SUBREGIONAL OFFICE FOR THE PACIFIC ISLANDS

Mission Report

Samoa Biofuel Study Report
February 2009

Prepared by:

Rex Demafelis
Domingo Angeles
FAO Consultants

	FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

EXECUTIVE SUMMARY

The most suitable biofuel crop under the agro-ecological conditions of Samoa was determined. Secondary and primary data on the status of the agricultural sector of Samoa, and its soil and climate and socio-economic conditions were gathered from Agrometeorological Station, Ministry of Agriculture, Ministry of Natural Resources, Pacific Islands Greenhouse Gas Abatement Through Renewable Energy Project, University of South Pacific, Ministry of Commerce, Industry and Labor, Food and Agriculture Organization, and from the farmer's and business group. Most of the data gathered were focused on the production and trade of major crops in Samoa. Ocular observation of Upolu and Savaii to determine the existing vegetation, soil physical characteristics which include topography, drainage, depth and soil texture and accessibility were also conducted. The existing climatic indicators such as temperature, rainfall pattern and distribution including typhoon occurrence were also assessed Land use was also determined.

The agro-ecological requirements of bioethanol crops such as cassava, breadfruit and biodiesel crops such as African oil palm, coconut and jatropha were determined from the literature. Sugarcane, corn and sweet sorghum as bioethanol sources were not considered because their commercial production require thorough land preparation which is not possible under Samoa's rocky soil conditions. Breadfruit which has food uses and considered as staple and export crop was also not considered.

Based on the biophysical assessment of the existing area, we identified close to 15,000 ha of disaggregated area suitable for all crops except for African oil palm which strict requirements for soil. Considering climate, we recommend coconut and jatropha as source of biodieasel and cassava as source of bioethanol. Varieties of these crops from other countries with similar climate were identified and recommended. Lakan and Sultan varieties of cassava from the Philippines were recommended because they are high yielding and resistant to scale insects, spider mites, leaf spot and bacterial blight. Pan 51 and CM 2106-6 varieties grown in Samoa are also being recommended. The Rayong varieties were also comparable to those in the Philippines. For coconut, the selection from the Philippines such as Laguna, San Ramon and Bago-Oshiro, were outstanding in terms of nut and copra yield. Samoan tall and Samoan Tall Samatu varieties can also be considered.

The target yield for cassava is 30 tons/ha, jatropha, 5 tons per ha and coconut, 120 nuts/palm/year (2.76 tons copra/ha). Cost of production for the three crops were also determined and presented in the report.

The use of refined oil is recommended for diesel blending to avoid engine troubles. Due to limitations in available of contiguous land for biofuel feedstock plantations, $\frac{1{,}000\,Liter}{day}$ biodiesel and refined oil production systems were used for financial and economic computation. However, for bioethanol production, the limitation on contiguous land availability was waived in favor of a 30 Million liter per year capacity the standard minimum for ethanol plant.

At cassava chips price of SAT 0.8 per Kg from a fresh tuber price of $\frac{SAT\,0.25}{Kg}$, the cost of production of ethanol from cassava at SAT 3.02 per liter, is higher than the pump price of gasoline in Samoa at SAT 2.625 per liter (December 2007 price). The total administrative and selling expenses for this case amount to SAT 0.03 per liter ethanol and interest on loan of SAT 0.07 per liter. At the minimum selling price of SAT 3.34 per liter ethanol, the company's unit mark-up amounts to SAT 0.32 per liter ethanol, which is equal to 10.60% mark-up. On the other hand, at the suggested selling price of SAT 3.40 per liter ethanol, the company's unit mark-up amounts to SAT 0.38 per liter ethanol, which is equal to 13.00% mark-up (See Table 31). This production was already based on the standard minimum plant capacity where below this production capacity, cost per liter increases. The hope of producing ethanol at the lower cost and export the excess to other countries in South Pacific seems impossible if it is compared against gasoline price. Although the use of bioethanol, especially sourcing the feedstock from new plantation will bring about job employment and environmental benefits in terms of reduction in toxic and greenhouse gas emission, policy-wise it would be hard to justify because it is not economically viable. To reap the benefits on the environmental aspects without producing bioethanol in Samoa, the use of bioethanol for gasoline blending maybe done through importation of bioethanol from Brazil at US $480 per ton, equivalent to SAT 1.2 per liter only. Due to corresponding reduced gasoline importation , blending of imported bioethanol would result to an annual positive net Foreign Exchange Saving in the amount of SAT 3.7 Million (based on 10% ethanol to gasoline blending and December 2007 price index 2007 and volume of 26M Li). This scheme will not require huge investment, yet it could test the social acceptability of bioethanol blending in Samoa and when time comes that bioethanol production in Samoa will be economically feasible, acceptability is already in place and investment fund availability would be the only problem to hurdle.

At Jatropha seed priced at $\frac{SAT\,1.0}{Kg}$ and Copra at $\frac{SAT\,1.3}{Kg}$, the cost of production per liter of Jatropha Biodiesel, Jatropha Refined Oil and Coconut Refined Oil are, SAT 5.4, 4.62 and 3.22, respectively. These prices are all higher than the diesel price of $\frac{SAT\,2.718}{Li}$ (Based on December 2007 price). These computed production costs were based on the cost of establishing new plantation areas for both coconut and Jatropha. Blending of biodiesel to diesel in Samoa at these price levels would be difficult to justify in all types of biofuels. Feedstock cost contributes approximately 80%, 85% and 82% for the production of Jatropha biodiesel, Jatropha Refined Oil and Coconut Refined Oil, respectively. For the biodiesel and refined Jatropha and coconut oil to be comparable to the price of diesel, price of a kilo Jatropha seed should be at SAT 0.4 and SAT 0.53, and price of a kilo copra should be SAT 1.063, respectively.

While the use of biofuel from new plantation areas (i.e. both Jatropha biodiesel and Refined Jatropha and Coconut Oil), is not economically attractive, the use of refined coconut oil sourced from existing coconut plantation maybe beneficial. Report of Cocogen Project on 15% coconut oil blended diesel test for 2,041 hours using 106,988 li (mixed fuel) showed no special engine trouble. However, the Cumming Engine KTTA 1963 with a 400 KW maximum generation capacity showed decreased in fuel consumption generation from

3.33 to 2.98 $\frac{kwh}{li}$. The power generation reduced to 89% only , or an increase in fuel consumption by 11%. Factoring in this reduced power generation, potential maximum savings of 0.168 per liter or 2.718% could be obtained if copra price is at SAT 0.84/kg. On the average buying price of copra at SAT 0.88, potential maximum savings is SAT 0.078 per liter of refined coconut oil.

However, at oil extraction recovery of 88% on 68% oil containing copra, the potential maximum savings per li refined coconut oil is SAT 0.568, 0.498 and 0.288 for copra prices at SAT 0.84, 0.88 and 1.0, respectively.

ACKNOWLEDGEMENT

We would like to acknowledge the help of Mr Aru Mathias of FAO Samoa for sharing with us relevant references on bio-physical features, existing land use and soils potentials of Samoa. He took time to accompany us during site visits of Savaii and Upolu. He together with Ed Langham and Rapa Young of EPC and Tevita Keresoma of FAO closely coordinated our activities in Samoa. We appreciate the assistance of Mr Australasia Titimoea who provided recent agro-meteorological data of the island. As Manager of a Program on Greenhouse Abatement through Renewable Energy Project in Pacific islands, Mr Solomone Fifita provided useful insights on biofuel project for Pacific Island countries and a regional policy statement to this effect. We also thank Mr Anare Matakavit for his clear vision of biofuel program for Samoa. Special thanks is due to Mr Pau Inoue, Senior Draftsman, Ministry of Natural Resources who provided us with GIS information on soils, topography and land use mapping system including the measurements of the total area in the two main islands covered by each land use. He also provided map for our purpose.

Mr David Hunter Professor of Soil Science and Mr Mareko Tofinga, Associate Professor in Crop Science, USP for sharing with us their research and development outputs for biofuel crops in the island and current research capability of USP to generate technologies for feedstock production. We also acknowledge with thanks Mr Asuao Kirifi Pouono, CEO, Ministry of Agriculture for his incisive views on biofuel in relation to food security thrusts of the government of Samoa. We also thank Mr Lemalu Samau Tate Simi, CEO, Ministry of Commerce, Industry and Labor for his briefing about the excellent investment environment in Samoa. Valuable information on research capacity of the Ministry of Agriculture and available technologies for breadfruit and cassava was provided to us by Mr Parate Matalavea, Principal Researcher and five officials of Crops Division, Ministry of Agriculture.

The authors would like also to thank the following government executives and private individuals who provided us with information which facilitated in coming up with this report:

Engr. Siloma Tago, Asst. Generation Manager of EPC
Hon. Lusia Seto Leau ,Deputy CEO. Ministry of Finance
Mr. Benjamin Pereiora ,Assistant CEO. Eco Policy and Planning Division, Min. of Finance
Ms. Silia Kilepoa ,Energy Coordinator, Min. of Finance
Mr. Faamatuainu Amosa Powoa ,Assistant CEO, Ministry of Works, Transportation and Inftrastucture and his associate
Hon. Tuun IeTi Taulealo, CEO, Ministry of Natural Resources and Environment
Mr. Mataia Uaine Silailai Assistant CEO, Ministry of Natural Resources and Environment
Mr. Saman Eluale Seto Managing Director, Petroleum Products Supplies
Mr. Tupuola. Plant Supervisor, Pacific Oil

Special acknowledgement is given to Ms Lasa Aiono and Mr Jeff Affoa of the Farmers Association of Samoa and to Papali I Grant Percival Managing Director Natural foods International for their valuable insights on the use of biofuel for the food production and processing industry

Special thanks to Mafeo Bejo and Larry Hernandez for their Filipino hospitality, and providing us a home in Samoa.

To all FAO staff who welcomed us warmly and made our stay pleasing, enjoyable and memorable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX FIGURES

BIOFUEL CROPS FOR SAMOA

1. INTRODUCTION

The continuous spiraling cost of oil and petroleum products has triggered many developed and developing countries to explore alternative but renewable and sustainable sources of energy. Wind, biomass, water, sunlight has been explored to supply part of the energy requirements of many countries. Then biofuel comes into the picture. The use of starch and oil-rich crops and their conversion to fuel provided a new impetus to the impending oil crisis and the continuous dependence of many governments to fossil fuel. Brazil and the United States have taken the lead to produce biofuels as part o f their energy security programs. Malaysia, Indonesia and the Philippines have taken aggressive steps and passed laws on the development, production and utilization of biofuel. Australia adopted it so that it can get most of what it needs to improve the livelihood of their farmers while Thailand has been coming to the forefront in the production of biofuel from cassava.

Recognizing the threat engenders by too much dependence of island countries to fossil fuel, the Pacific island nations notwithstanding, has adopted a policy on oil security using biuofuel. Coconut, a major crop of commerce in the Pacific is being eyed as a prospective source. Biomass energy is also being considered in light of the island's rich and luxuriant vegetation SOPAC considered that the impact to agriculture of the use of coconut for biofuel, is limited.

As an island country in the South Pacific, Samoa also faces the challenge on the use of biofuel and renewable energy as alternative to fossil fuel. Its pronouncements in its strategic plan is clear "to enhance the quality of life for all through access to reliable, affordable and environmentally sound energy services and supply" The consultation made by PGRE among the stakeholders in Samoa resulted in the adoption of a national strategic policy framework on the use of renewable energy. This policy instrument will surely strengthen the country's sustainable development strategies. One of its objectives is 'to successfully change from fossil fuel dependency to renewable energy' while its goal is to increase the share of renewable energy source to the total national energy requirements by 20 percent. It is a modest target. To achieve this, the government has strengthened existing institutions to enable it to implement various energy programs. The Ministry of Natural Resources, Environment and Meteorology has created the Renewable Energy Division under its wings. The Department of Finance has also created a renewable energy division.

To meet the government goals to improve, and develop an efficient power sector, the ADB supported power generation from renewable source being implemented by Electric Power Corporation of Samoa in its Power Expansion Programme.

Given Samoa's environmental conditions, the use of biofuel can provide a strategic option to meet its targets. The use of biofuel has been proven effective both in terms of its economic feasibility and environmental safety. The far greater issue is on the production of feedstock. While the regional potential has been estimated to reach 30 percent of the transport fuel, the production in Samoa is challenged by the country's constraining climate, soil impedance, fertility, and farm mechanization. Off hand, the far greater challenge is the issue of food security. Growing biofuel crops will collide head on with agricultural crops in some respects and will have a consequent impact to the country's economy, and balance of trade payments in general and to the farming sector in particular.

The objectives of the study are to determine to most suitable feedstock under existing agro-ecological conditions of Samoa and assess viability of utilizing various feedstock for biofuel production. The study also provides background on the potential and feasible processes for the biofuel production from different feedstocks such as cassava, breadfruit, sugarcane, coconut, palm and Jatropha. Samoa's fuel supply and demand as well as price history was reviewed. For policy purposes, the cost of production of biodiesel and bioethanol were computed and compared with diesel and gasoline prices in Samoa (of December 2007).

2. PLANNING PROCESS

Given the above objectives, the project consultants pursued the following approaches to gather the necessary information namely:

a) interview with different stakeholders including but not limited to, ministry of agriculture, the chief operating officer of agriculture, the chief operating officer of meteorology, the registrar and professors of the University of Samoa, the planning officer of MNR, fruit, ornamental and vegetable growers, the Chief of Research Section and commercial crops and trade Section, 0f the Crops division. The purpose of the consultation is to gather data and insights on the use of biofuel, including the research and development potentials of and current technologies available from R and D institutions;

b) gathering of pertinent documents on the current situationer of the local agricultural industry;

c) ocular inspection of the island of Upolu and Savaii to determine the existing degree of vegetation, the actual soil profile and characteristics and crop performance according to changes in soil type, fertility and topography; and

d) photo documentation of study sites to reflect the existing cropping patterns and relative vigor of the existing vegetative stand.

The suitability of various feedstocks under existing soil and climatic conditions of Samoa was determined. Key persons from University of South Pacific, Ministry of Natural Resources, Ministry of Agriculture, Ministry of Commerce, Industry and Labor, Farmers Association in Samoa, Pacific Islands Greenhouse Gas Abatement Through Renewable Energy Project (PIGGAREP) and EPC were interviewed. Data were gathered regarding the soil and climate of the country including existing water resources, topography, and socio-economic conditions. The list of persons interviewed is presented in Appendix Table 1.

Pertinent data were also gathered from the literature regarding the agriculture situationer in Samoa, including but not limited to land use, production, export, policies, historical climate changes, and soil characteristics.

Feedstock refers to raw materials used for biofuel production.
Bioethanol – shall refer to ethanol produced from feedstock and other biomass.
Biodiesel – shall refer to Fatty Acid Methyl Ester (FAME) or mono-alkyl esters derived from vegetable oils or animal fats and other biomass-derived oils.

Ocular assessment of existing sites in Upolu and Savaii in terms of vegetation, soil, topography, accessibility and water availability was conducted. Photographs of existing cropping systems, and soil were taken.

Data on land availability and government permitting on conversions were gathered from Ministry of Natural Resources and Environment. Road network, bulk transport, pier and shipping costs were solicited from the Ministry of Works, Transportation and Infrastruction and Petroleum Products supplies. Pacific Oil Inc provided the yield and cost data of oil production from copra.

3. AGRICULTURE IN SAMOA

Agriculture is still and will remain a major source of income that props Samoan economy. Major farming activities were focused on coconut production after taro production collapsed in the middle of 1990 after blight diseased toppled the island's dominance in taro's export trade. Before this collapse, taro export amounted to $1.1 million as against coconut's $540 thousand. It also get knuckled down by Typhoon Ofa in 1990's and Typhoon Val in December 1991 whose destructible wind had caused severe damage and loss to agricultural production The country's GDP after that decreased by almost 50% during the 1989-91 inclusive period. It further shrunk to 8% in 2003-04. The major crops in Samoa are presented in Table 1.

Table 1. Area devoted to major agricultural crops in Samoa.

Crops	Area (ha)
Coconut	23,310
Cocoa	6,556
Taro	14,771
Ta'amu	3,278
Bananas	2,266
Yam	243
Other vegetable crops	607
Total	51,033

Source: FAOSTAT Data

Among the crops, coconut, breadfruit and taro have dominated the country's agriculture landscape. They were subsistence crops among the small hold farmers with breadfruit and taro being eaten as traditional alternative to rice for staple. Ta'amu is a root crop of comparable significance as taro (Curry, 1955). Banana particularly the plantains have been used as food because of its high starch content while cacao is grown in almost 10% of the country's cropped area (Fig 1). The firs six major crops also constitute 97% of the total agricultural area. When taro leaf blight spread throughout the country in epidemic proportion, it resulted in significant reduction in its production in the middle of 1993.

Coconut remains the backbone of Samoa's agricultural economy (Figure 2). It is the source of income to many people and is grown chiefly for home consumption. Their products are major components of households' diet. While many of the palms are senile, their canopies serve as nurse crops to partial shade loving crops like cacao, taro and to a certain extent banana. Cocoa production is geared mainly for processing for the local market.

The total contribution of agricultural to GDP of Samoa in 2006/07 (Ministry of Finance) was SAT80.2 million, which is about 6% of the total GDP earnings of SAT1.3 billion. It grew by 1.8% from 2004/05 to 2006/07. Major agricultural export products include coconut cream, nonu juice, taro, coconut oil, nonu fruit and dessicated coconut.

Figure 1. Banana, papaya and cacao in an intercropping system in Aleisa in Upolu.

Figure 2. Typical coconut farms in Savaii (left) and Upolu (right).

As is the past, the predominant type of land ownership in Samoa is customary. It is not surprising that close to 90% of total agricultural area in the country is classified as customary land. The mixed intercropping system where crops are interspersed with no systematic pattern was the major production system. In 1989, average farm size was 7 ha. The land is divided in parcels ranging from 2 parcels to 4 parcels in Opulu and up to parcels in Savai'I. These parcels are planted to coconut or banana and within each parcel; two or more crops are grown in it.

Samoa's land is also vulnerable to degradation in light of its changing use and erosion brought about by monocropping and slash and burn cultivation system. Aside from its vulnerability to strong typhoon, the country's agricultural development is perceived to be restricted by land tenure status which classifies 90% of the country's agricultural land as customary land where development is determined by Matai or family head which assigns the use of land for agriculture. Some lands remained unused or used for less productive purposes. Communal lands are assigned for firewood gathering areas.

