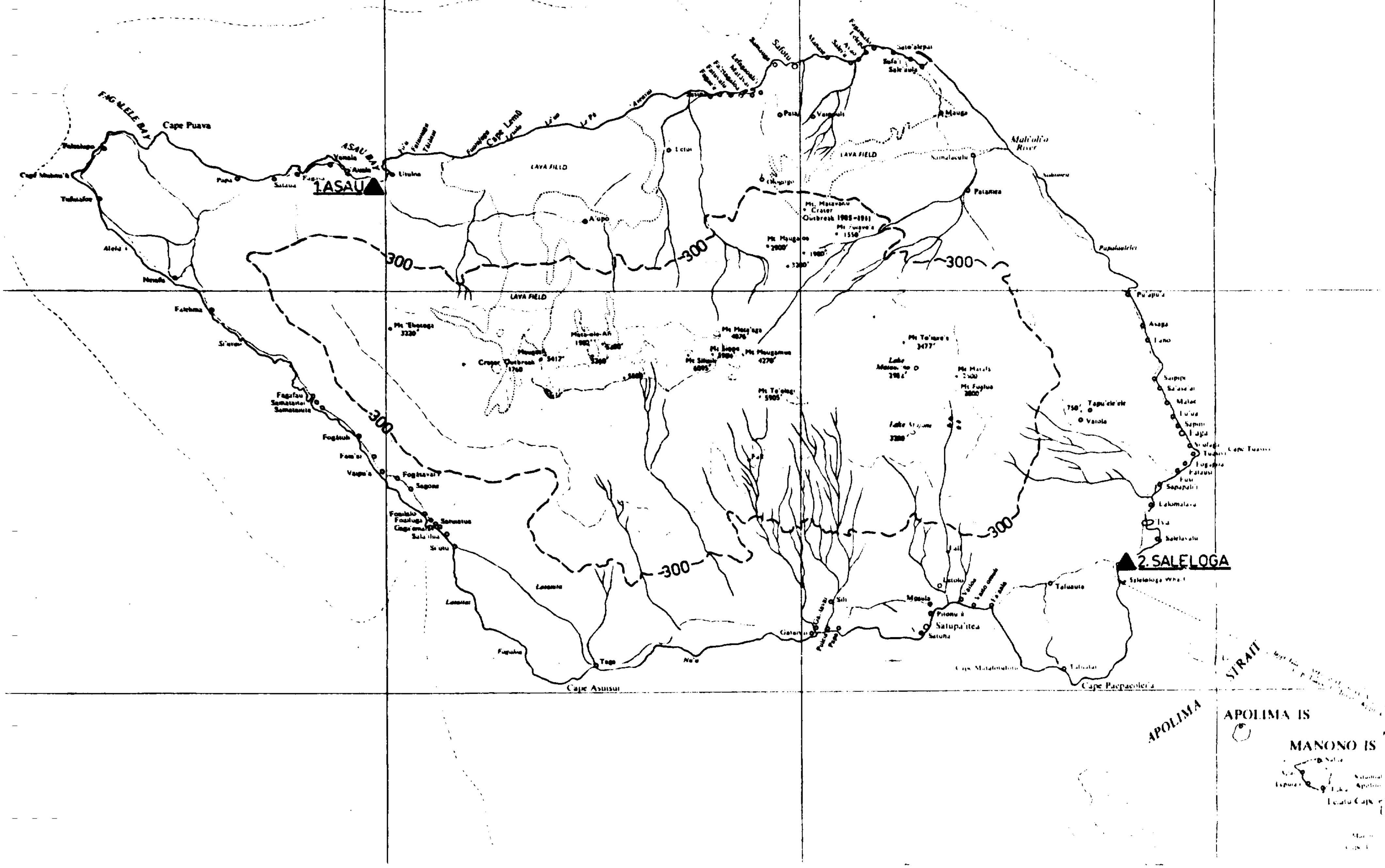
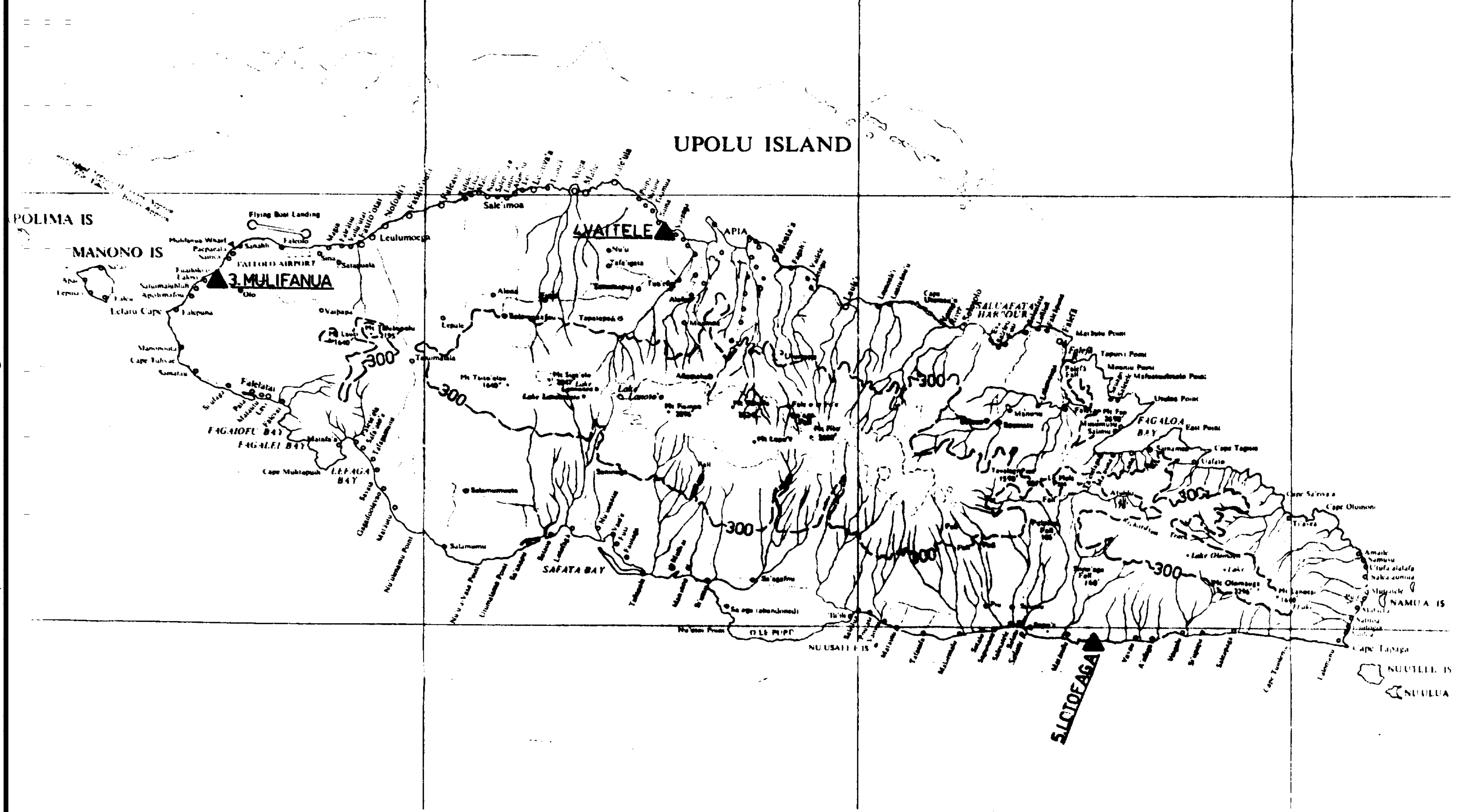


FIG. 14


UPOLU ISLAND
POLIMA IS
MANONO IS
Flying Boat Landing
FALEOLO AIRPORT
3. MULIFANUA
Leulumoega
Sale'imoa
4. VAITELE
APIA
SALUAFATA HARBOUR
FAGALOA BAY
Cape Tagese
Lelata Cape
Falelatai
FAGAIOFU BAY
FAGALEI BAY
LEFAGA BAY
Salamumu
SAFATA BAY
300
NUUSAFEE IS
5. LOTOFAGA
NAMUA IS
Cape Tapaga
NUUTELE IS
NUULUA

with an extension of a further 30 years. Repatriation of capital, dividends, profit and royalties are freely allowed.

If the company is registered in New Zealand, special provisions can apply, see Section 3.5.2.

Enterprises in the field of agro-industry and research and development come within the framework of the Enterprise Incentives Act 1965, see Section 3.5.2.

8.2 Agricultural Land

There is considerable land in Western Samoa that could be devoted to producing starch bearing crops. The crops being considered, taro, ta'amu, breadfruit and bananas should all be grown below the 300 m altitude line, see Figs. 13 & 14. Cassava can grow on higher land.

During the field trip, opinions varied considerably on the amount of land which could be made available to an agro-industry. There was considerable opinion that no land was available, however, there was an opinion that land could be available if the venture was economic. Certainly in the long term, Western Samoa could not allow a large amount of land to be used for growing crops for the export market if the earnings had to be used to buy similar imported food. The weight of opinion is that Western Samoa in the long term future may have problems feeding its population.

There are large tracts of suitable land on the South-East coast of Upolu which could grow taro and cassava. There are suitable, if more scattered, areas on Savai'i. Breadfruit trees grow all over both islands though the majority (70%) are estimated to be on Upolu. Breadfruit could be intercropped with taro, cassava or other staples.

With no intercropping and growing 20 tonnes/ha per year of a 25% starch crop, and assuming factories are 80% efficient, then the four options being considered (Section 6.0) would require the following planted area each year.