As more and more countries in Asia and the Pacific are being challenged to increase production and land productivity through farming systems and value adding activities, Samoa has started to give more focus to competitiveness by producing agricultural products of highest quality acceptable to international markets. It sees the need to train its farming communities and young agriculture professionals on the latest production and post-production technologies and in the generation of new knowledge to improve productivity. The underlying need to shift from traditional farming systems to commercial farming has all the more been recognized.

Agriculture is also being perceived as being a career of inferior status as others. The major challenge is how this perception be changed so that more and more young students will pursue a career in agriculture. It happens everywhere and the University of South Pacific in Alafua has felt the brunt of this downward enrollment trend with reported fewer application among students in the agriculture program.

4. BIOPHYSICAL FEATURES OF SAMOA

4.1. Location

The State of Samoa is located northeast of Fiji between 13°15’ and 14°5’ South Latitude and 171°23’ and 172°48’ West Longitude. It is bounded at the eastern side by American Samoa, west by Wallis and Futuna, south by Tonga and north by Tokelau islands An archipelago, it consists of two big islands namely Opolu and Savai’i and a number of smaller islands namely Apolima, Manono, Fanuatapu, Namu’a, Nu’utele, Nu’usafe’e, Nu’ulua and Nu’ulopa with a total land mass of 2,934 square kilometers. Opolu has a total land area of 1110 sq km and is home to about 75% of the country’s population. Savaii has a total area of 1820 sq km.

4.2. Economy

The economy is agriculture based with gross national product coming traditionally from agricultural exports. It has also been dependent on development aid, and remittances from overseas workers. About 2/3 of its work force is employed in agriculture contributing 90% of exports. These major export products consist of coconut cream, coconut oil, and copra. The manufacturing sector is mainly involved in the processing of agricultural products. Tourism has been seen as potential source of income with 70,0000 tourists visiting the island in 1996. The Samoan Government has called for deregulation of the financial sector, encouragement of investment, and continued fiscal discipline. Observers point to the flexibility of the labor market as a basic strength for future economic advances.

4.3. Land tenure

Three main types of land tenure exist in Samoa namely: government or public land, freehold land and customary land. Government and freehold lands are the main type in the urban area while customary lands chiefly dominate the rural area.

Customary Lands. About 81% of Samoa's land consists of customary land or those areas held according to Samoan custom and usage. The land is owned by the community or individual families. A matai or the head of an extended family manages it and determines its uses by family members. Since 1960, the Constitution of Samoa protects these lands from alienation or sale except by way of lease or license in accordance with the Alienation of Customary Land Act 1965. Customary land is the most commonly leased type of land in Samoa. The lease however is regulated by the Ministry of Natural Resources, Environment and Meteorology to make sure that the landowner is amply protected against inappropriate land deal.

Freehold Lands. Freehold land comprises 4% of the total land area. It is land held from Samoa for an estate in fee simple and landowners independently manage their own lands which can be alienated in any manner desired by the owner be it through sale, gifting, leasing, licensing or exchange.

Typical landscapes in some sections of Upolu are characterized by the predominace of grasslands used for grazing and in some cases remain under- or unutilized. (Figures 3 & 4).

Figure 3. Idle rocky lands in Upolu.

Figure 4. Grasslands used for grazing livestocks.

Government or Public Lands. This comprises about 15% of land in Samoa. These lands are administered and managed by MNREM through the Land Board according to Lands, Survey and Environment Act 1989. According to the Act the government through the Land Board can lease it but never sell it unless allowed by the Samoan Parliament. Of government land, about 5% is managed by government corporations like the Samoa Land Corporation (SLC) responsible primarily for the sale of these lands for commercial or residential uses.

4.4. Climate

Rainfall

Samoa is in the humid tropic whose climate is determined by rainfall pattern (Figure 5). It has distinct seasons: wet from November to April and dry from May to October. Seasonal rainfall pattern according to the Ministry of Agriculture and growers, is slowly shifting from pronounced to more uniform with precipitation occurring even during the dry season. Sitting on the Pacific seas, the humid air brings an average annual rainfall of 288 cm. Rainfall ranges from 250 cm at the western section of Savaii and Upolu to 600 cm at the north/northeast up to the uplands of Savaii. The rainfall map of Savaii is presented in Fig 5. Rainfall is also in the range of 150 cm in the coast and 400 cm in the uplands during the wet season and 75 cm to 200 cm in the same zone during the dry season. Of the total annual rainfall, about 75% occurs during the wet season. Northwest of Opolu and western Savaii has longer dry season than the other sides of the islands. From 1890-2007, the average annual rainfall in Samoa was 290.16 cm rainfall

Climate has changed and marked by shifting seasons. The beginning of the wet season occurs in November but in 2004 it remained dry and continued to be so up to the first half of 2005. The Ministry for Environment and Natural Resources Meteorology Division reported that 2005 was drier than normal. The usually six months wet season has been interspersed with more frequent dry spells and occurrence of short torrential rains causing flash flood in Apia’s coastal areas. Heavy downpours occur mainly in the months of June and July due to South Pacific convergence zones. Higher amount of rainfall above average levels was recorded in April during the wet season. This has significantly affected agricultural production used primarily for food, feeds and other non-food products. These changes in climate, however, have improved flowering and fruiting of some fruit crops and vegetable crops. Coconut production remains unaffected by drier than average weather. For vegetables, dry conditions minimize the spread of disease, especially fungus and bacteria that thrive under wet conditions. Yields or root crops and pasture crops were also significantly reduced. These resulted to reduction of available feeds to cattle.

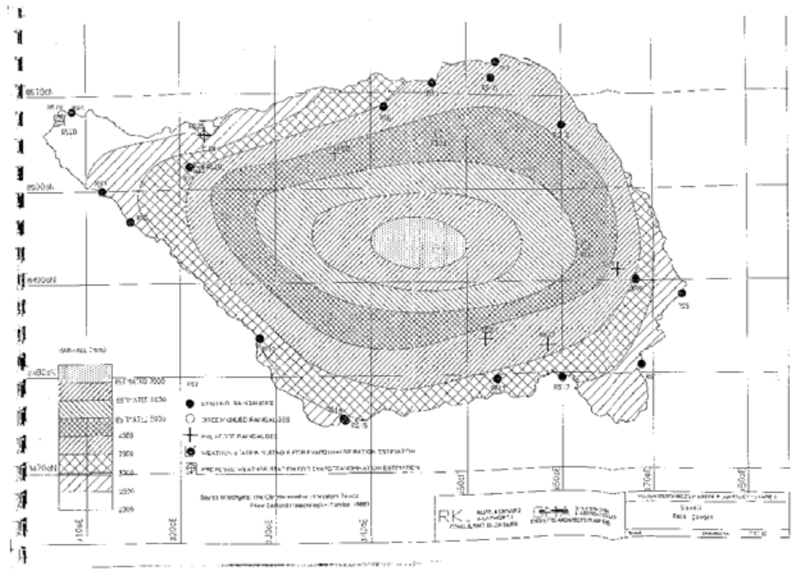


Figure 5. Rainfall map of Savaii

Temperature

Annual mean temperature ranges from 20°C to 30°C with little fluctuations during the year. The warmest period occurs in February to March and coolest in July to August. The highest temperature was recorded at 35ºC in Faleolo, while the lowest was 11.1ºC recorded at Afiamalu. Prevailing south-easterly trade winds cause slightly higher temperatures in the north-west parts of the islands (Government of Samoa [GoS], 1990). Being in the humid tropics, humidity in the island is high and averages 80%. Light duration averages 2,500 hours annually.

A study of Samoa's meteorological data collected over 101 years finds the mean temperature during this period increasing by 0.59°C (Table 2). The maximum and minimum temperature also increased by 0.67°C and 0.18°C respectively (Meteorology Division, 2003). It is projected that Samoa will continue to experience increases in average temperature.

Table 2. Average changes in atmospheric temperature from 1901-2001.

Climate Element:	**Trend (1901-2001)**
Maximum Temperature	0.67 °C increase
Minimum Temperature	0.18 °C increase
Mean Temperature	0.59 °C increase
Precipitation	49.28 mm decrease

The average temperature in July was 25ºC, about 1ºC lower than the temperature in Jan to March which had a temperature of about 26ºC. Mean temperature decreases at higher elevation and went down to 23ºC at 400 meters above sea level (masl) and 18ºC at 1,200 masl (Curry, 1955). This combined with high relative humidity resulted to higher rainfall especially in Savaii. The minimum- maximum temperature as recorded in Apia weather station from 1941-2008 is presented in Table 3. The variation is typical of tropical environment and will not affect the growth and productivity of the feedstocks for biofuel.

Table 3. Average monthly minimum and maximum temperature (◦C) in Samoa from 1948-2008.

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MIN	19.4	19.4	21.1	19.5	17.6	17.6	17.7	18.1	17.5	19.4	19.2	19.9
MAX	33.8	34.0	33.7	33.2	33.6	32.5	31.7	32.1	35.3	32.4	33.1	34.9

Typhoon

The country is typhoon prone. Historical records show that since 1923 until 1990, only three typhoons packing strong winds have caused severe damages to agriculture in Samoa. These typhoons occurred in 1966 in which the typhoon carried a 150lm/r wind, followed by typhoon Gina in 1989 (Crawley and Titimaea, 1991) and then the strongest typhoon Ofa in 1990 and Val in 1991 (Crawley, 1992). Typhoon Heta also struck Samoa in February 2004 and caused considerable damage to local agriculture. In 2005, five tropical cyclones developed around Samoa's region. These include Lola, Meena, Nancy, Olaf and Percy with the latter two tropical cyclones classified as Class 5 (Major Hurricanes). These typhoons caused serious damages to agricultural crops and had affected about 30% of coconut plantation and about 100% of breadfruit and banana. Coconut was without fruits for two years due to the typhoon. It had also resulted to significant reduction in export earnings. The minor and major cyclone events in Samoa are presented in Table 4.

Samoa has undergone a shift from weak El nino phase to neutral El nino phase. This makes weather forecasting a little difficult. The occurrence of three tropical cyclones in Samoan waters early in 2005 was typical of the El nino weather (MNREM – Meteorology Division, Personal Communication, May 2004). The average number of typhoon crossing Samoa from 1980-2008 is 1.0 making it almost typhoon free.

Table 4. Average speed (km/hr) of minor and major cyclones in Samoa

MINOR CYCLONE EVENTS

Name	Average wind speed	Max Intensity
Cyclone Rae	74	83

MAJOR CYCLONE EVENTS

Cyclone Ofa	110	178
Cyclone Heta	212	294

4.5. Soil

The predominant soil order in upland Samoa is *Andisol.* It is derived from volcanic ash and has good structure and less compact sub-layer. Samoan soils are chiefly friable, non-sticky when moist, well drained but has low water holding capacity. The upland or highland soils are thicker than the lowland due to heavier ash deposition. However, these types of soil are not generally used for agricultural production since they are shallow, stony and have coarse textural properties that are unsuitable for most types of farm mechanization.

Samoan soil is generally volcanic and relatively young. When volcanoes erupted in 1900, lava flows to hillside and spreads to the lower slopes. The Land Resource Planning Study of Western Samoa (GoS, 1990) describes briefly the soils type in the island country. "The Fagaloa Volcanics occur predominantly in north-eastern and south-western parts of Upolu and in northeastern parts of Savai'i. The areas are deeply dissected with boulders and stones occurring chiefly on steep and very steep slopes and on the bases of the slopes. Salani Volcanics occur throughout both islands chiefly on upper foothills and uplands. Mulifanua, Lefaga and Puapua Volcanics form the parent materials of the greater part of Upolu and Savai'i. Aopo Volcanics are restricted to relatively recent flows and their youthfulness is expressed in flattish, stony and bouldery surfaces. Vini Volcanics occur on the offshore islands, east of Upolu and in southern Savai'i. Colluvium occurs on the lower parts of hilly and steep land particularly on Upolu. The materials include many stones and boulders, which move down slope. Alluvium deposited by the main rivers is not extensive in Samoa, but forms the parent material of the most versatile soils. Coral sand stripes along the coastline lie in front of swamps and depressions in which organic deposits overlie coral or basaltic sands. Locally they are intersected by estuarine deposits under tidal influence. Shallow upland peats occur in a few small areas in Upolu and in central-eastern Savai'i".

While Samoa soil is generally volcanic, there are soil types with few to limited limitations and therefore have larger potentials for agriculture. ANZDEC/DSIR (1990) classified the country's soil as either suitable or unsuitable to agriculture. There were four land classes according to severity of soil limitations for agricultural crop production. These limitations can be due to presence of rocks or boulders and lost of top soil due to erosion (Table 5). Land class 1and 2 were the most suitable soil class for agricultural production. In fact it occupies the larger area near the Apia port, northwest Opolu and towards the inland from the coastal villages.

Table 5. Description of land classes in Samoa. Take note that Class 1 and 2 are suitable for agriculture.

Land Class	Description
1	Few limitations to agricultural use. Flat to gently sloping. Fertility varies considerable and stones are fairly absent
2	Moderate limitations due to agricultural use and few limitations to forestry. Include flat lands with drainage problems in hilly to rolling topography. Fifty percent or more of the surface is covered with boulders. Fertility is medium to high
3	Severe limitations to agricultural use and moderate to severe limitations to forestry. This soil class had 50% of its surface having stones and boulders or lava sheets. On steep slopes, erosion becomes moderate to severe.
4	Unsuitable for agriculture and forestry. Soil surface is covered with stones and boulders This includes the

	swamp and

Figure 6. A suitable soil in between Fugi and Viata in Savaii. Soil is clay loam with sparse stones.

Table 6 shows the relative proportion of the country's land classes. Land class 1 was only about 14% of the total land area (hectares)followed by land class 2 which accounts to 42%. Both land class occupied about 56% of the total and area.

Table 6. Land classes in Samoa according to their suitability for agriculture.

Land class	Upolu	Savaii	Total
1	221.9 19.6%	179.8 10.6%	401.6 14.2%
2	561.6 49.6%	632.7 37.3%	1193.6 42.2%
3	108.7 9.6%	490.2 28.9%	599.6 21.2%
4	238.9 21.1%	393.5 23.2	633.6 22.4

4.6. Socio-Economic Profile

The Ministry of Finance Statistics Department published the most recent data on population. In 2006, the total population of the country reached 180,741 of which 36% was found in 5 of 24 political districts. These districts were Vaimauga West, Faleata East, Faleata West and Sagaga le Falefa. Despite Savaii's greater land area which accounts to 58% of Samoa's total, against Opolu s 38%, it has only 24% of the population, compared to 76% of Upolu. Half of the population is 19 years old and younger. Male to female ratio of the population was 1.07 is to 1; about 505 were20 years old and above

Survey in 2006 indicated that Samoa had 23,079 households. Since the 1991 census, average growth rate of population has been 0.56% with urbanization expanding at about 1.5% per year. Growth rate declines due S due largely to emigration to New Zealand, Australia and the United States. Samoans live in 330 villages with13-66 households per village. About 52% of the villages have 100 to 499 people. In 2001, 22% of the population resided in Apia, Samoa's only urban centre, 30% in northwest Upolu (the airport vicinity), 24% in the rest of Upolu, and nearly all of the remaining 24% in Savai'i. The number of households grew by 4% over from 1991-2001 the average household size increased from 7.3 to 7.7 persons.

Total employment in all age groups in 2006 was 56,649 persons of which 15,587 were classified as unpaid family assistant. Of the total employed, 17,124 persons were in agriculture and the rest were almost evenly distributed in 18 sectors ranging from fishing, manufacturing, construction, transport, education among others. About 25% of employed population received an annual salary in between $5000-$10000

4.7. Water Availability

Having a climate with longer rainy season and sometimes border to even distribution of rainfall, Samoa has abundant supply of water. Its volcanic origin has resulted to development of terrains with abundant streams and waterfalls. However due to high water infiltration brought about by light soil texture, the western part of Upolu and the larger parts of Savaii lack surface water. Groundwater and rainwater catchments are the major sources of water in these areas which dry up during the dry season. This makes it difficult to establish irrigation facilities for agricultural crops during the dry season. Samoan water is used for drinking and cleaning. Estimates cited that more than three-quarter of Samoan population has access to piped water.

4.8. Land Use

Over the last twenty years, Samoa land cover has undergone much face lifting. It has been traditionally used for agriculture and forestry. The advances in the country's economy have propelled much of the changes from traditional subsistence agriculture to commercial agriculture. Apart from forest and secondary forest and agriculture, Samoa's landscape is also characterized by mixed intercropping where the secondary forest is interspersed with agricultural crops or where effective land use has increased through crop intensification. Thus coconut is mixed with other crops while banana are inter-planted with cacao and other economic crops

Using aerial photos taken in 1999, forest resources have been inventoried and assessed with inconsistent results during the previous years. When land use was evaluated in the 1980s, about 50% of the total area of about 285, 000 ha was forest. And of the total forest lands, about 55,000 ha are considered under protection forests as National Parks and Reserves and the rest are commercial forests (Samoa, Dept. of Economic Development, 1985). Other crops of economic importance such as coconut and copra under tree crops cover 77, 211 ha (The ADB report, 1985). The land use patterns in the 1990s are presented in Table 7. Forested areas in Samoa were close to 171000 ha or 60%of total area which include all forest types and mangrove and forested wetlands.