	Hectare
Flour	92
Crystal Starch	44
Sugar Substitute	182
Fuel Additive	862

Van Wissen estimated (June 1978) that there was 50,000-100,000 tonnes per year of breadfruit grown in Western Samoa. The lower figure is twice that required to totally satisfy the four options, without the need to plant any new crops. Opinion is that half the breadfruit rots on the ground and is not consumed.

8.3 Electrical Power

The availability of electric power was discussed with the Electric Power Corporation. At present, electricity is 12 sene/unit but will be 14 sene/unit by June 1980. It is generated at 50 hertz.

8.3.1 Asau

Asau has 2.5 MW generated by the timber mill of which 1.5 MW is in excess. At present, it is not reliable but by 1982 it will be. There is 104,000 ha of operable forest with 1.5 million cubic metres of sawlogs available in Western Samoa.

8.3.2 Salelologa

Salelologa will be connected with Asau by 1984 to augment the diesel generated electrical power there. Under present plans, there would be 500 kW of reserve capacity for distribution in 1984 but no more than 200 kW could be made available to a single factory.

8.3.3 Vaitele

Vaitele has available power which would cost $15,000 - $20,000 to connect to any specific site.

8.3.4 South-East Upolu

South-East Upolu could have power transmitted from a hydroelectric station 15 km away. This would cost perhaps $40,000. This could be financed separately as an infrastructure cost.

8.3.5 Mulifanua

Mulifanua is the proposed site of a wood-fired,steam generated power station to be fuelled by coconut logs. There is some power at present but not enough to power a factory. There is 59,000 ha of Western Samoa under coconuts with an estimated stem volume of 3 million cubic metres (twice that of sawnlogs).

A small mini hydroelectric power station could be installed, dedicated to a factory. It would cost an estimated $2,000/kW and 1 sene/kW running expenses.

8.4 Water and Effluent

All water used in Western Samoa is charged for at $59.40 per 1000 m^3 which is due to increase to $88 per 1000 m^3 in early 1980. There is no charge for effluent disposal, which must be done with all due consideration to the environment after discussions with the Public Water Department.

Bore water is always below 20°C and surface water below 22°C. There is low potential for irrigating effluent on to land because of high rainfall, but piping to streams or the coast is a good possibility because of the fast flowing streams and the strong currents outside the coral reefs.

The following table grades the sites according to the quantity, quality and the area's ability to cope with factory effluents, with 1 being most suitable 4 being least suitable.

Site	Type of Water	Quality	Quantity	Effluent
Asau	Bore	2	2	3
Salelologa	Surface	3	2	2
Vaitele	Bore	2	3	1
S.E. Upolu	Surface(plus 10 km of pipeline)	4	3	1
Mulifanua	Bore	3	4	2

The sea is close to all sites and can be usefully used for cooling purposes, though there are always the inherent dangers of contamination of the food products by salt.

The bore water at Asau has a conductivity of 1,500 micro mho's/cm and is very clean microbiologically.

The Palauli River at Salelologa has a flow of 440-580 m^3/hour with a total coliform count of 0-600 per ml.

Vaitele has 440-550 m^3/hour from its normal bores with three extra stand-by bores of 45 m^3/hour each. The water has less than 50 ppm chloride content. One of the bores is very clean with FTU=0 and coliforms of 100-200/ml (fecal coliforms = 0) and one of the bores is very dirty with 270-300 FTU and up to 11,000/ml total coliforms.

8.5 Transport

8.5.1 Road

The road between Asau and Salelologa will be a sealed all weather road in the foreseeable future. The road between Mulifanua and Apia around the coast, along the South-East coast of Upolu, over the cross island road and over Le Mafa Pass are all weather roads that would handle and not be affected by transport up to the size of 6 tonne trucks.

8.5.2 Sea

There is a regular vehicle and passenger service between Salelologa and Mulifanua by two landing craft every two hours daily. The landing craft can be made available for journeys from Apia to Asau and Apia to Salelologa. Charter prices are:

Apia/Asau	$1,400
Apia/Salelologa	$1,200
Mulifanua/Salelologa	$300 (Return $500)

The craft will carry 150-160 tonnes, are 25 m long and will carry four 32 m^3 containers.

A single truck journey costs $50 and a passenger $1.00 between Mulifanua and Salelologa.

8.6 Fuel

Diesel fuel is $1.13/Imp. gallon (25 sene/litre) and wood could be used to fuel a boiler on Upolu. Asau has one great advantage, the timber mill runs a 55,000 lbs/hour boiler and a 3150 kVA steam turbine. It could either supply surplus steam or could supply over 10 million super feet of timber waste as sawdust. It has quoted $15/tonne for sawdust for fuelling a boiler.

8.7 Labour

There is a large labour pool available at, or near Vaitele. However, a number of workers travel to Vaitele each day from across Upolu to the brewery and cigarette factory. It was considered that all sites would have labour available.

9.0 FINANCIAL ANALYSIS

9.1 General Considerations

9.1.1 Transport Costs

The crop requirements for any of the plants cannot be grown immediately adjacent to the site of the factory because of the large area of land that is required. In Savai'i, the two sites are at either end of the island equidistant from possible agricultural areas. In Upolu, the Mulifanua and Vaitele sites are equally far from the probable growing areas though the Lotofaga site is more closely associated. In general, it is considered that an average journey for any crop pick-up, whether it is from a village or dedicated factory plantation, would be 48 kms.

A six tonne truck is the maximum size that can be considered as giving all weather coverage of the islands to all the sites at which the crop would be gathered. Each truck would carry its own scales to enable the supplier to be paid immed'ately. A six tonne truck would conveniently keep a 0.5 tonne/hour plant operational by driving 8 hours/day.

The cost per tonne of agricultural produce has been calculated as $2.86 per tonne, Appendix G.

9.1.2 Agricultural Cost

Breadfruit would seem to be the cheapest form of starch available, Table 7. The cost of collecting this from a village environment has been calculated, Appendix G. This would not differ if a dedicated plantation was used as labour would still be $2.50/day.

As an essential part of the overall project, 50 tonne of taro starch will be made. This is estimated as costing at least $50 per tonne (Section 5.5).

9.1.3 Chemical Costs

The cost of enzymes, sulphuric acid, superphosphate, aqua ammonia, antifoam, sterilants and micronutrients have all been costed from Australian ports. Many of the basic chemicals are made in Australia and are cheaper than from New Zealand. The specialist chemicals have been quoted by the Australian offices of international suppliers as they considered Australia as the probable supply point. Supply frequency and reliability is important as otherwise very large inventories of chemicals have to be carried.

9.1.4 Plant Costs

Supply of moving machinery has been costed from Australian ports. However, the tanks, piping, etc., have been costed at Australian costs of fabrication, but made in Western Samoa. It was the opinion of local fabricators that they could match Australian/New Zealand costs of fabrication - labour being cheaper but productivity lower.

9.1.5 Siting

There would not be enough agricultural produce on either island to run all plant options, i.e., crystal starch, flour starch, glucose syrups and ethanol. Fuel cost is extremely important for the ethanol plant. Sawdust fuel and chips from the Asau sawmill costs $15.00 per tonne at Asau but $40 per tonne landed at Vaitele. Thus, it is considered essential that the ethanol plant be sited at Asau and thus the sawdust fuel for the ethanol option has been costed at $15.00 per tonne. The Upolu factory is best sited at Vaitele for starch, dextrose syrups and flour as this is closest to the major market and water and electricity are more available.

9.1.6 Plant Options

At this time, it is worthwhile repeating the options and the target prices which must be met to compete with imports (or in the case with crystal starch as an export).

Crystal Starch	-	250 tonnes of 88% solid @ $420/tonne (plus 50 tonnes of taro starch @ $300/tonne)
Flour Starch	-	525.5 tonnes of 88% solid @ $311.37/tonne
Glucose Syrup	-	1102 tonnes of 83% solid @ $366.17/tonne
Ethanol	-	2.6 Ml @ $0.35/litre + $40,000 of CO_2

The options that will be costed are:

- A Crystal Starch
- B Crystal Starch/Flour
- C Glucose Syrup
- B&C Crystal Starch/Flour/Glucose Syrup
- D Ethanol for Fuel

9.1.7 Working Capital

Throughout the analyses, the working capital has been calculated on the following basis:

Wages	:	6 weeks
Chemicals	:	4 months ensuring security of supply as all come from overseas
Raw materials	:	1 week as the farmer would be paid immediately and this would allow some storage
Fuel	:	1 month to give good security of supply
Maintenance Material	:	3 months as most would be specialised items which would have to come from overseas
Product	:	Locally used products such as flour, syrup, fuel ethanol would be on 30 days invoice but the crystal starch would be on 90 days as it is exported and shipping time must be allowed for.

9.1.8 General Cash Flow Considerations

All the factory options are of small size. It has been assumed that the factories could all be completed within 12 months of a contract being signed and that they would linearly be brought to full production during the first six months of the second year. The manager and his skilled laboratory/technical operations advisor would be employed during the final three months of the first year when equipment installation and office and laboratory establishment would be occurring.

The fuel costs have been taken out of the transport and the utilities cost and have been escalated in real terms by 3.5% per year from a base figure of $1.16 per gallon now - 12 months before contract signing. The fuel ethanol product has similarly been escalated by 3.5% per year in real terms from $1.58 per gallon now.

Interest on working capital is taken as 12% per annum.

Building maintenance has been taken at 2% of building cost, machinery maintenance at 20% of machinery cost and insurance at 2½%of assets.

9.2 Crystal Starch Manufacture

9.2.1 Plant Cost

	$
Mechanical equipment CIF Apia and erection	196,570
Piping	59,000
Instrumentation	19,000
Electrical	47,200
General equipment costs	20,000
Site preparation	14,000
Buildings (320 m^2 @ $176 per m^2)	56,320
Home office engineering, Commissioning supervision, Site distributables	206,000
Contingency (10%)	61,800
Say, $680,000	679,890

9.2.2 Other Costs

Total crop processed 313 tonnes taro and 1567 tonnes breadfruit.

	$
Materials	
Breadfruit @ $7.00/tonne	10,969
(@ $21.00/tonne)	(32,907)
Taro @ $50.00/tonne	15,650
Transport @ $ 2.86/tonne	5,377
General chemicals, e.g. acid/alkali	1,000
Specialised chemicals, e.g. cleaners/ metabisulphite	1,000
Utilities	
Electricity @ $50.14/kW	20,284
Water @ $88/kW	140
Labour (as Appendix I)	107,638
Working capital	74,750

9.2.3 Cash Flow Analysis

Table 13 overleaf shows the cash flow for such a manufacturing facility. The option is not viable commercially. However, if the plant was financed overseas and paid for during the 15 year life of the factory then, as far as an overall trade balance for Western Samoa is concerned, the plant annual instalments would

equal cash saving on imports - Cash spent overseas

		$
=$120,000	- Maintenance materials	30,690
	- Fuel for transport	4,812
	- Chemicals	20,000

= $82,498.

That is, the cost of the factory, $680,000, could be borrowed at up to 8½% per year over 15 years before the starch manufacturing

TABLE 13

A. STARCH MANUFACTURE

CASH OUT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Materials	0	21,885	29,180	29,180											
Transport Fuel	0	4,006	5,529	5,721	5,919	6,126	6,343	6,564	6,795	7,031	7,277	7,532	7,797	8,067	8,351
Utilities	0	15,318	20,424	20,424											
Auxiliary Fuel	-														
Maintenance (Building)	0	845	1,126	1,126											
Maintenance (Machinery)	0	60,536	80,714	80,714											
Labour	9,000	107,638	107.638	107,638											
Working Capital Interest	0	6,728	8,970	8,970											
Insurance	15,300	15,300	15,300	15,300											
Plant Cost	680,000														
CASH IN:															
Sales	0	90,000	120,000	120,000											
CASH FLOW:	(704,300)	(142,256)	(148,881)	(149,073)	(149,271)	(149,478)	(149,695)	(149,916)	(150,147)	(150,383)	(150,629)	(150,884)	(151,149)	(151,419)	(151,703)

facility adversely affected the balance of payments, with all the benefits of the multiplier improving trade within Samoa.

9.3 Flour and Crystal Starch Manufacture

9.3.1 Plant Cost

	$
Mechanical equipment CIF Apia and erection	291,000
Piping	87,000
Instrumentation	23,000
Electrical	59,000
General equipment costs	25,000
Site preparation	14,000
Buildings(320 m^2 @ $176 per m^2)	56,320
Home office engineering, Commissioning supervision, Site distributables	278,000
Contingency (10%)	83,300
	961,620

Say $962,00C

9.3.2 Other Costs

Total crop processed 313 tonnes taro and 4857 tonnes breadfruit.

	$
Materials	
Breadfruit @ $7.00 /tonne	33,999
(@ $21.00/tonne)	(101,997)
Taro @ $50.00/tonne	15,650
Transport @ $ 2.86/tonne	5,377
General chemicals	3,000
Specialised chemicals	1,000
Utilities	
Electricity @ $0.14/kW	55,815
Water @ $88/kW	380
Labour (as Appendix I)	108,027
Working capital	103,533

9.3.3 Cash Flow Analysis

Table 14 shows the cash flow position for this option. It is not commercially viable. However, similarly to the crystal starch facility it would benefit the Western Samoan balance of trade by import substitution and crystal starch export.

The imports would increase by	$
Maintenance materials	57,393
Fuel for transport	13,287
Chemicals	4,000
	74,680

However, import substitution and exports would save the country $283,625

This saving is more than sufficient to finance the plant capital at commercial rates of interest.

9.4 Dextrose Syrup Manufacture

9.4.1 Plant Costs

	$
Mechanical equipment CIF Apia and erection	348,000
Piping	140,000
Instrumentation	42,000
Electrical	68,000
General Equipment Costs	30,000
Site Preparation	16,720
Buildings(380 m^2 @ $176 per m^2)	66,880
Home office engineering, Commissioning supervision, Site distributables	356,000
Contingency (10%)	106,760
	1,174,360

Say $1,174,000

TABLE 14

B. STARCH/FLOUR MANUFACTURE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CASH OUT:															
Materials	0	41,353	55,137	55,137											
Transport Fuel	0	11,061	15,266	15,798	16,343	16,915	17,513	18,125	18,763	19,415	20,093	20,798	21,529	22,274	23,059
Utilities	0	42,146	56,195	56,195											
Auxiliary Fuel	-														
Maintenance (Building)	0	845	1,126	1,126											
Maintenance (Machinery)	0	85,245	113,660	113,660											
Labour	9,000	108,027	108,027	108,027											
Working Capital Interest	0	9,318	12,424	12,424											
Insurance	21,645	21,645	21,645	21,645											
Plant Cost	962,000	0	0	0											
CASH IN:															
Sales	0	212,719	283,625	283,625											
CASH FLOW:	(992,645)	(106,921)	(99,855)	(100,387)	(100,932)	(101,504)	(102,102)	(102,714)	(103,352)	(104,004)	(104,682)	(105,387)	(106,118)	(106,863)	(107,648)

9.4.2 Other costs

Total crop processed 5986 tonnes breadfruit.

	$
Materials	
Breadfruit @ $7.00/tonne	41,902
(@ $21.00/tonne)	125,706
Transport @ $2.86/tonne	17,120
Specialisea chemcials	1,500
General chemicals	3,000
Enzymes @ 6.25/kg	33,270
Utilities	
Electricity @ $0.14/kW	29,434
Water @ $88/1000 m^3	1,200
Auxiliary fuel for boiler @ $1.16/gallon	53,336
Labour (as Appendix I)	112,059
Working capital	111,683

9.4.3 Cash Flow Analysis

Table 15 overleaf shows the cash flow situation. There is a negative cash flow for the entire life of the factory, so commercially it is not a viable proposition. Taking the same simplistic view as before,

	$
Imports increase by	
Maintenance	74,145
Fuel (transport and boiler)	15,384
Chemicals and enzymes	37,770
	127,299
Import substitution would save	403,519

This would make a worthwhile improvement to the trade balance.

TABLE 15

C. GLUCOSE SYRUP MANUFACTURE

CASH OUT:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Materials	0	61,046	81,395	81,395											
Transport Fuel	0	12,806	17,676	18,292	18,923	19,585	20,278	20,986	21,725	22,480	23,265	24,081	24,928	25,790	26,698
Utilities	0	22,941	30,588	30,588											
Auxiliary Fuel	0	44,400	61,283	63,418	65,606	67,902	70,304	72,760	75,322	77,938	80,660	83,489	86,425	89,415	92,564
Maintenance (Building)	0	1,004	1,338	1,338											
Maintenance (Machinery)	0	110,214	146,952	146,952											
Labour	9,000	112,059	112,059	112,059											
Working Capital Interest	0	10,051	13,402	13,402											
Insurance	26,415	26,415	26,415	26,415											
Plant Cost	1,174,000	0	0	0											
CASH IN:															
Sales	0	302,639	403,519	403,519											
CASH FLOW:	(1,209,415)	(98,297)	(87,589)	(90,408)	(93,227)	(96,185)	(99,280)	(102,444)	(105,745)	(109,525)	(112,759)	(116,404)	(120,187)	(124,039)	(128,096)

9.5 Integrated Production of Starch and Syrup

9.5.1 Plant Cost

	$
Mechanical equipment CIF Apia and erection	472,000
Piping	115,000
Instrumentation	40,000
Electrical	104,250
General equipment costs	50,000
Site preparation	24,000
Buildings(545 m^2 @ \$176 per m^2)	96,000
Home office engineering, Commissioning supervision, Site distributables	443,000
Contingency (10%)	134,425
	1,478,675

Say \$1,479,000

9.5.2 Other costs

Total crop processed 313 tonnes taro and 10,843 tonnes breadfruit.

	$
Materials	
Breadfruit @ \$7.00/tonne	75,902
(@ \$21.00/tonne)	227,703
Taro @ \$50.00/tonne	15,650
Transport costs @ \$2.86/tonne	31,906
General chemicals	5,000
Speciality chemicals	2,000
Enzymes	33,270
Utilities	
Electricity @ \$0.14/kW	85,249
Water @ \$88/1000 m^3	1,200
Auxiliary fuel @ \$1.16/gal	53,336
Labour (as Appendix I)	126,877
Working capital	195,600

9.5.3 Cash Flow Analysis

Table 16 shows that there is a negative cash flow for all but one year. It is not a commercially viable proposition. However, there would be considerable benefit to the Western Samoan balance of trade.