Table 7. Land-cover categories of Samoa (based on 1999 aerial photos)

Main category	Description	Area (ha)		Percentage
		Savaii	Upolu	
Forest	Land with a tree crown cover of more that 10% and a minimum size of 1 hectare. Includes man made plantation forests, mangrove forests and other natural forests	118,037	52, 406	60.0
Agricultural Land	i. **Plantations** – permanent agricultural installations, mostly tree crops or continued/repeated planting of e.g. coconuts or bananas (agro-industrial) ii. **Mixed Crops** – land currently and recently cultivated with a mixture of herbaceous and tree crops such as root crops, taro, yam, cassava, breadfruit etc. This includes areas of current cropping and adjacent areas recently abandoned and now overgrown with secondary shrub and tree species	28,621 (Plantations - 26, 158) (Mixed Crops - 2, 463)	34,476 (Plantation - 26, 770) (Mixed Crop - 7, 706)	22.3
Wooded Land (Scrub)	Areas with dominance of woody perennial shrubs of less than 5-7m height and without a definite crown	15, 065	7, 000	7.8
Built-up Area	All settlement areas, encompasses continuous developments, industrial or commercial built-up areas and scattered isolated houses including gardens and inner-city parks	1,772	5,292	2.5
Barren Land	All land lacking any vegetation cover except for infrastructure and built up areas	1, 973	30	0.7
Infrastructure	All roads (hard surfaced or loose) and infrastructure related facilities (e.g. airports/airstrips, ports, wharves, sports compounds etc.)	32	432	0.2
Other	Includes grass land, lakes, rivers and wetlands	5,379	13,141	6.5
Total	**170,879**	**112,777**		**100**

Agricultural plantation was about 53, 000 ha or 19% of the total area. These are found more uniformly both in Opulu and Savaii. However, mixed crops, grassland and built-up area were chiefly found in Upolu. Barren land of solid rocks, boulders and lava flows from Mt Silisili was dominant soil types in Savaii. Landslides in mountain slopes render these areas unproductive for many agricultural crops. The remaining forest covers in both islands was 47% in Opolu and 69% in Savaii. With the advancing development the forest landscape has undergone changes with conversion of forest lands to agricultural and residential uses. Land under agricultural use, however, is and remains under customary ownership. The secondary forest and agricultural land in Samoa is presented in Figures 7 and 8.

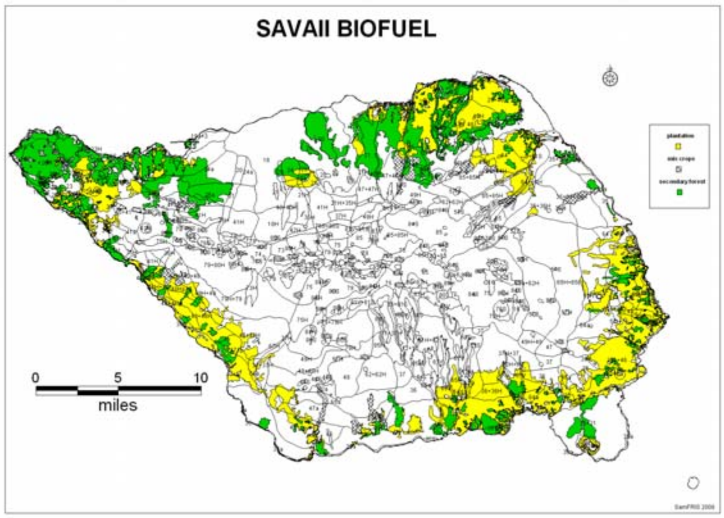


Figure 7. Map of Savaii showing the secondary forest in green and agricultural land in yellow.

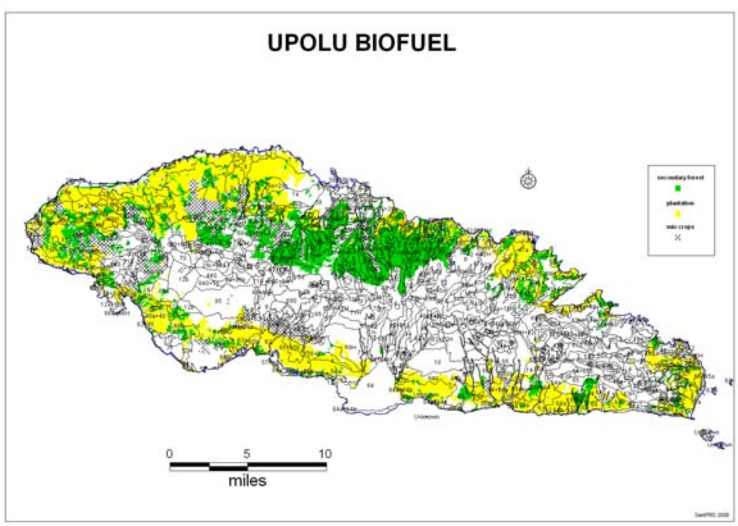


Figure 8. Map of Upolu showing the secondary forest in green and agricultural land in yellow.

4.9. Land Degradation

The resultant intensification of land use of the agricultural lnd of Samoa has resulted to slow but continuous degradation due to soil erosion, loss of soil infertility and consequently reduction of productivity. In a report presented by Tuivavalagi, Hunter and Amosa (2001) on '*Tackling Land Degradation and Unsustainable Land Use in Samoa's* land degradation was attributed monocropping. It disturbs the soil, loosens it and makes it prone to erosion. Water loss through runoff thus increases. The traditional mixed ropping systems which increase land vegetative covers with perennial crops as one of the component crops reduces soil erosion and promotes water conservation. Land degradation is greatest on bare slopes or areas with sparse vegetative covers. Not only did the disturbance of forest reduction in luxuriant vegetative growth due to slash and burn or commercial logging result to land erosion, it has also been referred to have caused strong cyclones in Samoa (SamFRIS report, 2005).

5. AGRO-ECOLOGICAL REQUIREMENTS OF BIOFUEL CROPS

There are crops of importance to the biofuel industry worldwide. The major feedstock for bioethanol is corn and sugarcane. However, for the production of these crops to be viable, farm mechanization in contiguous commercial areas is needed. These could not be easily done in Samoa due to the country's limiting physical land features and terrain. With shallow, bouldery and rocky soils, land preparation and cultivation become difficult. Due to these constraints, we identified three candidate crops as feedstocks for Samoa's bioethanol program and two crops namely coconut and oil palm for biodiesel program.

5.1. Cassava. The crop is grown within 30º north and south of the equator. Cassava is cultivated generally in the humid tropics. Noted for its tuberous roots, cassava is the second most important root crop of India and has been widely distributed in South America. Its cultivation dated back some 4000 years ago when it was reported to be growing in Peru and 2000 years ago in Mexico

It grows over a range of soil types but grows best in well-drained fertile soil. Tolerant to marginal soils, it can be grown even in eroded, depleted and infertile soils due to low pH with high levels of iron, aluminium and manganese. Its pH requirement ranges from 4.7 to 8.7. Although it is tolerant to basic soils, the crop may not tolerate high pH soils due to salinity.

Cassava is tolerant to stressful conditions and grows well even when annual rainfall is 75cm/year. Although the crop produces the highest yield in places with uniform distribution of rainfall, it can also be grown in areas with about 6 months of dry season during which the older leaves senesce and the plant becomes dormant. It requires 150 cm rainfall per year for optimum growth although it has been reported to thrive in places with 64 to 403 cm of rainfall. Soils under wet feet is undesirable as prolonged flooding of about 24 hours may reduce growth, cause wilting and leaf abscission and kill the crop. This is the reason why cassava is preferable planted in mounds. It is grown from sea level up to 1,100 meters above sea level. In Peru and Ecuador, it is grown in the highlands with average annual temperature of 16-17oC. It requires an annual temperature of 14.7 to 27.8 ˚C.

5.2. Breadfruit. According to Morton, breadfruit is widely distributed in the tropics. It thrives at latitude between 17ºN and S but can grow up to 23ºN. It was brought to Hawaii from Samoa in the 12th century and has been grown in the Marquesas, and Tahiti in the early 16th century. The French brought it to the French West Indies from the Philippines in 1772. It reached Jamaica by French navigators en route to Martinique. From Jamaica, it flourished in the West Indies in the lowlands of Central America and South America. The Spaniards came in the Philippines and brought it to Mexico and Central America long before it reached the West Indies.

Breadfruit is cultivated in practically all countries in the south Pacific. So important is the crop in the South Pacific Islands that in late 1700's a Tongan breadfruit variety was introduced to Martinique via Mauritius. This variety were spread through out the Caribbean and to Central and South America, Africa, India, southeast Asia, Madagascar, the Maldives, the Seychelles, Indonesia, Sri Lanka and Northern Australia. Florida is also known for its breadfruit.

Breadfruit requires a temperature ranging from, 20-40ºC. It is best grown in areas with rainfall ranging from 150-300cm and relative humidity of 70-90%. Rainfall stimulates shoot growth, flowering and fruit growth. It grows from 0 to 1500 meters above sea level. It is best grown in places below 650 meter above sea level although it has been reported to thrive up to 1550 meters. Places with even distribution of rainfall are ideal although it is grown in areas with up to 3 months dry period. Although trees can be grown under partial shade of coconut and other agroforest species, best performance is noted in open. Young trees prefer 20-50% shade. Stems and shoots break under strong winds but quickly recover.

Tree performance is best in deep, fertile well drained friable alluvial soil (E. Soepadmo, edible fruits and nuts in tropics) with pH 6.1 to 7.4. It prefers light and medium textured soils. It also grows in shallow coral atoll soils. In New Guinea they have been found at the edge of the forest and near swamps. When soil is overly wet they abscise their fruits. Yield declines in marginal soils. Varietal differences exist in terms of tolerance to drought, shallow soils, and high pH soils

5.3. African Oil Palm. African oil palm was discovered as ornamental plant 5000 years ago. Reported trade of palm oil to Europe dated back in 1600. Britain processed it to soap in 1830's and by 1900's it was processed into margarine. Today, 90% of world's oil requirements come from palm oil.

African oil palm thrives well in the humid tropics. It requires an annual rainfall of 150 – 200 cm more or less evenly distributed throughout the year. Its mean annual maximum temperature requirement ranges from 29-33ºC and mean minimum temperature ranges from 22-24ºC. It is grown in open areas requiring not less than 5 hours of continuous sunshine per day. It is grown in flat terrain up to 12º slope. Being an exacting crop, it performs best in fertile soils. Soil depth should be 75 cm or deeper without any soil impediments like rocks or boulders. Loam to fine sandy clay loam with high water holding capacity is bests. In coastal areas salinity level should not exceed 1000umhos/cm at 60-90 cm deep. Strongly required is soil with friable to moderately firm. PH ranges from 4 to 6 with a peat layer of 0.6m. Soil should be moderately permeable. During the dry season, irrigation is necessary.

5.4. Coconut. Coconut is the major crop of commerce in Samoa. Grown predominantly in the as component in subsistence and commercial farming communities, coconut occupies a greater area more than any crops in Samoan uplands. According to Asian Development Bank report, the area planted to coconut has not changed over the last 40 years. It is the single most important crop in the total cropped areas on Samoan soils. More than 85% of all palms are raised under customary lands (DSA, 1990).

The crop is the source of livelihood to many sectors of the population and is considered the backbone of Samoa's agriculture base economy. In both Upolu and Savaii, a total of 13,889 households are growing coconuts (Table 8) chiefly for home consumption. Coconut is also a major source of foreign exchange earnings of the country through its exports of coconut oil, coconut cream, copra and copra meal. It is, however, threatened highly efficient production in Indonesia, Thailand, India and the Philippines

Table 8. Number of Households Growing Coconut in Both Savai'i and Upolu (Market Link, 2008).

	Upolu	%	Savaii	%	Total
For Home consumption only	6585	73	3169	65	9754
For Sale only	123	1	98	2	221
For both Home and for Sale	2298	26	1616	33	3914
Total	9006		4883		**13,889**

Coconut thrives over a wide range of soil type from sandy to clay loam soil but requires deep well-drained fertile soil with pH 5.5 to 7. The highest productivity are places near the coast because of high concentration of chloride which has been reported in the Philippines as having the most favorable influence on nut size and thickness of the solid endosperm. Because of its continuous flowering habit, it is best grown in places with even distribution of rainfall or with longer rainy season with average annual precipitation ranging from 150-250 cm. The lower latitudes, with about uniform rainfall in the Pacific is the best place for coconut. Even in the Philippines with about similar climate as in Samoa, best places were found in areas with even distribution of rainfall (Table 9) with a total annual rainfall of 1800-2000 mm per year. This is equivalent to 105mm/mo or 4-5 mm/day. Higher yield is attained at 80-90%.

Table 9. Site suitability of coconut according to rainfall.

Description	Maximum number of dry months	Suitability
Wet (rainy throughout the year)	1.5	Highly suitable
Humid (rain evenly distributed)	3	Suitable
Moist (rain sufficiently distributed)	4.5	Suitable
Dry (rain not sufficiently distributed	6	Fairly suitable
Barren (deficient rainfall)	9	Unsuitable

The palm is grown up to 600 masl. At higher elevation palms tend to grow slower and become stunted. It is tolerant to strong typhoon of up to 120 km/hr hour but succumbs to stronger typhoon signals of up to 180 km/hr which can cause serious blow down, windthrow, leaf breakage and abscission among others.

6. CROP SUITABILITY EVALUATION

Samoa's total agricultural land is only 53,000 ha half of which is devoted to coconut and the rest to other crops such as taro, cacao, banana and other crops of importance to Samoan food requirement and economy. Based on climate, the crops above are highly adapted in Samoa. The 150 cm rainfall and its distribution required by cassava, oil palm, breadfruit and coconut are easily satisfied. While the country has distinct season, the length of the dry period is not critical as to significantly affect production. The temperature in Samoa is within the range required by the crops. Even the increases in temperature for the last 100 years were insignificant to make it unfavorable to crop production.

6.1. African oil palm

African oil palm average annual rainfall requirement of 200 cm can be met by the islands average rainfall of 288 cm. In Savaii, the western coast had an average rainfall of 250 cm and the north/northeastern part had 600 cm. This is high, and to a certain extent disadvantageous to the palm as it may result to failed pollination. What is not met is the crop requirements for even distribution of rainfall. Samoa has distinct dry season and even when there are spells of rain periods during this season as a result of climate change, such may not be enough to meet the crops more exacting requirements. Continuous dry period results to decline in growth and subsequently yield. This is also the reason why the plant requires deep soil of not less than one meter deep that is high in organic matter and water holding capacity. It will be very expensive if irrigation facilities will be installed if only to meet the plat's requirements during the dry season. Samoa's temperature and long light duration are conducive to the crop's growth.

What could restrict successful production of African oil palm is its relative sensitivity to strong wind. While there are sparsely growing stand of oil palm in typhoon prone areas in Luzon in the Philippines, its commercial production is centered in typhoon free areas of Mindanao. Its trunk is not as strong as coconut.

The infertile soils of most part of the island in terms of depth and mechanical impedance may be a limiting factor for the crop's continued vigorous growth and superior yield performance. African oil palm is also a monoecious crop where both the male and female flowers are borne on the same plant. It has been observed that when the crop is exposed to stressful conditions either to soil infertility, poor light intensity, and improper farming practices, its male to female ratio will increase thus reducing production. Aside from being prone to adverse environmental conditions African oil palm is also sensitive to poor soil fertility. It easily manifests soil nutrient deficiencies unlike coconut and therefore would require regular fertilization.

6.2. Coconut

Coconut on the other hand has proven its resilience under poor management and stresses either due to adverse soil infertility problem or poor environment. It can withstand strong wind although wind velocity of 250 km per hour can cause leaf breakage, blowdown, and windthrow of the crown. Coconut thrives well even when underfertilized, or poorly maintained. Its continuous flowering habit under Samoa's abundant rainfall enables it to produce fruits year round. However, some of the country's existing coconut stand are already old and past their peak production.

6.3. Cassava

Similarly cassava has been grown over a wide range of soil types and environment yet still produces acceptable yields. Its rainfall and temperature requirements are met under Samoa's tropical climate. The island has a short period of dry season of around three months. But such period may not be too long enough to significantly reduce yield. It is sensitive to waterlogging which rarely happens in Samoan soils except in low lying areas and basins. The only problem in Samoa is the rocky and stony soils which will restrict land preparation by animal drawn implements much more by mechanization.

6.4. Breadfruit

The abundance of breadfruit in Samoa has proven its hardiness despite soil mechanical impedance. Although strong wind can cause limb breakage, defoliation and witdthrow, the crop is relatively tolerant as it quickly recovers by generating new shoots. It has also an extensive root system and does not easily succumb to blowdown during strong typhoon. Samoa's changing climate which resulted to intermittent rains during the dry season has resulted to continuous flowering of the crop.

6.5. Jatropha

Jatropha is also a prospective crop worthy of careful study. There is no doubt of the suitability of the island's soil and climate to Jatropha's requirements. It has been reported to withstand unholy environment due to soil infertility and drought but attains better yields in fertile, well drained soils. Where other crops of commerce could not be grown because of existing soils, and climate jatropha stands as alternative crop, can grow and produce modest yield. While its requirements are still being studied, we will consider it in this study. The crop can withstand the harshness of the environment due to the presence of rocks, and soil infertility which characterizes some parts of Savaii. It can be grown under coconut, in slopes and grasslands.

The soil of Samoa is rocky to bouldery. Very few soils types are classified as having silty loam to clay loam soil without rocks or boulders. Stones might be present but are not critical to production. Site visit to assess Samoan soils in both islands reveals that there only limited soil types in the country that is suitable to agricultural production. The suitability of the soil is based in its textural characteristics and the absence of boulders or rocks. These soil types are presented in Table 10.

Table 10. Types of soil in Opulu and Savaii.

Code	Soil type	Area (ha)	
		Opulu	**Savaii**
28	Magia stony clay loam	95.26	4.86
29	A ana stony silty clay	63.23	326.7
31	Vailele stony sility clay loam	17.48	
32	Moamoa stony clay		
33	Vaipouli silty clay loam		477.13
37	Asoleilei stony silty loam		719.5
38	Puna gravelly clay loam		7.45
40	Lefuga stony silty clay loam	27.99	79.75
41	Tanumalala stony silty clay loam	209.71	
45	Tapuele silty clay		182.97
52	Tafua silty clay loam		185.1
55	Olomauga stony silty clay	754.05	162.8
56	Fagapolo silty clay	83.53	
58	Papaula silty clay	1358.92	
58a	Papaula stony silty clay	137.61	
59	Avele stony silty clay	477.51	
60	Solosolo silty clay loam	127.34	
62	Etemuly silty clay loam	1534.72	
64	Falealili silty clay loam	2912.67	1175.2
64a	Falealili stony silty clay		1593.4
65	Fagapa silty clay loam		207.3
65a	Fagaga stony clay loam		2657.62
72	Uafato silty clay		80.66
	TOTAL	**7800.02**	**7860.44**

These soil types were mapped and located in Upolu and Savaii. Their relative location is presented in Figures 9 and 10.