The imports would increase by	$
Maintenance materials	92,528
Fuel (transport and boiler)	28,671
Chemicals	40,270
	161,469

However, import substitution and exports would save $687,144

This saving is more than sufficient to finance the factory at commerical interest rates. For instance, at 10% interest and and estimated $1,100,000 spent overseas of the overall plant cost it would cost $144,622 per year in interest and capital repayments. So there would be an overall improvement to the balance of payments of

$687,144 - $144,622 - $161,469 = $381,053

9.6 Ethanol Manufacture

9.6.1 Plant Costs

	$
Mechanical equipment CIF Apia and erection	711,500
Piping	193,000
Instrumentation	56,000
Electrical	143,000
General equipment costs	60,000
Site preparation	26,000
Buildings(600 m^2 @ $176 per m^2)	106,000
Home office engineering, Commissioning supervision, Site distributables	640,000
Contingency (10%)	193,550
Say, $2,129,000	2,129,050

TABLE 16

B + C. STARCH/FLOUR/GLUCOSE SYRUP MANUFACTURE

CASH OUT:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Materials	0	101,273	135,031	135,031											
Transport Fuel	0	23,868	32,943	34,091	35,276	36,501	37,793	39,113	40,490	41,896	43,360	44,881	46,459	48,066	49,759
Utilities	0	64,802	86,403	86,403											
Auxiliary Fuel	0	44,400	61,283	63,418	65,606	67,902	70,304	72,760	75,322	77,938	80,660	83,489	86,425	89,415	92,564
Maintenance (Building)	0	1,440	1,920	1,920											
Maintenance (Machinery)	0	137,351	183,135	183,135											
Labour	9,000	126,877	126,877	126,877											
Working Capital Interest	0	17,604	23,472	23,472											
Insurance	33,278	33,278	33,278	33,278											
Plant Cost	1,479,000	0	0	0											
CASH IN:															
Sales	0	515,358	687,144	687,144											
CASH FLOW:	(1,521,278)	(35,535)	2,802	(481)	(3,845)	(7,375)	(11,069)	(14,845)	(18,784)	(22,806)	(26,992)	(31,342)	(35,856)	(40,453)	(45,295)

9.6.2 Other Costs

Total crop processed 21,950 tonnes breadfruit.

Materials	$
Breadfruit @ $7.00/tonne	153,650
(@ $21.00/tonne)	460,950
Transport @ $2.86/tonne	62,777
General chemicals	60,000
Speciality chemicals	25,000
Enzymes @ $6.25/kg	173,750
Utilities	
Wood chips/sawdust @ $15.00/tonne	127,215
Water @ $88/1000 m^3	29,000
Auxiliary fuel @ $1.16/gal	3,000
Labour (as Appendix J)	130,032
Working capital	189,033

9.6.3 Cash Flow Analysis

Table 17 gives the cash flow analysis for this fuel ethanol facility. There is a positive cash flow though at very much less than a commercial interest would expect. The Internal Rate of Return is only 1.43%. However, this is for a factory which has a large number of safeguards financially built in, including a 15 year write off period, no scrap value at the end, a 20% machinery maintenance component, a 68% on cost for the labour component and $15.00 per tonne for timber waste at present not utilisable at all and only 3.5% per year real increase in the cost of fuel when OPEC have a stated policy of aiming for a 10% real increase per year.

This fuel ethanol factory has great potential for saving Western Samoa a great deal of foreign exchange.

TABLE 17

D. FUEL ETHANOL FACTORY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CASH OUT:															
Materials	0	314,038	418,717	418,717						418,717					
Transport Fuel	0	46,961	64,816	67,074	69,389	71,817	74,358	76,955	79,665	82,432	85,311	88,303	91,409	94,571	97,902
Utilities	0	117,159	156,212	156,212						156,212					
Auxiliary Fuel	0	3,330	3,447	3,568	3,691	3,820	3,955	4,093	4,237	4,384	4,538	4,697	4,862	5,030	5,207
Maintenance (Building)	0	1,590	2,120	2,120						2,120					
Maintenance (Machinery)	0	203,558	271,410	271,410						271,410					
Labour	9,000	97,524	130,032	130,032						130,032					
Working Capital Interest	0	17,013	22,684	22,684						22,684					
Insurance	47,903	47,903	47,903	47,903						47,903					
Plant Cost	2,129,000	0	0	0						0					
CASH IN:															
Sales Ethanol	0	756,893	1,044,680	1,081,080	1,118,390	1,157,520	1,198,470	1,240,330	1,284,010	1,328,600	1,375,010	1,423,240	1,473,290	1,524,250	1,577,940
CO_2	0	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000
TOTAL SALES	0	796,893	1,084,680	1,121,080	1,158,390	1,197,520	1,238,470	1,280,330	1,324,000	1,368,600	1,415,010	1,463,240	1,513,290	1,564,250	1,617,940
CASH FLOW:	(2,185,903)	(52,183)	(32,661)	1,360	36,232	72,805	111,079	150,204	190,920	232,706	276,083	321,162	367,941	415,571	465,753

I.R.R. = 1.43%

The imports would increase by

	$
Maintenance materials	136,765
Fuel for transport and boiler	56,411
Chemicals and enzymes	258,750
	451,926

Import substitution (of fuel) saving is $910,000 now, escalated by at least 3.5% in real terms compared to imports. Plus, the potential to use 2,000 tonnes per year of carbon dioxide for food preservation either using it as an enert blanket or as solid CO_2 for chilling.

In a similar way to the fully integrated starch/flour/syrup factory borrowing the overseas component of the factory $1,500,000 at 10% interest, the overall improvement to the balance of payments would be $910,000 - $451,926 - $197,200 = $260,874 before any escalation in the fuel price.

10

10.0 DISCUSSION

Section 9.0 shows that only the fuel ethanol factory has a positive internal rate of return, and that is very small, 1.4%. However, this would improve if the OPEC figure of 10% per annum real increase in the price of fuel was applied rather than the more conservative 3.5% per year. The price of oil almost doubled in 1979 and is said to be going to $40.00 per barrel in 1980, another 50% increase.

There are other considerations, however. All of the options considered would have a beneficial effect on the balance of payments either by import substitution or with exports. Thus, a Government could choose to operate one or more of the agro-industrial factories described in this report to improve the trade balance.

From discussions with the banking and economic development officials, it was made clear that there were a wide variety of possible ways of financing these industrial/food operations. Indeed, a promise was made to give enough detail in this report such that financial and agricultural experts in Western Samoa could put other values to many of the parameters discussed.

The financial viability of the projects considered are heavily dependent on the findings of H.L.M. van Wissen, FAO Associate expert in Agronomy, who reported on "Breadfruit - a Cash Crop in Western Samoa" (June, 1978).

From limited experimental work, we have been able to establish that processing breadfruit or taro to starch, glucose syrups or ethanol should pose no problems.

Unless there is sufficient land area to plant breadfruit, or sufficient breadfruit already available (as van Wissen reported) to supply 11,000 tonnes to a factory, then the projects should be looked at very critically.

If there are no agricultural problems, then it would be sensible to build a crystal starch production facility first, ensuring that the raw materials handling section is oversized sufficiently to handle the feed for a combined starch/glucose facility. This would only increase the cost of the crystal starch factory by an estimated $10,000. Taro starch production is considered an essential and worthwhile part of the baby weaning food programme in Western Samoa and perhaps eventually the whole of the South Pacific Island region, so should be produced from the beginning.

The factory could also supply its laboratory with samples to produce valuable data on which to base the future expansion into starch for flour and glucose syrups. Trial bakery runs could also be done on an extended scale.

The rest of the factory could be built after, say, a two year fact finding trial period. This course of action is not recommended unless there is adequate evidence that SUFFICIENT agricultural produce, probably breadfruit, is available AT THE RIGHT PRICE to supply the complete starch/flour/glucose facility.

The economic establishment of any fuel alcohol factory based on starch and/or a sugar source is so dependent on such a wide range of imputs that each country must be independently critically assessed, particularly with regard to raw material cost.
In studies now being done for the Thailand government we have found ways of producing ethanol as cheap or cheaper than the local fuels. In Australia, it is more expensive to produce ethanol than petrol even on a very large scale. In Papua New Guinea, by having a dedicated plantation producing cassava, we can produce ethanol at parity with petrol.

In Western Samoa, the fact that breadruit are grown everywhere with no attention, fertilizer, irrigation, nor insecticides to increase its production price is just the factor that will tip the scales in favour of a fuel alcohol factory.

11.0 CONCLUSIONS

1. Taro is too expensive a raw material to be used as a source of starch for any purpose other than as a special ingredient in the baby weaning food.

2. Cassava is too expensive a source of starch to be used for food or industrial products in Western Samoa or overseas.

3. A market survey found that -

   (a) Australia would accept 250 tonnes/year of crystal starch.

   (b) Western Samoa needs 50 tonnes/year of taro starch for baby food.

   (c) A 20% substitution of gluten enriched starch in Western Samoan bakery products would use 525.5 tonnes of starch.

   (d) Most of the white sugar imports into Western Samoa could be substituted with 1102 tonnes of glucose.

   (e) A 20% substitution of motor spirit by ethanol in Western Samoa would require 2.6 Ml of ethanol.

4. Breadfruit is the cheapest form of starch and can be grown and harvested for $7.00/tonne.

5. Bananas would never be available for a factory at $7.00/tonne, they would simply be ploughed back in the soil.

6. Using van Wissen's conservative estimate, there is already more breadfruit unharvested in Western Samoa than would be needed to produce all the starch, flour, glucose and ethanol needed by Western Samoa.

7. The ethanol production facility was the only factory to produce a positive internal rate of return and even this was only 1.4%.

8. The Government of Western Samoa may choose to invest in such agro-industrial programmes as they will improve the balance of payments situation.

9. It is too expensive to preserve taro, or any other crop in Western Samoa using gamma radiation.

10. The balance of payments will be improved by $260,874 if ethanol were made at Asau and also provide jobs for 59 local people.

11. The balance of payments will be improved by $381,053 if the fully integrated factory is built at Vaitele and provide jobs for 34 local people.

12. Taro shows no real advantages in its use in biodegradable plastics. Potentially, it is better being of smaller particle size. However, sago of very large particle size is also being considered. Thus price is the important criterion.

12

12.0 RECOMMENDATIONS

1. H.L.M. van Wissen should be asked to comment on the price and availability of breadfruit in Western Samoa. He is currently the best expert in the world on growing breadfruit in Western Samoa. The cost and, for the ethanol plant, year around availability of breadfruit is critical to the success of the ventures.

2. The Government satisfies itself that sufficient breadfruit is available on Upolu to supply a combined glucose/starch/flour agro-industrial complex at a price necessary to satisfy Government objectives.

3. The first stage of a factory to produce crystal starch/taro starch/flour/glucose is built at Vaitele. This would consist basically of the crystal starch plant with a sufficiently oversized raw materials handling capacity to supply the future expansion to make the other products.

4. The Government satisfies itself that sufficient breadfruit is available on Savai'i to supply an ethanol factory at Asau.

6. The ethanol factory should not be built until sufficient experience has been gained in running the first stage of the Upolu factory, and local tests are completed on starch hydrolysis and fermentation.

7. The factory should be built by a company prepared to manage the project for a period of 5 years at least.

APPENDICES

APPENDIX A

WESTERN SAMOAN FREIGHT RATES

APIA/AUSTRALIA	$800 per Container*
	+ 7.5% Bunker Surcharge
	+ $0.75 per tonne (or m^3)
AUSTRALIA/APIA	$1,580 per Container
	+ 7.5% Bunker Surcharge
	+ Wharfage

NB: A container is 20 tonne or 32.2 m^3

HAMBURG/APIA	$135.50 per tonne (Fragile Cargo)
HAMBURG/APIA	$ 82.50 per tonne (Sugar)
ROTTERDAM/APIA	$168.75 per tonne (Inflammable Cargo)
ANTWERP/APIA	$120.40 per tonne (Sugar)

*Subsidised rate to assist exports.

APPENDIX B

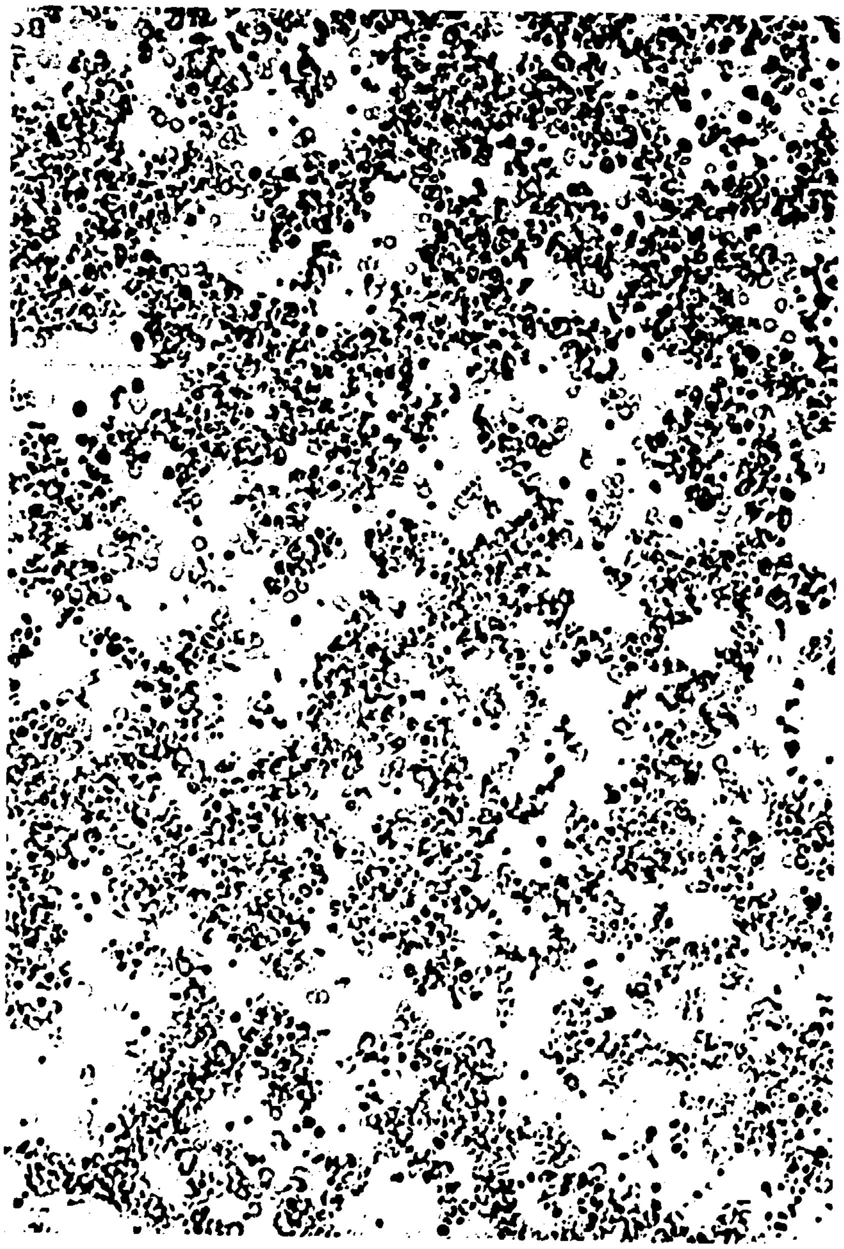


FIG. 31.—Taro starch.

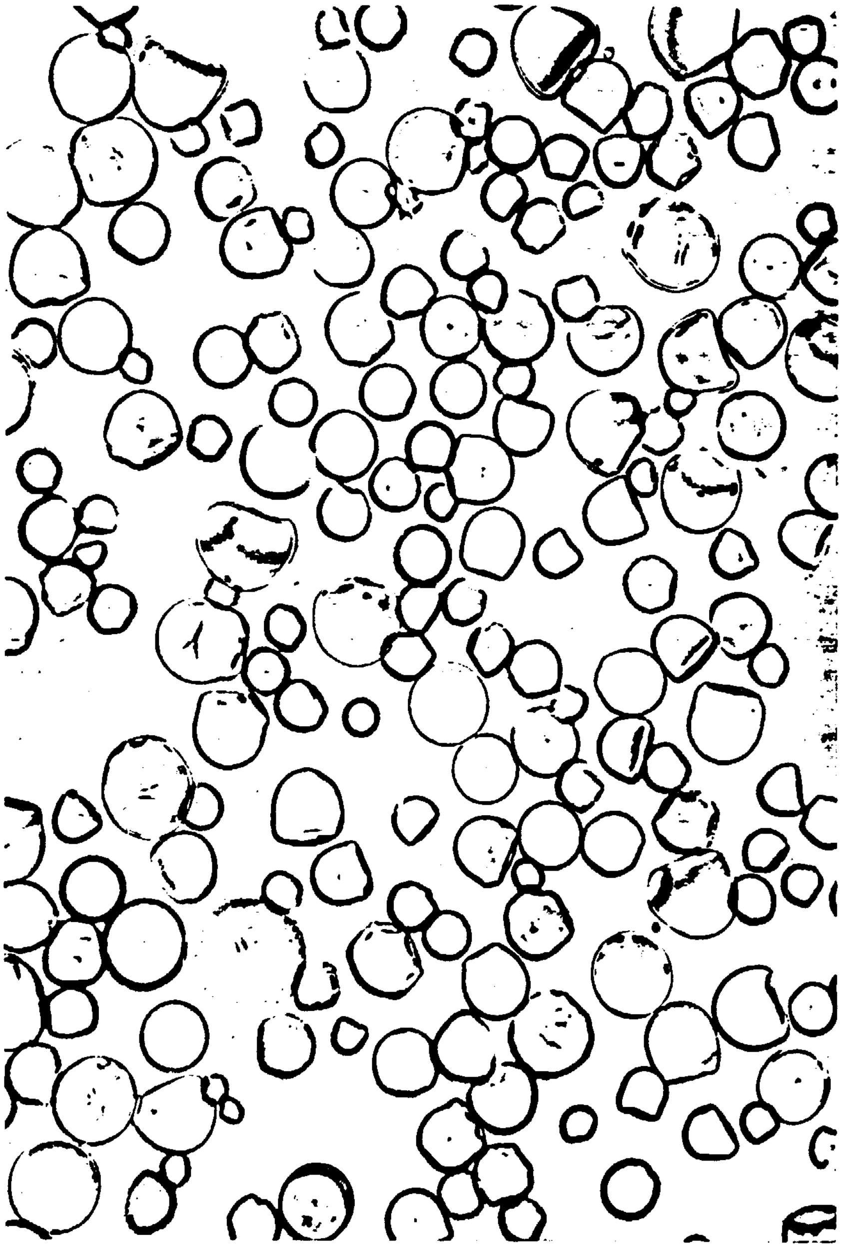


Fig. 23.—Tapioca starch.