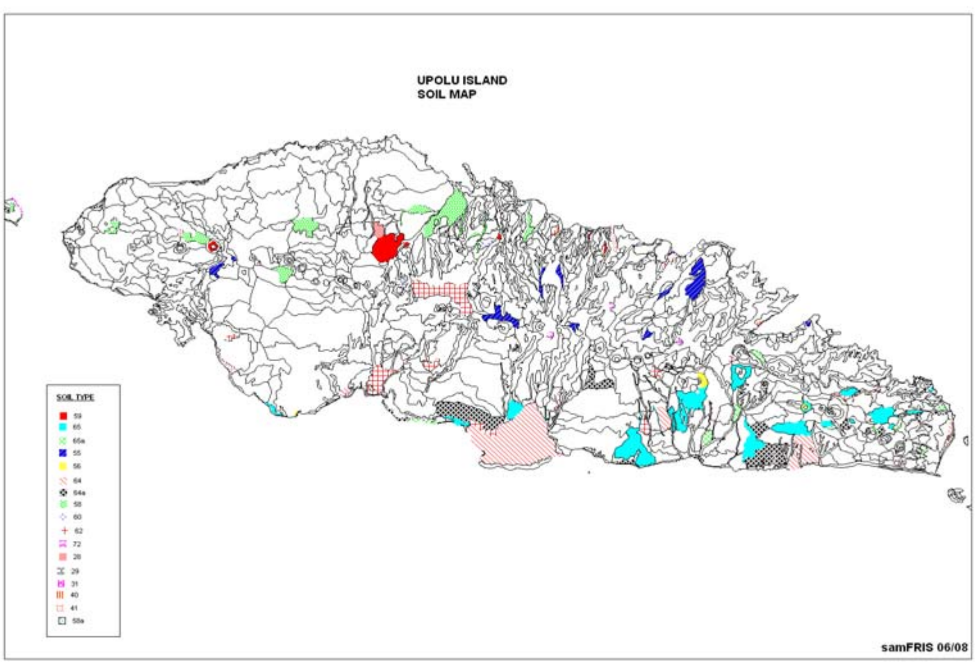


Figure 9. Soil map of Upolu showing the different soil types suitable for biofuel.

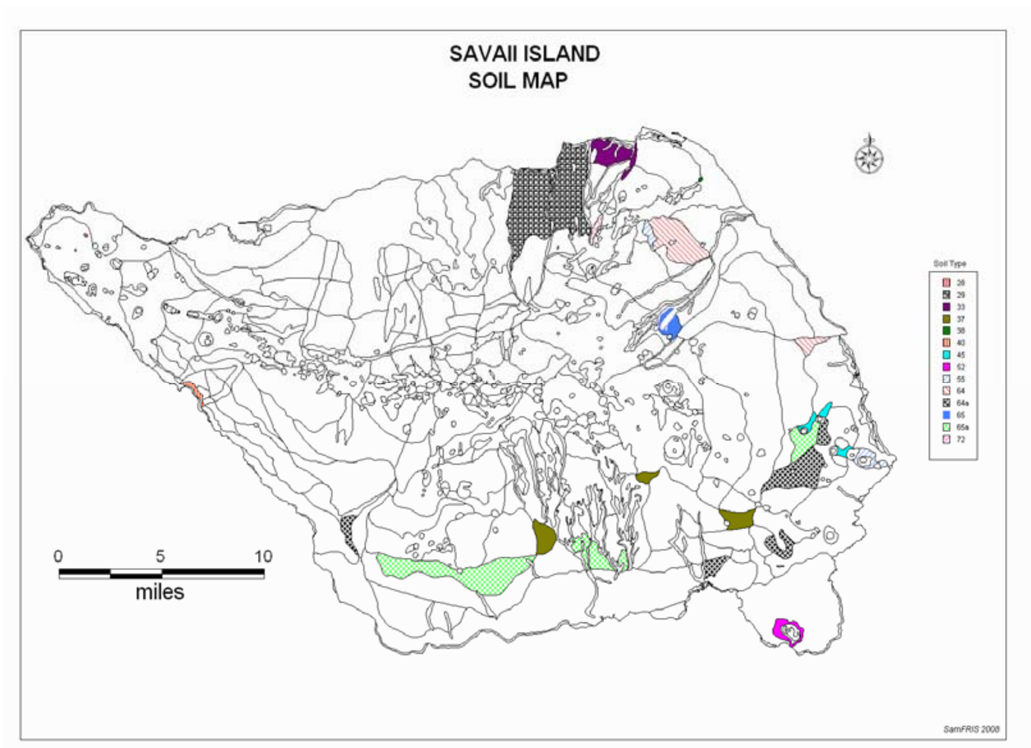


Figure 10. Soil map of Savaii showing areas suitable for crop production.

Based on the climate and soils of the island including the existing vegetation, topography, water availability, the only practicable crops of prospective importance to Samoa's biofuel program are breadfruit and cassava for bioethanol; and jatropha and coconut for biodiesel.

7. RECOMMENDED VARIETIES AND PROPAGATION

7.1. Cassava

7.1.1. Latin America.

a. Mantequiera is a variety of commerce in Cuba, Dominican Republic an Colombia.

7.1.2. Philippnes

a. Lakan 1. All purpose variety, yellow flesh and cream cortex. It has 45% dry matter and 33% starch. Resistant to leaf spot and bacterial blight. Average yield is 32t/ha.

b. Sultan 8. Industrial variety, white flesh and cream cortex, 40.5% dry matter, 30.6% starch. Field resistance to scale insects, spider mites, leaf spot and bacterial blight. Average yield is 39.1 t/ha.

c. Sultan 9. Industrial variety, white flesh and cream cortex, 38.6% dry matter and 28.6% starch. With field resistance to scale insects, spider mites, leaf spots and bacterial blight. Average yield is 35.6 t/ha.

d. Sultan 10. Industrial variety, white flesh and cream cortex, 36.5% dry matter and 26.8% starch. With field resistance to scale insects, spider mites, leaf spot and bacterial blight. Average yield is 40 t/ha.

7.1.3. Nigeria

Considered as center of cassava production, many commercial varieties are being grown in Nigeria. Their variety of commerce include|:

a. TMS 90257. The plant has profuse branching habit with wide canopy development and high tolerance to pest and diseases. Fresh root yield is 43%, dry matter yield of 25% and starch content of 23%.

b. TMS 84537 The plant has moderate branching habit with wide canopy development and high tolerance to pest and diseases. Fresh root yield is 43%, dry matter yield of 28% and starch content of 27%.

c. TMS 8200058. The plant has profuse branching habit with wide canopy development and high tolerance to pest and diseases. Fresh root yield is 35%, dry matter yield of 28% and starch content of 21%.

d. TMS 8200061. The plant has profuse branching habit with wide canopy development and high tolerance to pest and diseases. Fresh root yield is 39%, dry matter yield of 30% and starch content of 26%.

e. NR 8212. The plant has profuse branching habit with wide canopy development and high tolerance to pest and diseases. Fresh root yield is 30%, dry matter yield of 37% and starch content of 21%.

f. TMS 30572. The plant has profuse branching habit with wide canopy development and high tolerance to pest and diseases. Fresh root yield is 28%, dry matter yield of 34% and starch content of 23.6%.

g. TMS 90257. The plant has profuse branching habit with wide canopy development and high tolerance to pest and diseases. Fresh root yield is 32%, dry matter yield of 32% and starch content of 22%.

The highest starch content among the varieties is TMS 84537, while the higher fresh root yield was obtained from TMS 90257.

7.1.4. Samoa

Samoa maintains a collection of different varieties of cassava which have been tested for their agro-ecological performance in the island's climate. Based on the results of the trial (Hazelman, 1997), the varieties being recommended for Savaii and most likely for Upolu are as follows:

a. Pan 51. The cultivar comes from CIAT. It performs well over a wide range of environmental conditions. It has straight stem, white flesh, 4-5 meters tall, few to none branches and has good eating qualities. Average yield is 37.1 t/ha

b. Me- 17. The variety comes from Fiji and performs best in good environmental conditions. It is reported to produce low yields in rocky soils. It has white flesh, 3-4 meters tall, few branching habit and acceptable eating qualities. Yield per hectare is 33.3 tons.

c. CM 2106-6. The cultivar comes from CIAT and preferred for its good eating quality and better performance over a wide range of environmental conditions. It has white flesh, 2-3 meters high, and profuse branching. Average yield is 28.4 t/ha. It is among the selected varieties for cream and oil production

7.1.5. Malaysia

The varieties of commerce in Malaysia have similar performance as other varieties in the Asia Pacific. Lian (undated) reported the following varieties suitable in the soils and climate of Malaysia

a. Ubi kuning has a fresh root yield of 25.6 t/ha

b. Black twig. The variety yields a fresh root weight of 38.1 t/ha with starch content of 25.6%.

c. Perintis. It his high yielding and can give as high as 50.8 t/ha with 22.6% starch content

d. MM 92. This variety has wider adaptability and can tolerate acidic soils. It yields 45.7 t/ha with 205 starch content.

e. CM 6149-30. This variety produces 37.1 t/ha with 23% starch content

7.1.6. Thailand (Rojanaridpiched et al, undated)

One of the dominant growing areas of cassava in Southeast Asia, Thailand boasts of its Rayong series, varieties that are suitable for starch production and more importantly for bio ethanol production. These varieties are as follows:

a. Rayong. This variety has fresh root weight of 31.17 t/ha, dry weight of 11.73 t/ha and has 24.1%.

b. Rayong 5. The is variety yields 37.18 t/ha fresh root weight, 13.26t/ha root dry weight and with 23.5% starch

c. Kasetsart 50. The variety has an average fresh root weight of 33.63 t/ha with 12.51 t/ha dry root weight. Its starch content is 25%

d. MKUC34-114-206 gives 35.94 t/ha fresh root weight, 13.36 t/ha dry root weight and 25.4% starch content

In Indonesia, the variety of commercial importance is Adirsa which produces a yield of 43.06 t/ha fresh root weight with 26.82% starch content.

Cassava is propagated using stem cuttings from mature plants. The stem of cassava can be divided into sections: hardwood, semi-hardwood and shoot tip. The semi hardwood and hardwood is the best stem sections used for propagation. Plantation of bout 18 month old, the best cuttings consist of semi-hardwood cuttings. The topmost portion of the cuttings is discarded. About 30 cm log cuttings with about 5 active nodes are prepared and planted in slanted manner in previously prepared land. Stakes used as planting materials must be planted immediately after they are collected to prevent dehydration.

7.2. Breadfruit

The South Pacific Island has a rich germplasm pool of breadfruit varieties of local use and exported to New Zealand. They are grown in the backyard and have found a suitable place in Samoan climate. If it is to be grown commercially it is recommended to use the varieties of proven provenance in the country. These varieties are as follows:

a. Maopo. Considered the best variety according due its size and eating qualities, Maopo produces large oval fruits weighing 2 to 3 kg It has a starch content of about 70% of its dry matter. The fruit has also good processing quality and can be stored in 3 to 4 days after harvesting under room temperature and normal handling.

b. Puou. The plant produces medium sized fruits weighing between 1 to 1.3kg. It has high starch and reputedly the highest protein among the varieties. It is best for chip processing. The fruit is early maturing. Fruit is available practically throughout the year. The tree reaches 6 to 109 meters high, precocious, and high yielding. Tree height at full maturity reaches 16 to 20 meters.

d. Ma'afala'. This is most common in Polynesia. It is a smaller tree with height of up to 10 m. the fruits are oblong to oval and weighs 0.6 to 1 kg. The fruit has none to few seeds.

e. Mein iwe. This is the variety common in Federated States of Micronesia, Marshall Island and Kiribati. The fruit is white fleshed, seedless with average fruit weight of 1.6 kg

Estimate in Samoa pegged breadfruit yield at 20 t/ha (Wooten and Tumali, 1984) Table 11 shows the yield levels reported in the literature.

Table 11. Yield of breadfruit in different countries.

Reference	No of fruits per tree	Weight per fruit	Yield per hectare (t)	Place reported
Wooten and Tumali (1984)			20	Samoa
Purseglove, (1968)	700	1-4 kg		
Marte (1986)	200			
Anonymous (undated)	160-320	1.2	16-24	Barbados
Morton (1987)	50-150			

Because breadfruit does not produce seeds, the common method of propagation used is by root cuttings of about 2.5 to 6.5 cm thick, 20 cm long. Cuttings are allowed to produce adventitious shoots by inserting them horizontally or diagonally under shade. Once shoots are formed, the cuttings re transferred to pots where the new plant are allowed to grow until outplanting. Shoots arising from the roots can also be used.

7.3. Coconut

Philippines

The Philippines is one of the major producers in the world. Its copra and desiccated coconut is its top export. Its rich genetic resources and high yielding varieties can be tapped for the island's biofuel program. The coconut farming communities in the Philippines grow the Typica variety which is characterized as having enlarged boles, tasll, highly cross pollinating but late bearing which is attained in 6 to 7 years after planting. Its nut size is medium to large. The forms of Typica chiefly grown in the country are Laguna and San Ramon. A selection among the forms of Typica reveals the potential of Bago- Oshiro and Baybay forms

1. Laguna form. It produces medium size fruits averaging 156 nuts/palm/yr. Copra yield is about 195 g and fruit quality is fairly good.

2. San Ramon. This is the most common variety of coconut in the Philippines. It flowers in 3 to 5 years and produces 7 to 9 nuts per bunch and 14-17 bunches per year. Is average copra yield per nut is 220g .

3. Bago-Oshiro. This is a tall variety producing an average of 150 nuts per palm per year. Copra yield is 210 g/nut.

4. Baybay. The variety is highly vigorous, similar to Laguna but high yielding. The nut has thin husk and yields 288 g copra/nut

Samoa

1. Samoan Tall. Bears fruit in 5-7 years. Fruit weighs 1.99 kg, and meat weighs 710 g. The palm is highly sensitive to rhinoceros beetle and to hespid bettle. It is quite sensitive to rat infestation. The variety is most sensitive to drought especially in the dry areas of western Savaii. It is the variety of commerce in Samoa with high oil content.
2. Niu Afa Tall Samoa. The variety has an average fruit weight of 2.58 kg, and meat weight of 675 g. Like the Samoan Tall, it is sensitive to rhinoceros bettle It grows well in well drained soils and quite sensitive to drought. It is highly sensitive to low temperature. Bears fruit 5-7 years after planting. It is good for fiber production

3. Samoan Tall Samatau. Bearing fruit in 5-7 years after planting, the variety has an average meat yield of 710g/nut. It does not tolerate waterlogging and quite sensitive to drought. It is also sensitive to rhinoceros beetle and hispid bettle

Coconut is propagated using seednuts of recommended varieties. Seednuts are germinated in seedbeds established in flat area with well-drained, fertile soils close to source of water. Nuts are sown horizontally on its flat portion or with are depressed yield above the ground. In one hectare of germination beds, a total of 150,000 nuts can be sown. Nuts germinate in 10 weeks. After germination, the seedlings are potted in black polyethylene bags (45” x 45”). The seedlings are placed under full sun at a distance of 60 cm apart.

Nuts can also be grown in field nursery at a distance of 30 cm x 30 cm. At this distance, a total of 40,000 seedlings/ha can be raised. Seedlings are regularly watered and nuts amply protected against pest. The seedlings are fertilized with 20 g/seedling 2 months after potting and 40 g/seedling five months after potting. An additional amount of 25 g/seedling of potassium chloride after 2 months and 45 g/seedling after 5 months is applied.

7.4. Jatropha

There is no known variety of Jatropha in Samoa. What is available is the red-leaf and green-leaf variety. The performance of different collections of Jatropha is under trial in the Philippines. Jatropha is propagated by seeds. In Thailand, seed production ranges from 0.4 to 12 t/ha. Typical yield levels ranges from 3-4t/ha and oil yield is 30-35%.

Jatropha can be grown in low rainfall areas of 200mm/yr, on low fertility soils, marginal areas such as along canals, roadsides, railway tracks, fencelines and along farm borders. It can be grown even in alkaline soils. The crop is drought tolerant, hardy and easy to establish

8. COST ANALYSIS IN THE PRODUCTION OF BIOFUEL FEEDSTOCK

8.1. Coconut

We assume that coconut farm exists and the farm is weeded and fertilized.

The cost and return analysis of coconut shows that during the 5th year, the palm can generate a copra yield of 24kg/palm/yr. This was generated from a total nut yield of 24 kg/palm. The basic assumption in the presentation in Table 12 is that in one hectare a total of 115 plants can be raised. A palm of about 10 years old can produce a total of 120 nuts / palm per year. At 5 nuts per kilo of copra, a total of 24 kg/palm can be produced per year from a single palm. From 115 palms/ha, a total yield of 2.76tons of copra/ha/yr can be produced. Cost involves fertilization and weeding. A large part of the expenses will be used for harvesting and copra making. Cost of production is SAT 0.96.

Table 12. Cost and return analysis in the production of one hectare coconut.

A. Expenses	
Cost of inputs	
Complete fertilizer, 2.2 kg/palm	SAT 612.5
Urea, 0.5 kg/palm	90
Cost of labor	
Weeding, 16 md,	320
Fertilization, 8 md	160
Harvesting, SAT 40/1000pcs	480
Copra making, 0.5 tala/kg	980
Total	SAT 2642.5
B. Income, 24kg copra/palm, 2760kg/ha, SAT 1.3/kg 3588	
C. Net income: SAT 945.5	

The net income from 1 hectare of coconut is relatively lower. Return on investment was around 36%.

8.2. Cassava

The planting of cassava will be done at a distance of 1 x 1 meter. The cost of land preparation will be computed based on manual clearing and plowing. Stem cuttings will be prepared and this entails additional manpower. Only fertilization and weeding will be done. Since the island has shorter dry season, irrigation will not be practiced. A total yield of 30 tons is targeted. The cost and return analysis in the production of cassava per hectare is presented in Table 13.

Table 13. Cost and return analysis in the production of one hectare cassava.

A. Expenses	
Cost of inputs	
Complete fertilizer, 10 bags, SAT98/bag	SAT 980
Cassava stalks, SAT 0.289	289
Sub-total	SAT 1269
Cost of labor	
Land clearing and preparation, 20md	SAT 400
Preparation of planting materials, 6md	120
Planting, 10 md	200
Fertilizer application, 4 md	80
Spot weeding, 5 md	100
Blanket weeding, 20 md	400
Harvesting, 60 md	1200
Hauling and transportation, 15 md	300
Sub-Total	SAT 2800
TOTAL	4069
B. Income, 30 tons at SAT 0.25/kg	SAT 7500
C. Net income	SAT 3431

Cassava is more profitable than coconut. ROI is 84%. A total of 135 man days is needed to operate a 1 ha farm from planting to harvesting.