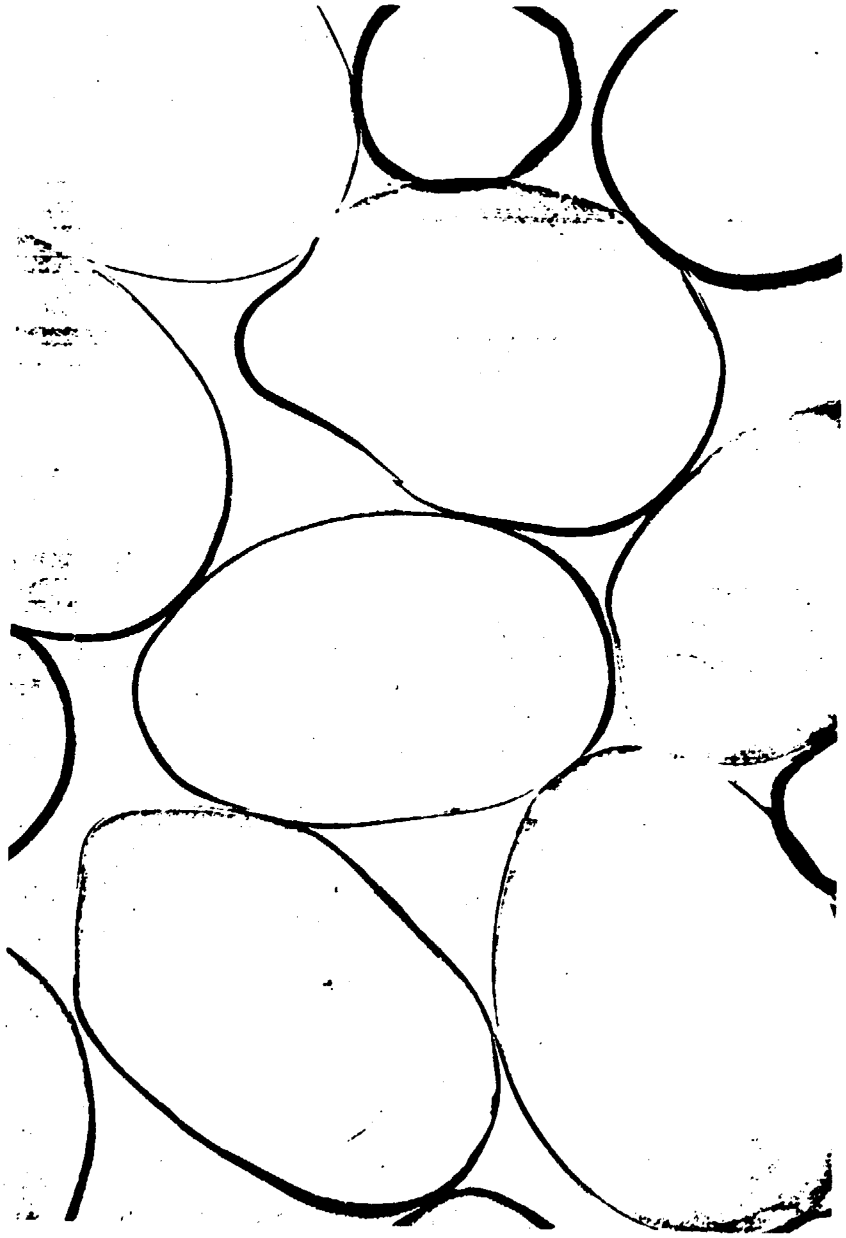


Fig. 5.—Canna starch.

Fig. 3.—Banana starch.

APPENDIX C

DETAILED ANALYSES OF VARIOUS TROPICAL CROPS

	% Water	% Starch	% Ash	% Fibre	% Protein	% Total Carbohydrate
Breadfruit(ULU)	80	12	0.8	1.2	0.75	
	70.8	26.2			1.7	
		20.2		4.1	0.8	
		22.0				
	67.8	27.82	1.[illegible]3	1.5	1.34	
Taro (Tuber)	63-85	13-19	0.6-1.3		1.4-3.0	
	77.5	19	1.3	0.4	2.5	
	73	23.7			1.9	
	58.1-74	17.6-29.6	1.1-1.7	0.6-1.2	0.9-1.5	
	59	35	1.3	1.0	0.72	35.2
	53.5	35.5	0.9	3.0	1.45	36.0
	68.1		1.02	0.3	1.2	
	53.5	28.0		1.0	2.4	
(Flour)	7.75	77.91	1.55	1.42	2.0	
Cassava	60	31.0	0.6	1.0	0.36	39.0
	62.0	37.0			0.7	
(Peeled)	62-65		0.3-1.3	0.8-1.3	0.7-2.6	32-35
	68	22.2	0.8	2.75	1.75	26.5
(Starch)	9-18	81-89	0.1-0.8		0.31-1.0	
Bananas (Green)	75.1	21.4	0.9	0.7	1.4	
(Green)						
(Green)	66.4	31.2	-		1.1	
(Flour)	12.35	-	3.2		2.5	80.7
Ripe Bananas (Flour)	2.5	7.8		3.25	4.86	83.3

APPENDIX D

EQUIPMENT LIST FOR CRYSTAL STARCH AND FLOUR STARCH PRODUCTION

1001	Dicer
1002	Force Fed Gorator
1003	Disc Mill
1004A	Crystal Starch Crusher
1004B	Pin Mill (Flour)
1101	Pulp Pump
1102	Screened Pulp Pump
1103	Starch Pump
1104	Washed Starch Pump
1105	Clean Starch Pump
1201	Starch Tank Agitator
1202	Washed Starch Agitator
1203	Clean Starch Agitator
1204	Air Fan
1401	Washer
1402	Brush Washer
1403	Coarse Sieve
1404	Fine Sieve
1405	Dewatering Centrifuge
1406	Washing Centrifuge
1407	Drying Centrifuge
1601	Solar Dryer (Wooden)
1801	Weigh Platform
2101	Root Conveyor
2201	Batch Cooker (Optional)
2301	Cool Store
2302	Pulp Tank
2303	Starch Tank
2304	Washed Starch Tank
2305	Clean Starch Tank
2306	Tray Filler

APPENDIX E

EQUIPMENT LIST FOR DEXTROSE PRODUCTION

1001	Dicer
1002	Pulper
1003	Disc Mill
1101	Pulp Pump
1102	Screened Pulp Pump
1103	Starch Pump
1104	Washed Starch Pump
1105	Clean Starch Pump
1106	Jet Cooker Pump
1107	Liquefied Starch Pump
1108	Filter Pump
1109	Syrup Pump
1110	Enzyme Dosing Pump
1201	Starch Tank Agitator
1202	Washed Starch Tank Agitator
1203	Carbon Tank Agitator
1401	Washer
1403	Coarse Sieve
1404	Fine Sieve
1405	Dewatering Centrifuge
1406	Hydrocyclone/Washing Centrifuge
1407	Filter Press
1601	Jet Cooker
1602	Liquefied Starch Cooler
1603	Syrup Evaporator
1801	Weigh Platform
2101	Root Conveyor
2202	Tubular Reactor
2302	Pulp Tank
2303	Starch Tank

APPENDIX E (cont'd)

2304	Washed Starch Tank
2305	Clean Starch Tank
2306	pH Adjusting Tank
2307	Liquefied Starch Tank
2308	Saccharification Dosing Tank
2309	Saccharification Tank
2310	Carbon Tank
2311	Filtered Dextrose Tank
2312	Syrup Tanks
	Boiler

APPENDIX F

EQUIPMENT LIST FOR ETHANOL PRODUCTION

1001	Dicer/Pulper
1002	Disc Mill
1003	Cassava Stem Dewatering Mill (Optional)
1101	Pulp Pump
1102	Liquefied Starch Pump
1103	Saccharified Starch Pump
1104	Fermenter Pump
1105	Dunder Pump
1106	Ethanol Pump
1107A/B	Dual Head Enzyme Pump
1108	Air Compressor
1201	Pulp Tank Agitator
1201	Liquefied Starch Tank Agitator
1401	Washer
1402	Ferment Centrifuge
1601	Jet Cooker
1602	Liquefied Starch Cooler
1603	Saccharified Starch Cooler
1604	Ferment Cooler
1605	Wash Preheater
1606	Rectifier Reboiler
1607	Rectifier Condenser
1608	Dehydrator Reboiler
1609	Dehydrator Condenser
1610	Ethanol Cooler
1801	Weigh Platform
2101	Root Conveyor
2201	Tubular Reactor
2202	Wash Column
2203	Rectifying Column
2204	Dehydrator Column
2205	Recovery Column

APPENDIX F (cont'd)

2301	Pulp Tank
2302	Liquefied Starch Tank
2303	Saccharification Tanks
2304	Fermenters
2305	Azeotrope Splitter
2306	Ethanol Storage Tanks
	Boiler
	Generator
	Diesel Stand-by Generator

APPENDIX G

TRANSPORT COSTS

The largest convenient vehicle for transporting crops from villages to factory is a 6 tonne truck.

	$	
Toyota Truck CIF Apia (Duty Free)	12,780	(Inc. $280 Shipping)
5 m Tray (Built in Apia)	1,700	
Spares @ 20% of Truck Cost	2,500	
TOTAL:	16,980	
Depreciation @ 10% per annum	1,698	
Maintenance @ 20% per annum	2,896	

The truck will have to travel between 20 and 40 miles/day (and return) for each pick-up. One truck will, therefore, deliver 12 tonne/8 hour day, travelling 10 miles/tonne delivered.

Fuel Usage = 12 miles/gallon

Fuel Cost = $1.13/gallon

Assume the truck can pay for its standing charges during the time the factory does not use it, by hiring out.

Factory will need one truck per 0.5 t/h for an 8 month period.

The truck will operate 157 days
and travel 18,710 miles

300 tonne starch will be made from this crop.

Delivered cost of crop (300 tonnes)	$
8/12 of depreciation	1,132.00
8/12 of maintenance	1,931.00
Driver @ $3.50/day	549.50
Fuel	1,771.28
TOTAL:	5,383.78

i.e., $17.95 per tonne (0.82 sene per lb)

APPENDIX H

COST OF BREADFRUIT

It is difficult to describe an average scenario for the picking of a village crop of breadfruit surplus to requirements. The following is suggested.

1. A one hour walk to the breadfruit plantation
2. Picking 3 breadfruit/minute of average weight 1 kg
3. A walk of 15 minutes return trip with 2 baskets full (25 kg total) to a central site where the truck can make the pick-up, say, 1 hour picking of 180 kg can be delivered to the site in 2 hours.

4. This procedure can be repeated in an 8 hour day allowing 1 hour for the return to the village.

Thus, one person can pick and deliver 360 kg of breadfruit to a central site to which a 6 tonne truck can gain access, in one day.

At $2.50 per man day (greatly in excess of coconuts according to Burgess), the breadfruit would cost under $7.00 per tonne (0.32 sene per lb).

At transport costs calculated in Appendix G, the price of breadfruit delivered at the factory gate would be -

$24.95 per tonne (1.13 sene per lb)

NB: This compares with 3.7 sene per lb. in Apia market (December, 1979)

APPENDIX I

FACTORY LABOUR COSTS

1.0 LABOUR REQUIREMENTS

		Crystal Starch	Flour Starch	Dextrose Production	Starch/Flour/ Dextrose
Manager (Technical)		1	1	1	1
Laboratory Supervisor		1	1	1	1
Laboratory Assistants		2	2	3	3
Factory Supervisors		3	3	4	4
Factory Workers					
-(1801/2301/1401)	Unskilled	8	12	18	24
-(1402/2302)	Skilled	3	3	3	3
-(1405/1407)	"	6	6	6	6
- 2306	"	3	3	-	3
- 1204	"	3	3	-	3
- 1004	"	3	3	-	3
- 1802	"	3	3	-	3
- 1407	"	-	-	3	3
- 1603	"	-	-	3	3

2.0 WAGE RATES

	$
Manager	30,000/year (Which includes all benefits)
Laboratory Supervisor	6,000/year
Laboratory Assistants (each)	1.00/hour
Factory Supervisors (each)	1.00/hour
Factory Workers (skilled)	4.00/day
Factory Workers (Unskilled)	2.50/day

3.0 WAGES COST PER YEAR

The Manager (technical), Laboratory Supervisor, Laboratory Assistants and Factory Supervisors would be employed all year.[1]

	A Crystal Starch $	B Flour/ Starch $	C Dextrose Production $	Starch/Flour/ Dextrose $
Manager (Technical)	30,000	30,000	30,000	30,000
Laboratory Supervisor	6,000	6,000	6,000	6,000
Laboratory Assistants	4,572	4,572	6,858	6,858
Factory Supervisors	6,858	6.858	9,144	9,144
Factory Workers[2] (Skilled)	13,440	12,432	8,400	15,120
Factory Workers[2] (Unskilled)	3,200	4,440	6,300	8,400
	64,070	64,302	66,702	75.522
GRAND TOTAL[3]	107,638	108,027	112,059	126,877

4.0 WAGE COST OF PRODUCING VARIOUS FACTORY OPTIONS

(Cost Proportioned According to the Starch Required)

		$	
A	Cost of Crystal Starch	430.55	per tonne Starch
C	Cost of Dextrose	101.69	per tonne Dextrose
B	Cost of Crystal Starch	139.30	per tonne Crystal
B	Cost of Flour	139.30	per tonne Flour
B + C	Cost of Starch	70.12	per tonne Crystal
B + C	Cost of Flour	70.12	per tonne Flour
B + C	Cost of Dextrose	65.79	per tonne Dextrose

1. 41 hours/week during 5½ day week (2 x 7 weeks)
   56 hours/week during 7 day week (2 x 6 weeks)
   40 hours/week for remainder of year (26 weeks)

2. 4 days/week for 5½ day week (2 x 7 weeks)
   7 days/week for 7 day week (2 x 6 weeks)
   4 days/week for 5½ day week to process taro

3. Includes 68% on cost to cover all allowances to permanent staff and overtime to part-time staff.

APPENDIX J

FUEL ALCOHOL LABOUR COSTS

1.0 LABOUR REQUIREMENTS

Manager		1
Laboratory Supervisor		1
Laboratory Assistants	(Per Shift)	1
Shift Engineer	(Per Shift)	1
Factory Workers		
Skilled	(Per Shift)	5
Unskilled	(Per Shift)	4

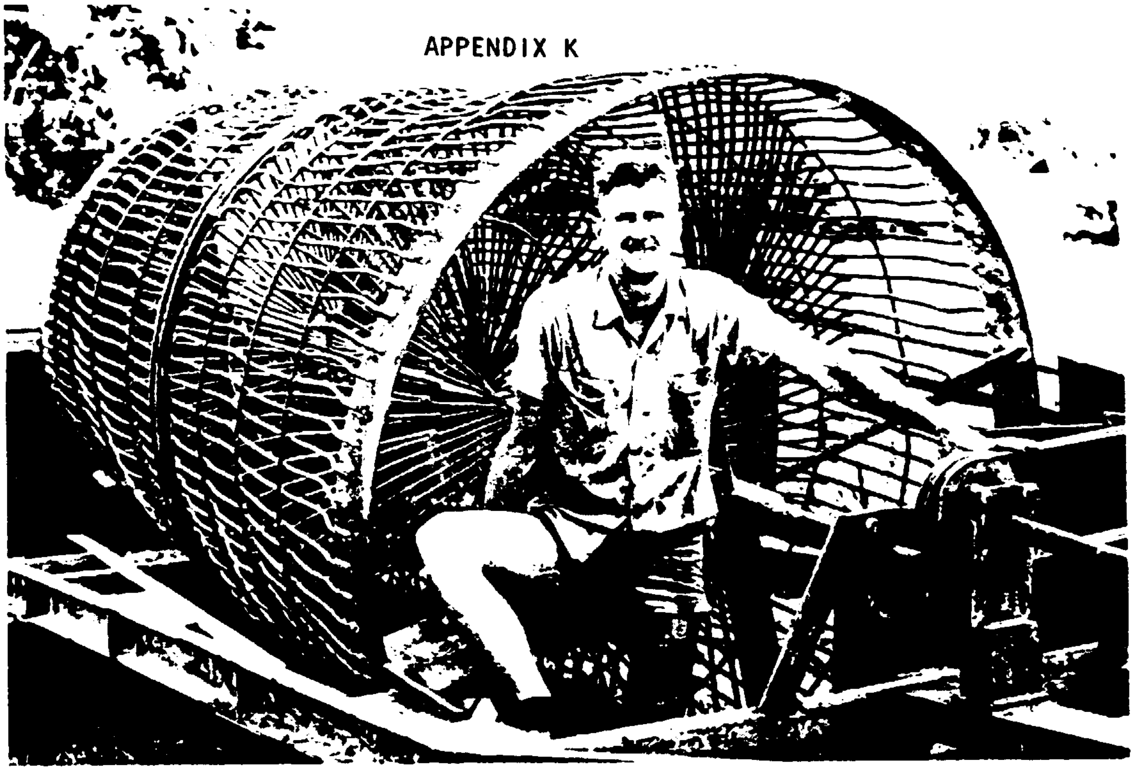
2.0 WAGE RATES (As Appendix

3.0 WAGES COST PER YEAR

	$
Manager	30,000
Laboratory Supervisor	6,000
Laboratory Assistants	7,200
Shift Engineer	7,200
Factory Workers (Skilled)	18,000
Factory Workers (Unskilled)	9,000
	77,400
GRAND TOTAL[1]	130,032

1. Includes 68% on cost to cover all allowances and overtime.

Home Made Stone Picker Very Efficient



An indication of the size and construction of the Hall stone-picker can be gauged from this photograph showing Mr. Hall standing at the front end of the machine.

A former contract cane harvester on sugar farms in North Queensland has decided to become a cane farmer himself. He is Mr. Bill Hall whose cane property adjoins the Bellenden Ker intake at Junction Creek in the Babinda Mill area.

One of the first problems Bill encountered after buying his farm was the huge quantity of stones that were just below the soil surface. Because of their size they were damaging the machinery used for preparing the ground for planting, besides making it difficult during the harvest.

After weeks of shifting and pulling stones by hand, Bill decided that a stone-picking machine needed to be developed. It was not so much the hard work that made the small but wiry farmer reach this decision. Time was the biggest factor because, no matter how hard he worked, stones seemed to keep appearing from nowhere to damage his farm machinery.

Bill thought out the design thoroughly as he shifted stones by hand to the side of the field before getting out his welding gear. Actual fabricating was completed over a five week period in between other farm duties. The major part of the machine was built from odds and ends found around the farm, but some steel was bought.

The circular cage of the stone picker is rotated by power supplied from the tractor P.T.O. As the cage is rotated it is also dragged through the stone affected fields to a depth of approximately 18 inches below the soil surface. This action scoops up the majority of stones, although some stones of larger dimensions still have to be dragged out by the tractor on an individual basis.

The inside of the cage has an ingenious auger type construction that transports the stones to a hopper bin attached to the rear of the stone-picking machine.

Bill can clear five acres of land a day with his invention, and finds it a lot easier on his back muscles.

He supplies the collected stone to the local shire council which uses it for riverbank reconstruction to stop soil erosion from taking place or restore eroded banks.

At right: This pile of rocks about 20 ft. high shows some of the sizeable rocks gathered by the stone-picker. They are destined for use in reconstruction of local river banks.

Local farmers who have seen the stone-picker in action are impressed with the efficiency of its operation. Even though it has cost Bill a lot of time and effort to design and make his stone-picker, he is quite happy to pass on his experience to other farmers at no cost.

TERMS OF REFERENCE

1.0 BACKGROUND INFORMATION

Production of taro in Western Samoa is one of the principal traditional agricultural occupations. It is consumed as a main staple food and in more recent years, has become an important export with export sales for 1978 expected to be close to one million tala.