8.3. Jatropha

Jatropha will be raised from seedlings. In the field, it will be planted at a distance of 2 x 3 meters with a population density of 1666 plants per hectare. About 1 kg of organic fertilizer per hill will be applied before planting. About 0.5 kg of complete fertilizer will be applied per hill for one year. This can be supplemented with 200 g of urea per hill. Weeding is done regularly as needed especially during the rainy season. The crop is infested with thrips and mites but the pests did not cause a serious threat. Pruning will be regularly practiced and only 3 to 4 vigorous branches are retained. About 3 to 4 months of vegetative flushing will pass before the three will flower.. A total of 24 fruiting branches can be found per plant. A plant with 36 branches will yield a total of 5tons/ha. Jatrophha comes to flowering twice a) first is during the onset of the rainy season and b) second is during the onset of the dry season. With pruning, flowering becomes non-seasonal. Fruits mature in 1 month. While the fruits do not ripen at the same time in a bunch, the nuts have been reported to have homogenous oil quality. The cost and return analysis for 1 hectare of jatropha is presented in Table 14. Jatropha will be processed and hauled on per kilo dry weight basis.

Fertilization will be increased gradually. Urea will applied starting on the second year at the rate of 100 g/plant up to 4th year. On the 5th year onwards, it will be applied at the rate of 150 g/plant. Complete fertilizer will be applied initially at 4 bags on the 1st, 8 bags/ha on the 2nd, 12 bags on the 3rd, 16 bags on the 4th and 20 bags on the 5th year.

Harvesting will commence on the 2nd year with a yield of 1 ton/ha. This will increase to 1.5 tons on the 3rd year, 2 tons on the 4th year and 5 tons on the 5th year onwards. Hauling will be paid at the rate of 0.01SAT while on site processing starts with 2 md during the first fruiting year. All labor cost is paid at a daily rate of SAT 20/day

Table 14. Cost and return analysis in the production of one ha jatropha farm

Items	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6
Cost of inputs						
Complete fertilizer	392	784	1176	1563	1960	1960
Urea	-	240	240	240	360	360
Planting materials	833	-	-	-	-	-
Sub-total	1225	1024	1416	1803	2320	2320
Cost of labor						
Land preparation 10 md	200	-	-	-	-	-
Staking, 4 md	80	-	-	-	-	-
Digging planting holes, 30 md	600	-	-	-	-	-
Planting, 6 md	120	-	-	-	-	-
Replanting, 2 md	40	-	-	-	-	-
Fertilization, 8 md	160	160	160	320	320	320
Weeding, 15 md	300	300	300	400	400	400
Pruning, 10 md	-	200	200	240	240	340
Harvesting, 0.1/kg	-	100	150	200	200	500
On site processing	-	40	80	120	120	300
Hauling	-	10	15	20	20	20
Sub-total	1500	810	905	1300	1300	1880
Total	2725	1834	2321	3103	3620	4200

8.4. Breadfruit

Breadfruit will be raised using grafted plants at a distance of 10 x 10 meters or at a population density of 100 trees per hectare.

The amount of fertilization for breadfruit increases with time. Coronel (1983) recommended the application of 100-200 g ammonium sulphate per tree one month after planting. This is repeated after 6 months. At bearing 300-500 g of complete fertilizer is applied per tree. The application of fertilizer is repeated before the end of the rainy season. Ammonium sulphate is available from the local market at around

SAT 40/bag of about 40 kg while complete fertilizer is sold at SAT 98/bag. The trees being grafted will bear fruit on the third year.

Yield of breadfruit varies (Table 15). Based on the data presented above, yield in Samoa could reach up to 18 tons/ha. Purseglove (1968) reported a yield of as many as 700 fruits per tree each having an average of 1-4 kg. In the Caribbean, a tree could produce 900 or an average of 200 fruits per tree. (Marte, 1986). Morton (1987) reported a conservative yield level of 50 to 150 fruits per tree. This is quite lower and may be due to the age of the tree used as basis for the report.

Table 15. Cost and return analysis in the production of one hectare breadfruit.

Item	0yr	3yr	6yr	9yr	12yr	15yr
Cost of inputs						
Planting materials						
100 plants at 5 SAT	500	-	-	-	-	-
Fertilizer						
Ammonium sulphate,	20	60	100	150	200	400
Complete fertilizer	47	147	245	368	490	980
Pruning shears, 2 pcs	26	-	-	-	-	-
Knapsack sprayer	210	-	-	-	-	-
Pruning saw, 2 pcs	-	-	53	-	-	-
Sub total	803	207	398	518	690	1380
Cost of labor						
Clearing, 10 md	200	-	-	-	-	-
Laying out, 2 md	40	-	-	-	-	-
Hauling, 2 md	40	-	-	-	-	-
Hole digging, 8 md	160	-	-	-	-	-
Planting, 4 md	80	-	-	-	-	-
Basal fertilization, 2 md	40	-	-	-	-	-
Weeding, 20 md	400	800	800	800	800	800
Fertilization, 6 md	120	120	120	160	200	200
Pruning	40	80	100	100	120	120`
Subtotal	1000	1020	1020	1060	1120	1120
Total	1803	1227	1418	1578	1810	2400
Income						
Marketable yield (number of fruits per tree)	-	50	150	150	150	150
Marketable yield (kg/tree)	-	60	180	180	180	180
Sales SAT 0.5/kg		3000	9000	9000	9000	9000
Net income	-1803	1773	7582	7422	7190	6600

9. PROCESSING METHODS OF BIOFUEL PRODUCTION

The following paragraphs describe process description of bioethanol and biodiesel productions.

9.1. Bioethanol

The following are processing methods of bioethanol production from starch, saccharine and cellulosic materials such as cassava, sugarcane and breadfruit wastes rspectively.

9.1.1. Ethanol Production from Cassava

PRIMARY PROCESSING (Rañola et al., 2007)

The primary process flow is shown in Figure 11. The fresh cassava tubers from farms will be weighed and classified according to their moisture content and purity at the receiving section. In order to minimize the loss of starch brought about by deterioration, the tubers must be processed not more than three days after delivery.

Fresh cassava tubers are then mechanically washed to remove impurities followed by peeling using a mechanical peeler. In order to increase the surface area, the peeled cassava tubers are chipped into uniform thickness. Drying of cassava chips is about 3 times faster than drying it in peeled tuber form.

Open sundrying will be employed during the dry season months when solar radiation is high and incidence of rainfall is small. During the wet season months, however, mechanical dryers will be utilized. It is assumed that throughout the harvest period, the initial moisture content of freshly harvested cassava meat is 60 percent wet basis. The desired final moisture content is 14 percent.

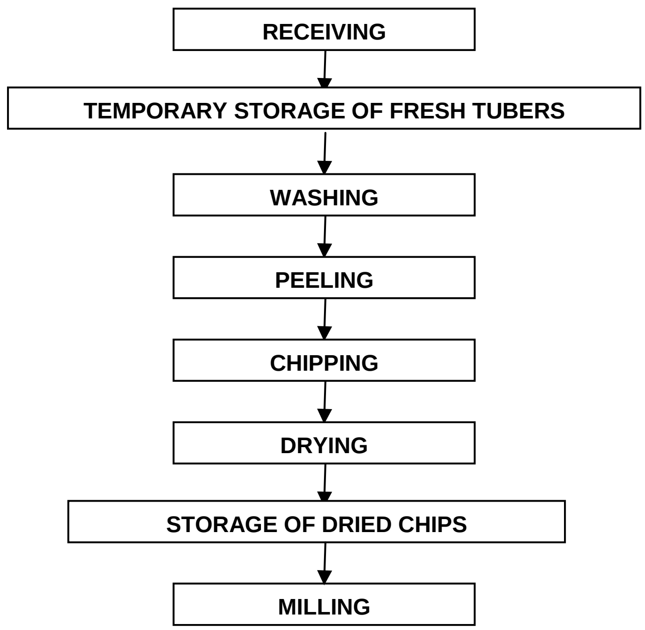


Figure 11. Process flow in the primary processing plant under the Corporate Farming Scheme, 2008.

WASHING

Before fresh cassava tubers are processed, impurities such as mud, sand and stones, must be removed. These impurities constitute about 5% of the total tubers' weight.

The washing step requires about 0.3 liters per kilogram of fresh cassava.

Belt conveyors will be used to convey cleaned fresh tubers to the peelers.

PEELING

The outer skin and the inner peel, which constitute about 16% of the total weight of the cleaned fresh tubers, are removed during peeling.

The cassava peels will be conveyed outside the processing plant using augers. Cassava peels will be sun dried from initial moisture content of 69% to final moisture content of 20%, which will then be stored and used as fuel for mechanical drying during wet season.

Cassava meat will be conveyed on belt conveyors to the chippers.

CHIPPING

Chipping is done to facilitate drying.

DRYING

Drying, to lower the moisture content from 60% to 14%, must be undertaken not later than three days of cassava tuber storage. Drying operation will be carried out in two ways: (1)

open sun drying during dry season (i.e. February to May) or when the weather permits and (2) mechanical drying during wet season (i.e. June to August). Due to cost consideration, this project will be very dependent on open sun drying.

Open sun drying can only be done at a maximum of 10 hours per day (7:00 AM to 5:00 PM). On the other hand, mechanical drying can be done 24 hours per day at 60°C drying temperature.

Cassava peel from the peeling operation and biogas from beer production will be used as fuel for the mechanical dryers.

MILLING

Milling using hammer mills is the last operation for the primary processing of cassava.

SECONDARY PROCESSING (Del Rosario et al., 2007)

STOICHIOMETRY OF ETHANOL PRODUCTION FROM DIFFERENT SUBSTRATES

Ethanol production from glucose (dextrose) by distillery yeast *Saccharomyces cerevisiae* is accompanied by the formation of minor by-products, such as acetaldehyde and glycerol, and of yeast biomass. Product partitioning depends on actual conditions such as concentrations of dissolved oxygen and glucose, pH and temperature. A general reaction mechanism for the conversion of glucose into ethanol and other products in yeast cell is presented below (Scheme 1):

$$\underset{\text{glucose}}{C_6H_{12}O_6} + NH_3 + O_2 \longrightarrow \underset{\text{yeast biomass}}{(CH_{1:62}O_{0.53}N_{0.15} + 1.29\ \text{ash})}$$

$$+ \underset{\text{ethanol}}{C_2H_5OH} + \underset{\text{acetaldehyde}}{CH_3CHO} + \underset{\text{glycerol}}{\begin{matrix} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{matrix}} + CO_2 + H_2O$$

(Scheme 1)

Under ideal conditions glucose is converted into ethanol in stoichiometric amounts, as shown in Scheme 2:

$$\underset{180\ \text{grams}}{C_6H_{12}O_6} \longrightarrow \underset{2 \times 46\ \text{grams}}{2C_2H_5OH} + \underset{2 \times 44\ \text{grams}}{2CO_2}$$

(Scheme 2)

According to reaction scheme 2, glucose is completely converted into ethanol. The substrate-to-product yield coefficient ($Y_{p/s}$) may be calculated from the mass ratio of substrate and product:

$$Y_{p/s} = \frac{\Delta P}{\Delta S} = \frac{\text{mass of product formed}}{\text{mass of substrate utilized}} \quad (1a)$$

$$Y_{p/s} = \frac{2 \times 46 \text{ grams}}{180 \text{ grams}} = 0.51 \quad (1b)$$

The fermentation efficiency (F.E.) in percent is calculated from the ratio of the actual yield coefficient to the stoichiometric or theoretical yield coefficient, equal to 0.51, as shown below:

$$\text{F.E.} = 100 \frac{(Y_{actual})}{(Y_{stoich})} \quad (2)$$

Ethanol can be produced from various substrates. The reaction scheme is shown below:

$$\frac{n}{2}(C_{12}H_{22}O_{11} + H_2O) \text{ (sucrose, n/2 (342 grams))} \xrightarrow{\text{invertase}} nC_6H_{12}O_6$$

$$\underset{\text{starch/cellulose/hexan, n (162 grams)}}{(C_6H_{10}O_5)n + nH_2O} \xrightarrow{\text{enzymes or acid}} \underset{\text{glucose, n (180 grams)}}{nC_6H_{12}O_6} \xrightarrow[\text{glycolytic enzymes}]{} \underset{\text{ethanol, 2n (46 grams)}}{2nC_2H_5OH} + 2nCO_2$$

(Scheme 3)

Hydrolysis of sucrose to glucose and fructose, is catalyzed by the enzyme invertase present in the yeast cell wall. The hydrolysis of the carbohydrate polymer (starch, cellulose or hexan) into glucose requires an acid or the corresponding enzyme (amylase, cellulase or hexanase). It should be noted that only polymers of a six-carbon sugar (hexose) such as glucose, fructose or mannose may be converted into ethanol by yeast (*S. cerevisiae).* However, pentoses, e.g. xylose, are now recently converted into ethanol by the advances in genetic engineering responsible for the development of new yeast strains. Alternatively, wild-type microorganisms may be used to directly ferment pentoses to ethanol.

From Scheme 3, $Y_{p/s}$ values can be calculated similar to those in equations (1a) and (1b):

$$Y_{p/s} = \frac{\Delta P}{\Delta S} = \frac{2n \text{ (46 grams)}}{n/2 \text{ (342 grams)}} = 0.54 \text{ (based on sucrose)} \quad (3a)$$

$$Y_{p/s} = \frac{\Delta P}{\Delta S} = \frac{2n \text{ (46 grams)}}{n \text{ (162 grams)}} = 0.57 \text{ (based on hexose polymer, e.g. starch)} \quad (3b)$$

The fermentation efficiency based on glucose, sucrose or hexose polymer may be calculated using the corresponding $Y_{p/s}$ values in equations (1b), (3a) and (3b).

SECONDARY PROCESSING OF CASSAVA FOR ETHANOL PRODUCTION

The main processes for ethanol production from cassava are shown in Figure 12 and are composed of the following:

(a) Liquefaction – gelatinization and dextrinization
(b) Enzymatic saccharification
(c) Ethanol fermentation
(d) Distillation – stripping, rectification and dehydration

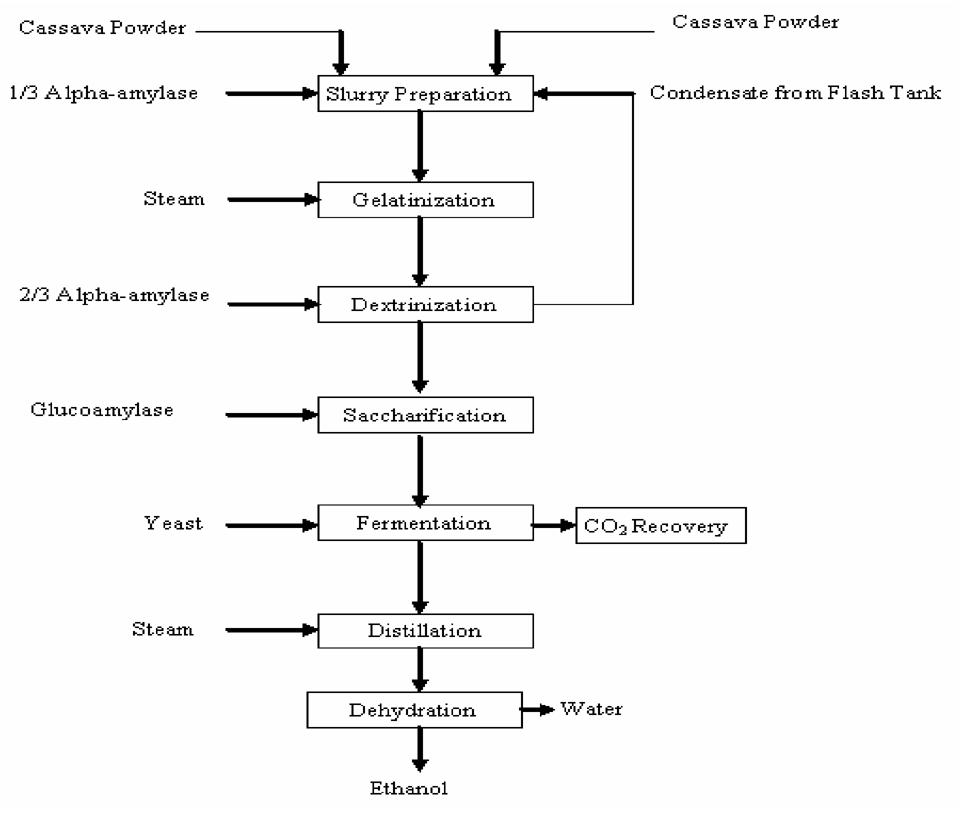


Figure 12. Flow Diagram for Ethanol Production from Cassava Powder.

Generally, the starchy substrate, cassava powder for example, is slurried in water, gelatinized with steam and then liquefied with alpha-amylase in order to dissolve and dextrinize the starch. The starch may be liquefied and pre-saccharified using alpha-amylase first and then with glucoamylase. The resulting sugar is cooled and transferred to the fermenter, where the yeast is added. Fermentation may be done in a continuous process with residence times of around 24-30 hours. This may also be done in batches, however, this processes often proceed at a higher dry matter level than when using continuous-flow processes. Ethanol from the fermented liquor ('beer') is then purified using a distillation process, wherein the ethanol is separated from the remaining stillage or slops. The ethanol is then concentrated by dehydration.

Cooking Process with Enzymatic Liquefaction

The starchy powder, after cassava chips milling, is cooked or gelatinized, dextrinized and then saccharified to convert starch to glucose. Gelatinization consists of dissolution of starch into a mash by steam cooking. Dextrinization involves the breakdown of the gelatinized starch into smaller fragments or dextrins by means of alpha – or beta-amylase or dilute acid, and saccharification consists of complete conversion of the dextrins into glucose through the action of glucoamylase or acid. Enzymes are favored over acid in starch hydrolysis since they are more selective and the product yields are higher.

Cassava powder is transferred into a continuous liquefaction tank, which is then added with alpha-amylase; the latter is heated with steam in order to maintain the temperature at 88 ^{0}C. In order to keep the pH at the optimum level (pH 6) and to supply calcium for the alpha-amylase, used caustic (soda) from the clean-in place as well as lime are mixed with the mash. Alternatively, new types of alpha-amylase are used which do not require exogenous calcium. Urea provides nitrogen to the yeast. The mash is then gelatinized at a temperature above the cassava starch gelatinization temperature of about 65^{0}C. Granules absorb a sufficient amount of water and enlarge to many times their original size as they are exposed to a temperature beyond that of the gelatinization temperature. This causes the starch granules to open up enough for the alpha-amylase to hydrolyze the long starch chains into shorter dextrins. The irreversible gelatinization, or starch paste formation, is characterized by an increase in solution viscosity, melting of the starch crystals, loss of birefringence and starch solubilization.