Under Government's rural development and access road programmes, substantial areas of new land have been put under taro cultivation and the export markets for taro are now beginning to show serious symptoms of over-supply. Government is concerned about this situation and has sent three major Trade Commissions overseas this year to find more export markets. Unless further markets and/or industrial use for taro are found, Government will be faced with the uneviable task of trying to limit village production of taro.

The Food Processing Laboratory has for some considerable time been investigating the use of taro flour as an ingedient for baby weaning food and as a possible substitute for wheat flour in bread. These are relatively non-specialised uses for taro flour.

However, more recently information has been received from overseas suggesting that taro starch can be used in the manufacture of biodegradable plastics. It is also likely that further specialised industrial uses for taro starch could be found when it is available in commercial quantities.

The Government of Western Samoa is desirous of having a complete feasibility study conducted on the production of taro starch.

2.0 OBJECTIVES OF THE PROJECT

A. Development Objectives

The Government wishes to establish a commercial taro starch industry and embarks upon to identify varied areas where taro starch could be used such as baby weaning food, substitute for wheat flour in bread, biodegradable plastics, special diet ingredients, etc. The envisaged capacity is between 1000 and 5000 tons of taro starch per annum.

B. Immediate Objectives

To conduct a feasibility study on the establishment of a commercial starch plant for Western Samoa in order to determine the production scale and to investigate in detail the possible industrial uses of starch in food and chemical industries.

3.0 SCOPE OF CONTRACTING SERVICE

(a) Undertake a study on the engineering aspect of the establishment of a commercial starch plant for Western Samoa and determine production capacity of taro starch by economics of scale and market survey. The production capacity is expected to be between 1000 and 5000 tons of taro starch per annum.

(b) Assess the possible industrial uses of starch in the plastics, textile, chemical and food industries taking also into account its uses in the domestic market in the production of beer, bread and other flour based products.

(c) Compute preliminary economic and financial profits of the project based on normal commercial operations.

(d) If the team of experts find it necessary to have more in-depth studies on the development of this industry, they would be expected to suggest in detail the manpower, equipment, vehicles and the budget requirements.

(e) Recommend how the plant could be modified to manufacture cassava starch, if necessary.

(f) Make recommendations on production of glucose in the same factory and make an initial market survey on it.

(g) Make recommendations on production of taro flour and taro chips.

(h) Post-harvest storage and handling of taro (particularly the possibility of gamma radiation to destroy viability).

Baume Conversion Tables for Starch Suspensions 60° F

	Suspension @ 60°F			Dry Solids Content				Water Content		
Be	Sp Gr	% D.S.*	Lbs / Gal	Lbs / Gal	Oz / Gal	Gr / Gal	Gm / Liter	Lbs H_2O / Gal Susp	Lbs H_2O / Lb Starch	Gal H_2O / Lb Starch
0.0	1.0000	0.00	8.328	0.000	—	—	—	8.328	—	—
0.5	1.0035	0.89	8.357	0.074	1.184	518	8.87	8.283	111.93	13.437
1.0	1.0069	1.78	8.386	0.149	2.384	1043	17.85	8.237	55.28	6.636
1.5	1.0105	2.66	8.416	0.224	3.584	1568	26.84	8.192	36.57	4.390
2.0	1.0140	3.55	8.445	0.300	4.800	2100	35.95	8.145	27.15	3.260
2.5	1.0176	4.44	8.475	0.376	6.016	2632	45.18	8.099	21.54	2.586
3.0	1.0211	5.33	8.504	0.453	7.248	3171	54.28	8.051	17.77	2.133
3.5	1.0248	6.22	8.535	0.531	8.496	3717	63.63	8.004	15.07	1.809
4.0	1.0285	7.11	8.566	0.609	9.744	4263	72.98	7.957	13.07	1.570
4.5	1.0322	8.00	8.596	0.688	11.008	4816	82.32	7.908	11.49	1.379
5.0	1.0358	8.89	8.626	0.767	12.272	5369	91.79	7.859	10.25	1.231
5.5	1.0396	9.77	8.658	0.846	13.536	5922	101.38	7.812	9.23	1.108
6.0	1.0433	10.66	8.689	0.926	14.816	6482	110.96	7.763	8.38	1.006
6.5	1.0470	11.55	8.720	1.007	16.112	7049	120.67	7.713	7.66	.920
7.0	1.0508	12.44	8.751	1.089	17.424	7623	130.49	7.662	7.04	.845
7.5	1.0547	13.33	8.784	1.171	18.736	8197	140.32	7.613	6.50	.780
8.0	1.0585	14.22	8.815	1.253	20.048	8771	150.15	7.562	6.04	.725
8.5	1.0624	15.10	8.848	1.336	21.376	9352	160.09	7.511	5.62	.675
9.0	1.0663	15.99	8.880	1.420	22.720	9940	170.16	7.460	5.25	.630
9.5	1.0703	16.88	8.914	1.505	24.080	10535	180.34	7.409	4.92	.591
10.0	1.0742	17.77	8.946	1.590	25.440	11130	190.53	7.356	4.63	.556
10.5	1.0782	18.66	8.979	1.676	26.816	11732	200.71	7.303	4.36	.523
11.0	1.0822	19.55	9.013	1.762	28.192	12334	211.14	7.251	4.12	.495
11.5	1.0862	20.44	9.047	1.849	29.584	12943	221.56	7.198	3.89	.467
12.0	1.0903	21.32	9.08[illegible]	1.936	30.976	13552	231.99	7.144	3.69	.443
12.5	1.0944	22.21	9.114	2.024	32.384	14168	242.65	7.090	3.50	.420
13.0	1.0986	23.10	9.149	2.113	33.808	14791	253.32	7.036	3.33	.400
13.5	1.1028	23.99	9.185	2.203	35.248	15421	263.98	6.982	3.17	.381
14.0	1.1071	24.88	9.220	2.294	36.704	16058	274.89	6.926	3.02	.363
14.5	1.1114	25.77	9.256	2.385	38.160	16695	285.79	6.871	2.88	.346
15.0	1.1156	26.66	9.291	2.477	39.632	17339	296.82	6.814	2.75	.330
15.5	1.1199	27.54	9.327	2.569	41.104	17983	307.84	6.758	2.63	.316
16.0	1.1242	28.43	9.363	2.662	42.592	18634	318.98	6.701	2.52	.303
16.5	1.1286	29.32	9.399	2.756	44.096	19292	330.25	6.643	2.41	.289
17.0	1.1330	30.21	9.436	2.851	45.616	19957	341.63	6.585	2.31	.277
17.5	1.1375	31.10	9.473	2.946	47.136	20622	353.02	6.527	2.22	.267
18.0	1.1419	31.99	9.510	3.042	48.672	21294	364.52	6.468	2.13	.256
18.5	1.1465	32.88	9.548	3.139	50.224	21973	376.14	6.409	2.04	.245
19.0	1.1510	33.76	9.586	3.236	51.776	22652	387.89	6.350	1.96	.235
19.5	1.1556	34.65	9.624	3.335	53.360	23345	397.23	6.289	1.89	.227
20.0	1.1602	35.54	9.662	3.434	54.944	24038	411.49	6.228	1.81	.217
20.5	1.1649	36.43	9.702	3.534	56.544	24738	423.48	6.168	1.75	.210
21.0	1.1696	37.32	9.741	3.635	58.160	25445	435.58	6.106	1.68	.202
21.5	1.1744	38.21	9.781	3.737	59.792	26159	447.80	6.044	1.62	.194
22.0	1.1791	39.09	9.820	3.839	61.424	26873	460.02	5.981	1.56	.187
22.5	1.1840	39.98	9.861	3.942	63.072	27594	472.49	5.919	1.50	.180
23.0	1.1888	40.87	9.901	4.047	64.752	28329	484.95	5.854	1.45	.174
23.5	1.1937	41.76	9.941	4.151	66.416	29057	497.41	5.790	1.39	.167
24.0	1.1986	42.65	9.982	4.257	68.112	29799	510.11	5.725	1.34	.161
24.5	1.2036	43.54	10.024	4.364	69.824	30548	522.93	5.660	1.30	.156
25.0	1.2086	44.43	10.065	4.472	71.552	31304	535.76	5.593	1.25	.150

*% D.S. = Be deg X 1.7770

Specific Gravity of Starch 1.5-1.6

Temperature Corrections

Temperature:	67	73	79	85	91	97	103	113	118	123
Add (°Be):	.1	.2	.3	.4	.5	.6	.7	.9	1.0	1.1

Note: This table is based on work of J. E. Cleland, E. E. Fauser and W. R. Fetzer.
See INDUSTRIAL AND ENGINEERING CHEMISTRY, Analytical Edition, Vol. 15, pp 193-200, 1943.

Davy

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conversion table

U.S. Standard Mesh Sizes

Mesh Number	Sieve Opening		
	Microns	Inches	Millimeters
5	4000	.157	4.0
6	3360	.132	3.36
7	2830	.111	2.83
8	2380	.0937	2.38
10	2000	.0787	2.0
12	1680	.0661	1.68
14	1410	.0555	1.41
16	1190	.0469	1.19
18	1000	.0394	1.00
20	840	.0331	.84
25	710	.0280	.71
30	590	.0232	.59
35	500	.0197	.50
40	420	.0165	.42
45	350	.0138	.35
50	297	.0117	.297
60	250	.0098	.250
70	210	.0083	.210
80	177	.0070	.177
100	149	.0059	.149
120	125	.0049	.125
140	105	.0041	.105
170	88	.0035	.088
200	74	.0029	.074
250	62	.0024	.062
270	53	.0021	.053
325	44	.0017	.044
400	37	.0015	.037

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BIBLIOGRAPHY

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