The alpha-amylase's action on the gelatinized starch results in a dramatic reduction of solution viscosity. In order to prevent retrogradation or recrystallization of the starch, dextrinization must be done immediately without allowing the solution to cool. Retrogradation produces a highly stable crystalline material that cannot be degraded by alpha-amylase leaving it unchanged in the fermenter. Retrogradation occurs when mash at low dextrose equivalent (DE) is exposed to 'cooled' surfaces such as those in heating exchangers used for cooling. The gelatinized starch mash should be cooled rapidly using a vacuum. The whole mash from a dry mill must be cooled to 80-85°C for effective liquefaction.

Pre-saccharification Process

Liquefaction and saccharification are the major steps in starch conversion. Starch slurry is first cooked in the presence of a heat-stable bacterial endo-alpha-amylase, which hydrolyses the alpha-1, 4-glycosidic bonds in pre-gelatinized starch. In effect, the viscosity of the gel decreases and maltodextrins are produced. Simple fermentable sugars (monosaccharides) result after further hydrolysis with glucoamylase (amyloglucosidase). The industrially important alpha-amylases used for liquefaction and saccharification are those from *Bacillus licheniformis, Bacillus subtilis and Aspergillus oryzae*.

Due to possible infection, saccharification has been a generally avoided process in fermentation plants. The process remains limited although new enzymes that can work at 65°C can be used in saccharification to reduce infection. High dextrose levels are intolerable for batch fermentation since high osmotic pressure significantly inhibits the yeast cells. When saccharification is used prior to fermentation batch processes, the enzyme dose can be reduced by 5-10%.

The saccharified mash in continuous fermentation undergoes continuous dilution as it mixes into the first fermenter. That is if desired, the mash can be fully saccharified prior to fermentation. The saccharification reaction is particularly fast until 70% dextrose and starts to slow down as the 95% dextrose is reached. Fermentation basically reduces the dextrose level by taking away the dextrose product, thereby increasing the saccharification reaction rate in the fermenter. The economic optimum is therefore found to be within 50-70 DE in the fermenter feed.

SIMULTANEOUS SACCHARIFICATION AND FERMENTATION (SSF)

Continuous saccharification and fermentation is successfully utilized by dry milling. When dry milling is employed, full utilization of fermentation vessel capacities (no filling/draining/sanitation) can be achieved. Also, there is easy control of continuous flows and the assurance of product consistency. Its disadvantages include susceptibility to infection from the whole grain and stillage recycle, and the disruption caused to production by the occasional sanitation of the fermenters.

Ethanol, CO_2 and biomass are produced during fermentation. Thus by measuring the CO_2 production as weight decreases or by HPLC analysis of ethanol, ethanol production and fermentation efficiency may be determined. The amount of ethanol produced can be computed based from the CO_2 produced by using stoichiometric ratios.

Ammonia, urea or a protein-degrading enzyme is added to the mash because of the low level of soluble nitrogen compounds in cassava. When nitrogen is insufficient, the growth of yeast is poor and the fermentation time is longer.

BATCH SACCHARIFICATION AND FERMENTATION (BSF)

Batch process for saccharification and fermentation usually take longer times and require greater volume and cost of container tanks. Pullulanase enzyme is usually required in order to prevent formation of unwanted reversion products from the starch hydrolyzate. However, batch processes minimize the adverse effects of contamination because process flows can easily be stopped for cleaning of process equipment.

DISTILLATION AND DEHYDRATION

Before the 8.5% beer from fermentation vats, the beer is first pumped to storage tanks with one-day storage capacity to stabilize liquid flow and achieve constant volumetric flow rate. The beer is then preheated to about 150ºF before finally being pumped to the distillation colum. The distillation column consists of stripping and rectifying sections with 46 and 56 plates, respectively. The stillage, which is residue from this process, contains non-fermentable solids and water and is pumped out from the bottom of the columns into the plate heat exchanger in order to pre-heat the beer before being fed to the beer column. The hot slops is subsequently cooled before brought to the wastewater treatment plant.

The bottoms product at 210ºF from the stripping column is used as heating medium in the pre-heater. Meanwhile, part of the vapor product of the stripping section is returned back to the column as reflux after passing through a condenser and the rest of the vapor is sent to the rectifying column.

In the rectifying column, water is further removed from the 90% vapor to produce a 95.6% by volume ethanol product, which is then sent to the molecular sieves column for further dehydrate the ethanol to produce 99.7% (v/v) ethanol. Two sieve columns are employed alternately to allow regeneration of the other without interrupting the process. The sieve column consists of 3 Å molecular sieve.

9.1.2. Ethanol from Sugarcane

A direct source of sugar for bioethanol production can be obtained from sugarcane. In the factory, the **millable stalks are weighed and prepared** for milling, then sent to the milling tandem for extraction of juice. The performance of the mill is measured in terms of **pol extraction** ([pol in mixed juice/(pol in mixed juice + pol in bagasse)] [100]). **Imbibition water** is added to the penultimate mill, in order to facilitate extraction of more juice from the cane. The level of pol extraction is directly proportional to the amount of imbibition water added during milling. Its amount is only limited by the energy requirement in the evaporators, which would later remove most of the water content of the clarified juice. After extraction, the process materials are divided into two namely, the **mixed juice** and the **bagasse. Bagasse** is the lignocellulosic by-product, which is sent to the furnace as fuel to generate heat for the boilers or steam generators. For an independent raw sugar factory (with no adjacent distillery or sugar refinery), some surplus bagasse may be obtained (about 20-25%) even after generating the required steam and electricity of the same factory. This surplus bagasse may then be used for other purposes, which in case of bioethanol production, may be converted to ethanol, either by biochemical or thermochemical process.

Mixed juice is the main process material which will be sent to the clarification station to remove the impurities (or non-sugars) from the juice. In a sugar factory, the **clarified juice** is sent to the multiple-effect evaporators to concentrate the juice, which will later be called **syrup**. After clarification, clarified juice and mud are produced. The mud is sent to a rotary vacuum filter where **filtrate** and **filtercakes** are obtained. The filtrate is returned to the process, while the by-product **filtercake** is collected and sent to the plantations. This material may be used to produce **organic fertilizer.** Castro (2006) cited the results of Quilloy (1983): mixing urea with various proportions of filtercake tended to produce higher cane and sugar yields than the application of urea alone or mudpress alone.

Potential substrates for fermentation

Clarified juice is about 16 Brix (or % soluble solids). Syrup is about 65 Brix. In case the syrup will be used as a substrate for fermentation, then its % brix should be much lower than this value, as the yeast (***Saccharomyces cerevisiae***, L.) or the bacteria ***(Zymomonas mobilis***, L.) will not thrive in 65 Brix. In case mixed juice will be used as substrate, then it should be subjected to an effective filtration to remove the non-sugars, even without the clarification process (heating, liming for coagulation/flocculation).

In a conventional sugar factory, the syrup is sent to the pan station for crystallization, to produce **massecuite** (mother liquor + sucrose crystals). Massecuite is centrifuged to produce **raw sugar** (about 97.5% sugar) and **final molasses. Final molasses** is a by-product which is still sugar-rich (about 55 % sugar including sucrose, glucose and fructose), hence it has always been used as a raw material for potable ethanol production.

Fermentation and Distillation

From the sugarcane plant, the potential substrates for fermentation are: the **filtered mixed juice, clarified juice, syrup, final molasses and the lignocellulosic bagasse.**

For a successful conversion to alcohol in a commercial scale, the following factors are very important: a) the choice of suitable type of yeast or bacteria, that will give the highest alcohol yield; b) the use of the right ingredients and correct amounts to serve as nutrient for the yeast and enhance its growth and vigor; c) the use of water that is free from undesirable substances; d) the use of suitable fermentation apparatus; and e) the fermentation technique that can be used to advantage to get maximum results (PHILSUTECH, 1992).

As in any fermentation, this process requires careful monitoring and control of the yeast/bacteria, pH and temperature to get the best results. Maintenance of pure strain of microorganisms is very vital in fermentation. The following procedures are adopted from the PHILSUTECH handbook.

Agar-agar slant culture. The starting point in the preparation of the fresh batch of yeast for each day's fermentation is the selection of a single yeast-cell from a master culture of a yeast that is well acclimatized. This is accomplished by dipping a sterilized platinum needle into the flask and brushing it over the surface for a sterile medium, hardened in a Petri dish. After several streaks are made, the point is finally reached where only single cells are dislodged on the medium. Following incubation for about 48 hours at 75 to 80°F, colonies of cells are visible to the naked eye.

After microscopic and macroscopic examination, four or five of the best of these colonies are selected from amongst the colonies which do not touch adjacent groups. It should be certain that each of the colonies grew from a single cell. Then these selected colonies are used to inoculate fresh media in test tubes. After one to two days, the best tube is selected. This is used to inoculate fresh tubes as the starting point in the production of pure culture yeast.

Culture from dried yeast. Sterilized and cooled molasses (10 Brix) in big culture flasks are used for yeast seeds. Into this solution are added 5 g of yeast/liter of wort; ammonium sulfate (1 g/liter of wort), and concentrated sulfuric acid (½ ml/liter of wort) to adjust the pH between 4-5. The flasks are covered with cheese cloth or cotton wad.

After 6 hours, the yeast becomes very active. Afterwards, the fermenting mash is transferred into demijohns. From this, it is gradually built up until the yeast attains sufficient vigor when it is transferred into the pure yeast culture apparatus containing sterilized and cooled molasses solution of 12 Brix. Yeast seed is aerated for its development. About 1.5 cu. ft/min./cu.ft, of fermenting mash gives optimum results.

After a sufficient amount of yeast seed has been built up in the bioreactor, then the seed is dropped into the pre-fermenters containing molasses solution of 15 Brix. Every time additional amounts of molasses are added, the corresponding doses of ingredients are also added. The mother yeast is maintained in the pre-fermenters, for the inoculation of the mother mix in the fermenters. The yeast seed is changed completely once contamination is observed.

Molasses of the desired brix, with the proper amount of ingredients, is pumped into the fermenters. The required amount of inoculant (or mother yeast) is about 10-12% of the capacity of the main fermenters. It has been observed that the yeast is most vigorous when the alcohol content of the beer is within its range of tolerance which is about 2.5 to 3.0 %, or an attenuation of 5 to 6 Brix.

Fermentation may also be incremental, fed-batch, or even continuous. At present, the fermentation industry also uses the following: pre-treatment of molasses, use of pure yeast apparatus, continuous fermenter. The ***Melle-Boinot*** process uses yeast sediment from the fermenters, separated by centrifugation. The diagram is as follows:

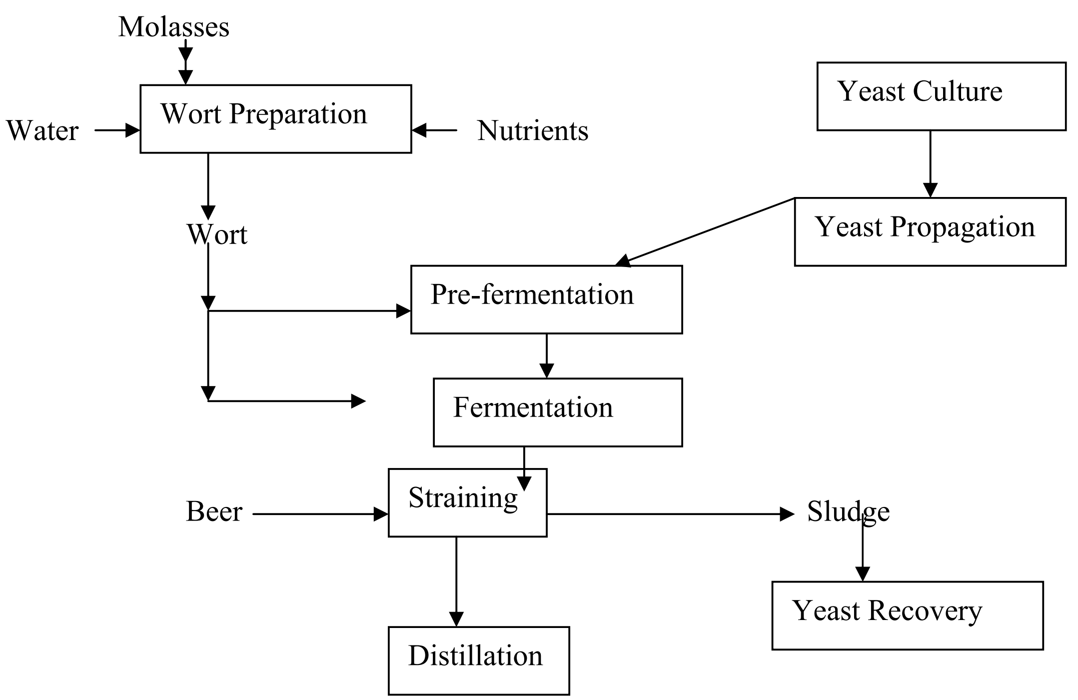


Figure 13. Flowchart of fermentation process: *Melle-Boinot Process*
(PHILSUTECH, 1997).

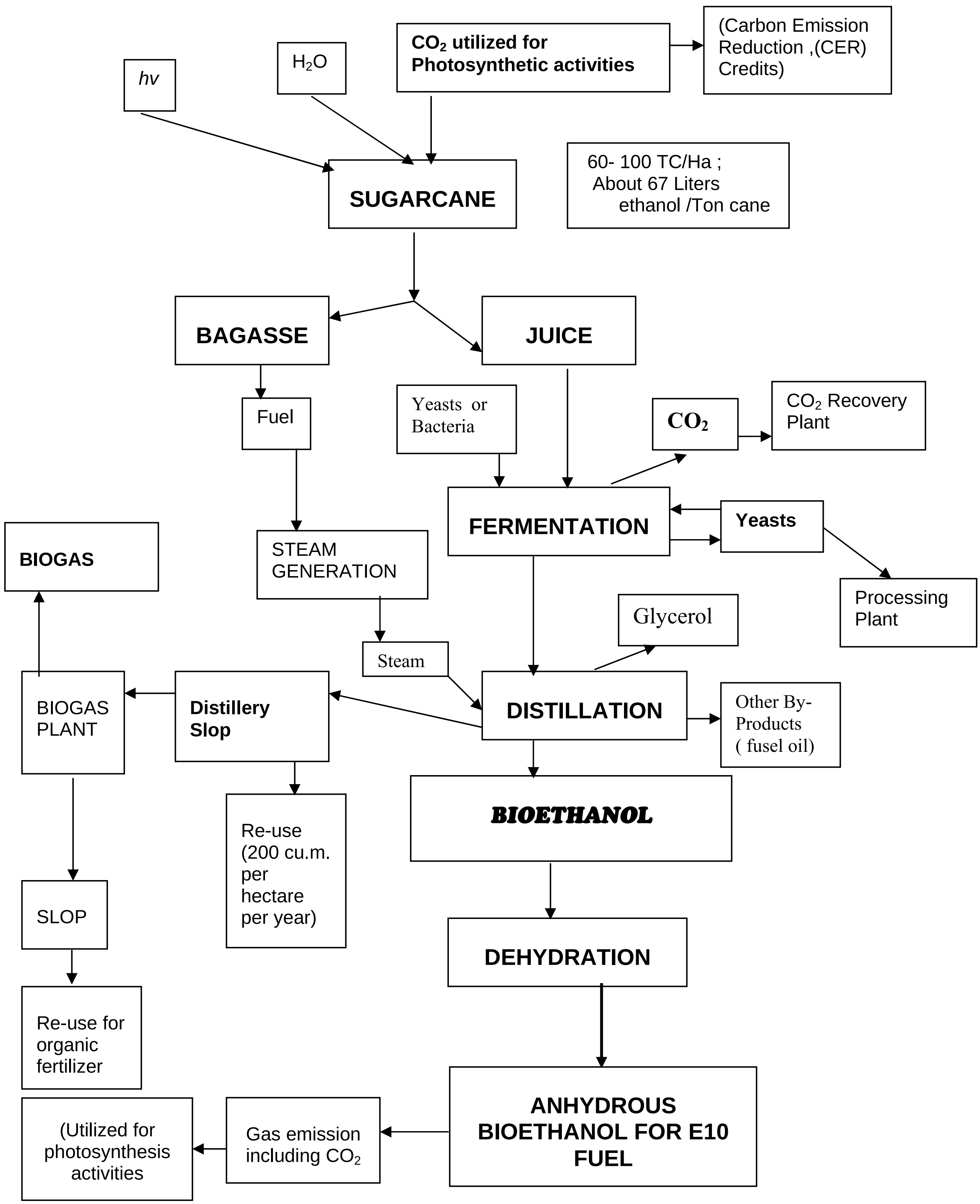


Figure 14. Flowchart of Bioethanol production from Sugarcane
(Source: Demafelis, Movillon, Badayos and Bataller, 2008).

9.1.3. Ethanol from Breadfruit Wastes

Another potential feedstock for bioethanol production is the breadfruit (*Artocarpus altilis*). Locally known as ulu, breadfruit is one of Samoa's most important traditional food staples. The most common varieties are maopo, puou, ma'afala and moamoalega. Since breadfruit is used as a staple food in Samoa, description to produce ethanol focus only on its wastes. On the average, it contains about 33% cellulosic wastes which can be pretreated and saccharified for bioethanol production. From an average fruit yield of 200 fruits per tree and mass of 1.2 to 2 kilogram per fruit, the minimum weight of cellulosic wastes that can be obtained would be about 79.2 kilogram per tree. These cellulosic wastes, which contain about 10% moisture, need to be dried first before any further processing. Then after drying, crude fiber should be extracted from the dry matter. The crude fiber, which is about 15% of the dry matter, can be saccharified to breakdown the starchy material to fermentable sugar. Assuming 50% saccharification efficiency, about 5.346 kilogram fermentables can be produced and fermented. For every kilogram of fermentable sugar, about 0.61 liter of theoretical 'beer' can be obtained and assuming 90% fermentation efficiency, about 2.93 liters of 'beer' per tree can be produced. The beer still needs to be purified by distillation and dehydration to produce anhydrous ethanol for fuel application. Assuming 98% distillation efficiency and 99.8% dehydration efficiency, about 2.87 liters of anhydrous ethanol can be produced. At present, ethanol production from cellulosic material is still expensive compared to starchy and saccharine materials. The schematic diagram for bioethanol production from the cellulosic wastes of breadfruit is presented below:

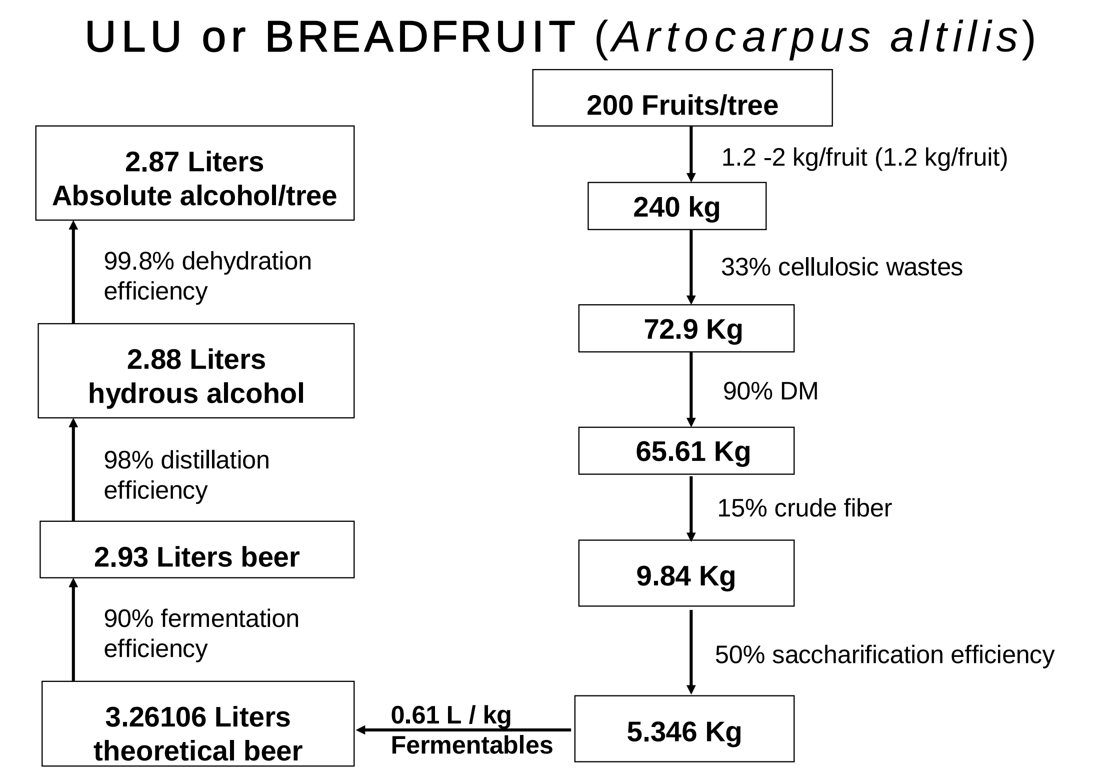


Figure 15. Schematic Diagram for Ethanol Production from Breadfruit (MOVILLON and BORINES, 2008).

9.2. Biodiesel

The following are the processing methods of biodiesel production from Jatropha, coconut and palm oils.

9.2.1. Jatropha Biodiesel Production

Fresh jatropha fruits are processed to remove impurities such as mud. Cleaned fresh jatropha fruits will be dehusked and deshelled to expose the seed for oil extraction.

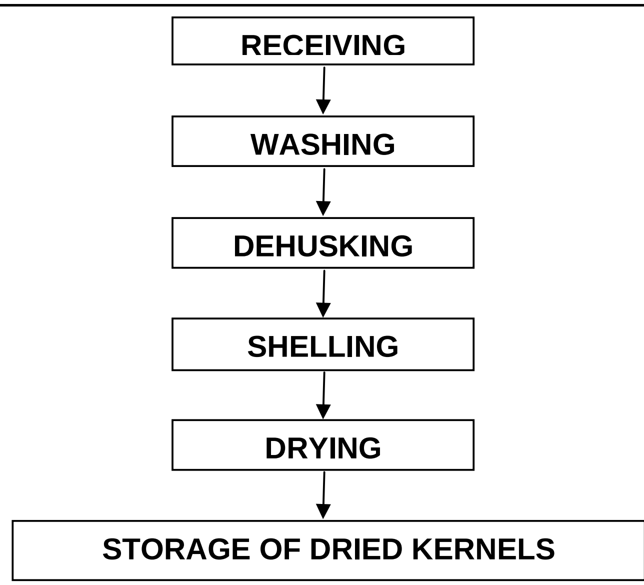


Figure 16. Primary Processing of Jatropha Seeds

Recovery of oil from any oil bearing seeds or materials can be done by mechanical, chemical or enzymatic extraction. Mechanical extraction has been commercially used for economic reason and ease in operation. The oil undergoes a series of pretreatments to remove or reduce the inherent gums, free fatty acids (FFA) and solid contents to acceptable levels. Gums are usually removed by adding 5-10% water to a pre-heated oil sample and allowing it to react for about one hour. The temperature of the sample is maintained at $60^{o}C$ in a water bath with constant stirring at approximately 400rpm. After degumming, the oil-water mixture is allowed to cool down and settle. Centrifugation is done in order to separate the gums from the oil-water mixture. The oil-water mixture is then heated to 80°C until it becomes clear. Sample of the degummed oil is subjected to a standard titrimetry method to determine its acid value and FFA level. When the FFA content of the oil is more than 5%, acid esterification is employed to reduce its level and recover some of the initial biodiesel formed. Measured amounts of methanol (2.25 g per gram of FFA) and sulfuric acid (0.05 g per gram of FFA) are reacted to a known amount of oil. Reaction is carried out at 60°C with constant stirring for one hour. Neutralization of FFA is normally done when FFA level is below 5%. FFAs are converted to soaps using 12% (w/v) sodium hydroxide (NaOH). Caustic refining of oil is performed at 50-60 °C for 30 minutes with constant stirring. The soaps are separated by centrifugation. In this process no initial biodiesel is formed. Then mist-washing of the pretreated oil follows to remove the impurities (salts, glycerol etc.) formed during the removal of FFA. Drying is employed by heating the oil-water mixture to prepare the oil for the transesterification process or the main biodiesel production stage. At this point, the oil is now refined and could be used for many purposes after filtration. Biodiesel maybe produced through acid, base or enzyme catalyzed reactions. The commonly used commercial production process is the base-catalyzed reaction of an alcohol with the triglyceride oils forming biodiesel (or fatty acid alkyl esters) and glycerol as by-product in a two phase mixture. The reaction is carried out under the optimum conditions (Demafelis et al., 2008) of 1:6.89:0.2 oil-to-methanol-to-NaOH molar ratio and 30mins reaction time at a reaction temperature of 53.7 °C. Glycerol and biodiesel are then recovered and both phases are refined to get high value price and application of each product. The biodiesel then undergoes a series of post-treatments to remove residual glycerol and other impurities by a combination of washings and drying. Washing is usually done by mist-spraying the biodiesel formed with 2% brine solution to remove excess glycerol. Then succeeding mist-spraying with distilled water aims to remove the excess salt solution in the biodiesel during the removal of residual glycerol. Then the biodiesel is dried and filtered to meet both moisture content and particulate specifications.

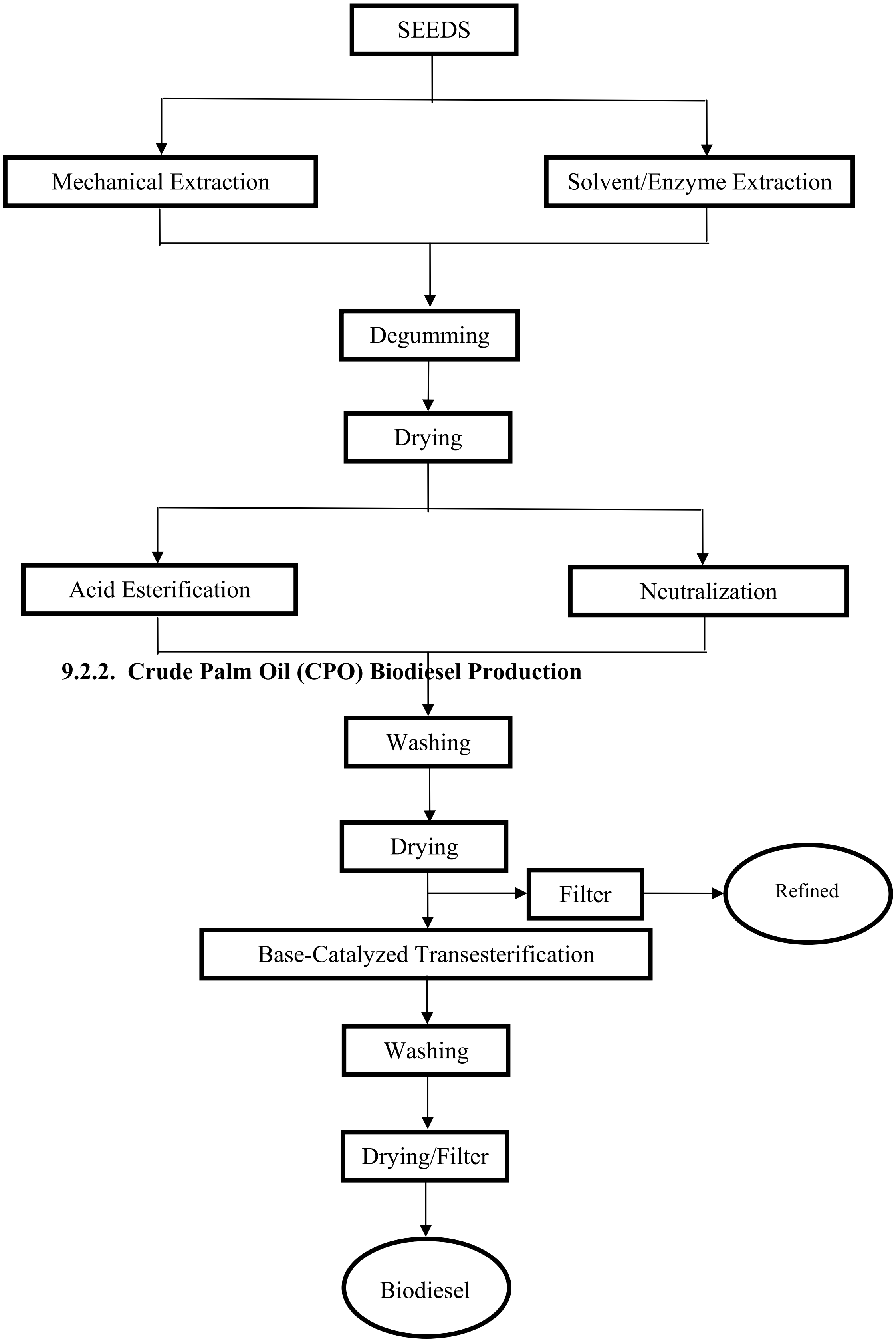


Figure 17. Process Flow Diagram for Jatropha Biodiesel Production

9.2.2. Crude Palm Oil (CPO) Biodiesel Production

Similar to Jatropha, after oil extraction, crude palm oil is preheated to a temperature of about 90-110ºC. Phosphoric acid is used in the removal of gums. The amount of phosphoric acid used is normally within the range of 0.05 – 0.1% of the oil weight. After degumming, the oil is treated with bleaching earth at 100 ºC before entering a vacuum bleacher. The amount of the acid activated clay is usually in the range of 0.5 – 2.0% by weight of oil and the residence time with continuous stirring is about 30 minutes. The adsorptive effect of the bleaching earth removes the trace metal complexes such as iron and copper, pigments, phosphatides and oxidation products as well as any residual phosphoric acid. The bleached oil is then filtered. The filtered oil undergoes deacidification and deodorization treatment. The process uses a combination of high temperature heating approximately about 240 - 260 ºC, under vacuum (2-4mmHg) and direct steam injection of about 2.5 – 4.0% by weight of oil (Leong, 1992 as cited by Morad). Free fatty acid in the form of palm acid distillate (PFAD) is removed as refining waste during the deodorization process. Carotenoid pigments, primary and secondary oxidation products are also removed in this process. The deodorized oil is then cooled before undergoing filtration. The filtered oil which is now refined oil will undergo a transesterification process. The reaction is carried out under the optimum conditions of 1:6:0.01 oil-to-methanol-to-KOH molar ratio and 60mins reaction time at a reaction temperature of 65°C.

Factors Affecting the Synthesis of Biodiesel from Crude Palm Kernel Oil

Results of study of Lalita Attanatho et al (2004) indicated that the catalyst concentration was the most important factor affecting the methyl ester yield. Other important factors are temperature, mass ratio of methanol-to-oil, and reaction time. This study also showed the optimum conditions for the synthesis of biodiesel from crude palm kernel oil, namely:

- room temperature
- 1% NaOH catalyst
- 1:3 mass ratio of methanol to oil
- 120 minute reaction time

The 92.77% production yield and 99.27% methyl ester concentration were obtained after using these optimum conditions.

Table 16. Factors affecting synthesis of FAME from Palm Oil.

FEEDSTOCK	NIGERIAN PALM KERNEL OIL (PKO)	THAILAND CRUDE PALM KERNEL OIL	PALM FATTY ACID DISTILLATE (PFAD)
Transesterification reaction conditions			
Temperature	60ºC	Room temperature	65ºC
Acid catalyst	-	-	1.834 wt. %
Catalyst			
NaOH	-	1%	0.396 M in methanol solution
KOH	1.0%	-	-
Reaction time	90 min.	120 min.	90 min.
Ethanol to Oil	1:5	-	-
Methanol to Oil	-	1:3 mass ratio	4.3:1 molar ratio
Biodiesel Yield	96%	92.77%	-
Methyl ester concentrate	-	99.27%	98%
Reference	Alamu et. al, 2007	Lalita et. al, 2004	Chongkhong et. al, 2007

9.2.3. Coconut Biodiesel Production

Similar to Jatropha and palm, after oil extraction, **c**rude coconut oil undergoes a series of pretreatment processes such as degumming, and acid esterification or neutralization depending on its FFA content to produce refined oil. Transesterification (or biodiesel production) of the refined oil is done using the optimum conditions of 1:6:0.01 oil-to-methanol-to-NaOH molar ratios. Maximum methyl ester yield is achieved in one hour reaction time under the reaction temperature between 60-67°C.

10. USE AND POTENTIAL OF BIOFUELS

10.1. Brazil

Brazil and US share the top billing in terms of ethanol production. While US is using corn as its primary feedstock, Brazil is using sugarcane. For crop season 2003/2004, Brazil produced 14.4 billion liters of ethanol from sugarcane generating an income of over US$ 8 billion and creating approximately 1 million jobs (Macedo et al 2004) Brazilian sugarcane – ethanol processing is the most competitive production system globally at US$ $\frac{480}{T}$ landed price in the Philippines (Demafelis et al, 2008).

In the last 30 years (1975-2004), Brazilian ethanol production from sugarcane increased 3 fold from 2,000 to 5,900 li anhydrous ethanol per hectare. This came about due to technological innovation increasing sugar juice content to 14%, national production average yield to 74 $\frac{MT}{ha}$, fermentation productivity of 13% volume ethanol per volume reactor-day (Smeets et al, 2006). The extensive use of ethanol in Brazil, whether in flex fuel vehicle that could be fuelled with any ethanol blends, or 100 ethanol engines or 25% blending with gasoline, put Brazil as the top carbon emission reduction and greenhouse gas effect mitigation country (Macedo et al, 2004).

Present distillery gate price of ethanol in Brazil is US$ 0.35 L^{-1}.

10.2. Indonesia

Indonesia is another top ethanol producer in Asia using sugarcane molasses and cassava. Panaka (2007) reported a total ethanol production of 163.6 Million liters per year in 2005 spread out in eight (8) locations in throughout Indonesia. In 2004 Indonesia exported a total of 22.2 Million liters valued at US$ 9.2 Million to Japan, Singapore, Taiwan among other countries.

Cassava plantation area in Indonesia totaling 1,239.86 million hectares with an average production of 14.9 tons per hectare. Ethanol productivity from cassava averages 4,500 li per hectare – year, comparable to sugarcanes 5,000-6,000 (Panaka, 2007). Indonesia plans to construct 62 additional ethanol distillery plants at 60,000 li/day. However, investors are encouraged to construct 2-3 times this capacities for reasons of efficiency . Estimated production cost of ethanol in Indonesia is USD 0.58 per liter.

10.3. Thailand

At present, Thailand' biodiesel industry is in its infancy. Its bioethanol industry has been growing so fast that as of March, 2008, total production capacity is about 500 million liters per year. However, its domestic demand is only half of this capacity (Biofuel News, March 20, 2008).

The bioethanol production of Thailand primarily uses sugarcane, cane molasses and cassava. Sugarcane molasses is the main feedstock used for ethanol production. However, when molasses based ethanol producer raised their product's price to cope with sharp price increase in molasses, cassava-based ethanol became an attractive feedstock in Thailand (Nguyen et al, November 2006).

Thailand is Asia's largest cassava producer with an average output of 20 million tons per year. Thailand's cassava domestic and export of requirements is about 16 million ton per year leaving about 4 million ton available every year equivalent to 540 million liters of ethanol per year (Gonsalves, September, 2006). Last year, Thailand's government approved the construction of 12 cassava ethanol plants with a total capacity of 1.2 billion liters per year (Nguyen et al, March 2007).

Although in Thailand, cassava–based ethanol is cheaper that molasses-based ethanol, still its production cost is higher that the gasoline domestic price . The government provides for fuel subsidies and tax incentives that make ethanol blended gasoline cheaper than gasoline (Nguyen et al, November, 2006).

The present strength in cassava and cassava-based ethanol productions in Thailand is due to well established research support and interests from both the government and private sector such as the Cassava and Starch Technology Research Unit (CSTRU) in Bangkok, Thailand and several universities.

10.4. Philippines

The cost of one liter of bioethanol may be calculated by getting the sum of the cost of feedstock and the processing cost (i.e. fermentation, distillation and dehydration). If sugarcane is the feedstock used, different business arrangements would yield different costs of feedstock. For the straight cane purchase system, cost per ton cane will range from $ 16.00 to $ 28.00. In addition, the fermentable sugar content of the sugarcane juice may vary from 9% to 11% (equivalent to about 49-60 liters absolute ethanol /TC). The following table shows the range of estimated values for the different costs of feedstocks.

Table 17. Feedstock and Processing Cost Per Liter of Ethanol at Different Cane Purchase Cost Per ton Cane (Movillon, Demafelis, Badayos, et al, 2008).

Cane purchase cost per ton cane	(Feedstocks + Processing Cost) Per Liter Ethanol, US$	(Feedstocks + Processing Cost) Per Liter Ethanol, US$
	9% Fermentable Sugar in Cane Juice	11% Fermentable Sugar in Cane Juice
US $ 16.00	US $ 0.51	US $ 0.45
US $ 20.00	US $ 0.60	US $ 0.51
US $ 24.00	US $ 0.67	US $0.58
US $ 28.00	US $ 0.75	US $ 0.65

For the producers of sugarcane, the cane purchase cost/TC may be lower or higher than the cost of cane for commercial sugar production, depending on the prevailing market price. On the other hand, this bioethanol cost should be considered in the larger scheme of additional revenues from bioethanol production, which may come from the 1) biogas generated from anaerobic digestion of distillery slop, 2) fertilizer value of the distillery slop (even before or after utilizing this anaerobic digestion to produce biogas), 3) other by-products like brewer's yeasts, glycerol, fusel oil, liquefied CO_2 for the beverage and other carbonated industries, and 4) CO_2 equivalent (from co-generation plant and bagasse utilization). Other benefits are the reduction of greenhouse gas (GHG) emissions with the use of fuel from plant materials, and potential job generation.

11. SAMOA'S ENERGY SUPPLY AND DEMAND SITUATION AND ASSOCIATED COSTS OF ELECTRICITY GENERATION

11.1. Energy: Supply and Demand Situation*

The demand for energy has grown considerably over the last 20 years, with Samoa's energy consumption shifting towards commercial energy use based on imported petroleum products and hydropower-generated electricity. The shift has been driven primarily by rapidly increasing demand for electricity as well as ground and sea transport. Total energy demand in 2000 was met by three main sources: biomass (47%), petroleum products (45%) and hydropower (8%). Biomass is used mainly for household cooking, whereas the major part of petroleum products is used by the transport sector and electricity generation. Fuel imports by government and the private sector increased by about 30% between 1998 and 2006 and fuel sales increased by over 20%.

Growth in all forms of commercial energy demand is expected to continue over the next 10 to 20 years supported by the increases in motor vehicles and demand for electricity. Meeting the demand for electricity will require imported diesel fuel, development of new hydro stations, and the development of other renewable energy sources. The latter option is to be encouraged, given the continuous increase in fuel prices and the potential adverse environmental impacts of increasing fuel consumption, which include contamination from poor handling and management of fuel and oil and greenhouse gas emissions.

The increase and diversity in energy demand, with the high associated costs, has highlighted the need for a comprehensive framework to guide and manage the growing energy sector. The first *Samoa National Energy Policy 2007* (SNEP) is intended to provide a clear direction for all energy developments in Samoa. The SNEP vision is *"to enhance the quality of life for all through access to reliable, affordable and environmentally sound energy services and supply*". In support of the Energy sector vision, the overarching goal is *"to increase the share and contribution of renewable energy in mass production and energy services and supply by 20% by year 2030"*.

This goal will be achieved through the successful implementation of strategies in five areas: Energy Planning and Management, Petroleum, Electricity, Transport and Renewable Energy. The strategic interventions in these areas will address the dimensions of energy efficiency and conservation, environmental and social aspects, human and institutional capacity, capital resource constraints, legal framework, and promotion and dissemination of information. This sub-section focuses on the first three areas; transport strategies are discussed in the transport sub-section below and renewable energy is discussed under Priority Area 3.

During SDS 2008–2012 and beyond, the objective of an efficient and effective coordination and management of the energy sector will be pursued. This requires institutional strengthening of the Energy Unit within the Ministry of Finance; the establishment of a Regulatory Body consisting of energy stakeholders from government and the private sector and with a mandate to govern the energy sector; the formulation of an appropriate legal framework for energy sector management; and the development of a reliable energy database management system.

The population's access to electricity is the highest in the Pacific at 98% in 2001. In the same year, 93% *Chamber of Commerce meeting* of all households used electricity for lighting compared to only 38% in 1981. Since then, rural populations not connected to the grid have been supplied with electricity from renewable sources: solar power was launched in early February 2007 to meet the electricity needs of residents of Apolima Island.

Power generation, transmission and distribution are provided by the state-owned Electric Power Corporation (EPC) under the EPC Act 1980. Currently, 40% to 50% of total electricity production is generated from hydropower and the rest by fossil fuel, with the percentages varying during the wet and dry seasons. Diesel generators operate in Upolu and Savai'i, and 8 hydropower plants operate in Upolu. However, existing capacity falls short of peak demand requirements in Upolu, with consequent blackouts, while weak transmission and distribution systems result in 15-20% line losses and cause brownouts and power surges that damage equipment. Hotel operators, manufacturers and other commercial users have been compelled to operate their own backup generators, and thereby have added an estimated 26% to capacity.[8] A major run of river hydro project for Savaii proposed for financing by the Asian Development Bank is now on hold. Simultaneously, the price of power is in the high range of Pacific region rates, while tariff adjustments in 2001-2007 have not kept pace with the rising price of imported fuel. This price-cost squeeze and weak revenue collection have put financial pressure on EPC.

During SDS 2008–2012, the objective of efficient, reliable, affordable and sustainable electricity services will be pursued. The Power Sector Expansion Project, which is supported by the Asian Development Bank and the governments of Australia and Japan, will be implemented. This project provides for an expansion in generation capacity, improvements in the efficiency of transmission and distribution systems, a review of the tariff structure, institutional strengthening of EPC, the opening up of power generation to private sector competition within a new regulatory framework, and a review of Community Service Obligations to be met by EPC. In addition, electricity generation from proven renewable energy technologies (hydro, wind, solar, biomass, geothermal) will be promoted; relevant environment regulations will be enforced; and demand-side management strategies will be developed to encourage increased energy efficiency amongst consumers. The latter will include public awareness campaigns and tariff adjustments that encourage importation of efficient electrical equipment and appliances.

Energy sector strategies include strategies for achieving the objective of ensuring access to reliable, affordable and safe petroleum products. These strategies include formulation and monitoring of the Contract on the Rationalization of the Supply of Petroleum Products 2008-2013, construction of the land route pipeline for the supply of petroleum, and exploration of the viability of sub-regional petroleum supply and distribution.

---

*ADB 2007. *Samoa: Private Sector Assessment. Consolidating Reform for Faster Growth*. Manila: Asian Development Bank.

11.2. Electricity and Water: *

Electricity and Water Industry production was at $58.2 million in 2006. Despite being one of the smaller industries n size with a share of 4.7% of GDP, its growth is vital in supporting growth in other sectors.

In 2006, the Electricity and Water Industry generated a value added of $46.7 million in real terms, an increase of 4.4%, following the 3.7% growth in 2005. The outturn reflects the increasing demand for electricity for developments in most sectors of the economy, including major construction works and the considerable number of new connections around the country and in the new settlement areas like Vaitele-Fou. Ongoing infrastructural and Institutional Strengthening works to improve water management and water quality throughout Samoa assisted the growth. Figure 18 shows the electricity and water-growth rates, 2002-2006.

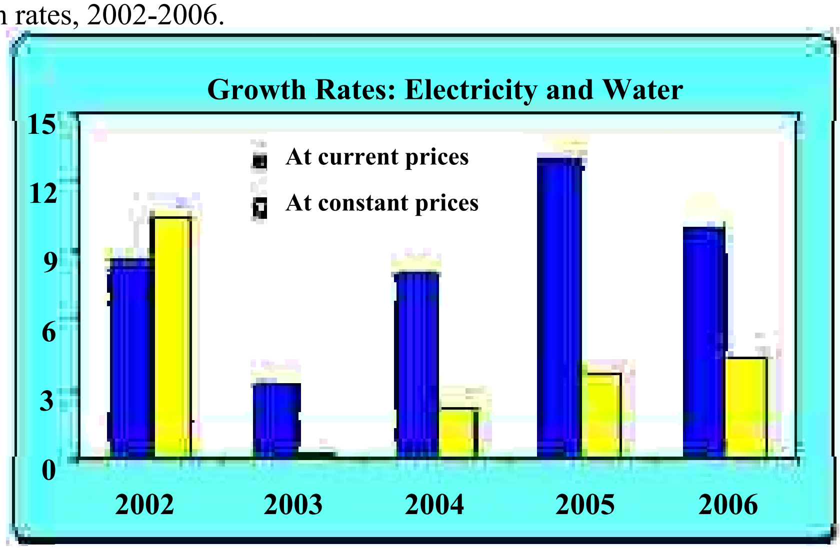


Figure 18. Electricity and Water – Growth rates, 2002 –2006.

Figure 19. Samoa's electricity generation cost per year, 2003-2008

Samoa's generation cost for the last 6 years (2003-2008) has steadily increased from 0.434 Tala/kwh (2003) to 0.956 Tala/kw (2008), with an average increase of about 20% per year.

11.3. Transport and Communication*

Transport and Communication activities have been and will continue to provide significant support to all sectors of the economy through the provision of information and technology, communication and transportation services. With such an important role the industry generated a nominal value added of $153.1 million in 2006. Transport and Communication is the second largest industry behind Commerce, with a share of 12.3%. Figure 20 shows the transport and communication growth-rates, 2002-2006.

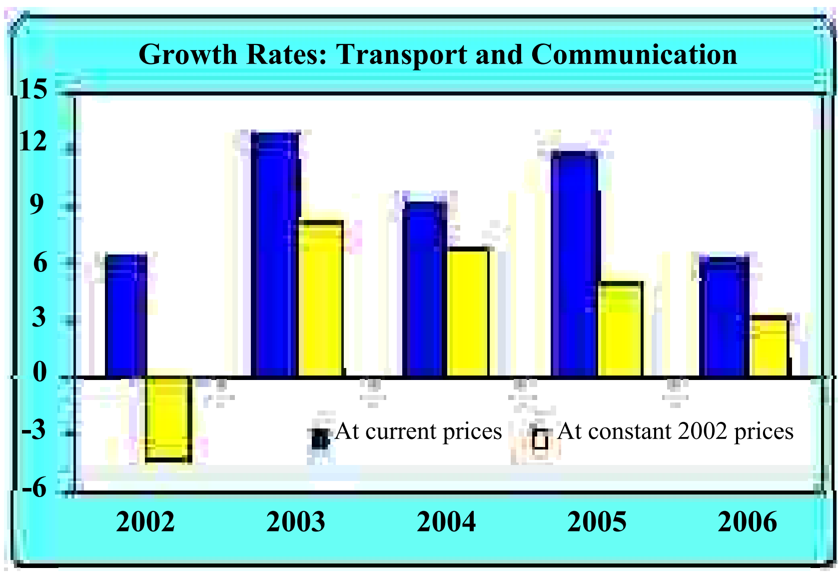


Figure 20. Transport and Communication – Growth rates, 2002–2006.

In real terms, Transport and Communication total production was $130.8 million, an increase of 3.1% compared to 2005 and contributing 0.4 percentage points to the overall growth. This growth was lower compared to the average annual growth in the past 4 years of 3.9%, although there was very strong growth towards the end of 2006 as Digicel rapidly expanded communication services.

Source: The Gross Domestic Product Report 2006 (Quarterly Economic Review for Dec. quarterly 2006).

Table 18. Petroleum Retail Prices in Year 2003.

PETROLEUM RETAIL PRICES (sene per litre)			
2003	Unleaded Petrol (ULP)	Diesel	Dual Purpose Kerosene (domestic)
January	141.70	141.20	132.20
February	149.30	148.30	137.50
March	160.30	155.20	144.10
April	169.00	162.90	150.00
May	147.60	147.10	128.80
June	140.20	139.90	125.90
July	143.70	138.00	124.30
August	145.50	135.00	120.70
September	153.10	139.80	128.00
October	152.30	144.00	131.20
November	146.50	140.40	127.70
December	149.30	142.20	131.60
Average Price	149.88	144.50	131.83

Table 19. Petroleum Retail Prices in Year 2004.

PETROLEUM RETAIL PRICES (sene per litre)			
2004	Unleaded Petrol (ULP)	Diesel	Dual Purpose Kerosene (domestic)
January	152.00	144.50	165.70
February	164.20	152.00	139.50
March	157.20	153.20	137.80
April	165.50	155.20	139.00
May	170.80	158.60	144.30
June	177.60	167.20	158.00
July	180.07	165.49	153.96
August	171.55	166.47	155.76
September	181.60	179.00	167.00
October	182.40	183.90	171.50
November	184.90	189.40	180.90
December	185.80	190.40	181.70
Average Price	172.80	167.11	157.93

Table 20. Petroleum Retail Prices in Year 2005.

PETROLEUM RETAIL PRICES (sene per litre)			
2005	Unleaded Petrol (ULP)	Diesel	Dual Purpose Kerosene (domestic)
January	175.90	182.00	167.60
February	169.40	176.70	162.30
March	182.00	181.50	168.90
April	194.40	193.10	182.50
May	200.10	205.50	200.30
June	193.20	198.90	196.30
July	191.10	202.70	191.80
August	206.20	220.10	204.40
September	215.70	215.40	205.80
October	238.30	225.10	216.90
November	227.90	229.70	219.60
December	215.20	217.80	204.40
Average Price	200.78	204.04	193.40

Table 21. Petroleum Retail Prices in Year 2006.

PETROLEUM RETAIL PRICES (sene per litre)			
2006	Unleaded Petrol (ULP)	Diesel	Dual Purpose Kerosene (domestic)
January	207.90	211.20	202.10
February	213.00	219.00	214.20
March	216.70	219.70	219.90
April	225.70	229.50	221.20
May	238.90	243.90	229.40
June	258.30	255.70	241.90
July	257.20	255.70	238.90
August	256.30	261.30	243.30
September	258.60	258.70	246.50
October	237.70	257.70	247.30
November	217.80	233.40	223.90
December	212.00	228.00	215.90
Average Price	233.34	239.48	228.71

Table 22. Petroleum Retail Prices in Year 2007.

PETROLEUM RETAIL PRICES (sene per litre)			
2007	Unleaded Petrol (ULP)	Diesel	Dual Purpose Kerosene (domestic)
January	216.90	226.30	219.40
February	216.60	218.70	212.60
March	211.30	221.30	206.50
April	234.30	227.90	214.10
May	242.20	237.10	220.80
June	255.10	243.50	226.50
July	257.70	246.20	228.90
August	252.20	246.20	231.00
September	240.60	247.00	231.00
October	240.30	253.50	235.20
November	245.70	258.10	239.30
December	262.50	271.80	260.80
Average Price	239.62	241.47	227.18

Table 23. Petroleum Retail Prices in Year 2008.

PETROLEUM RETAIL PRICES (sene per litre)			
2008	Unleaded Petrol (ULP)	Diesel	Dual Purpose Kerosene (domestic)
January	271.50	281.90	271.70
February	276.90	287.90	270.10
March	272.20	280.20	261.50
April	287.10	303.40	283.60
May	293.80	326.40	307.20
June	315.20	356.10	336.90
July	343.30	393.20	374.60
August	352.70	402.20	382.40
September	320.30	363.90	352.80
October			
November			
December			
Average Price	303.67	332.80	315.64

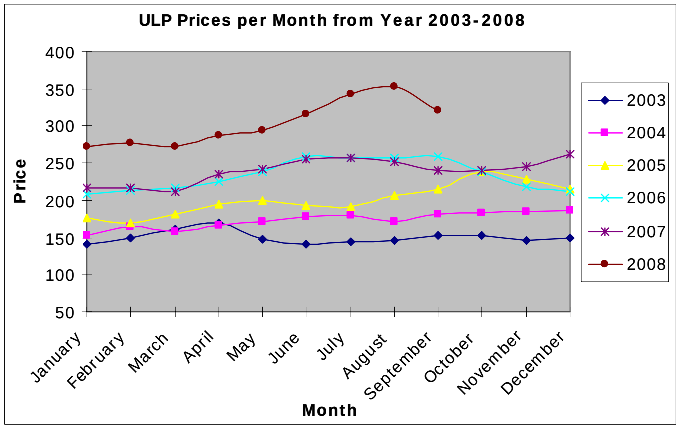


Figure 21. ULP Prices per Month from Year 2003-2008

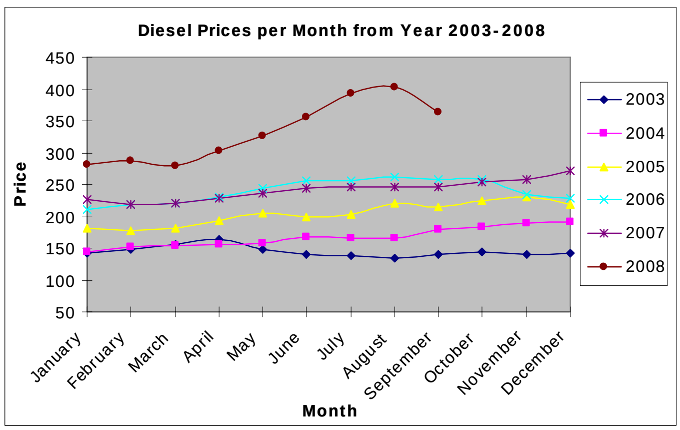


Figure 22. Diesel Prices per Month from Year 2003-2008

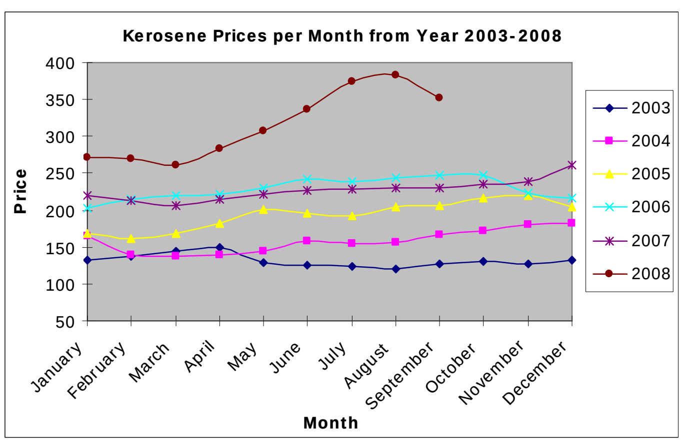


Figure 23. Kerosene Prices per Month from Year 2003-2008

ULP, Diesel as well as Kerosene prices per month from the year 2003 to year 2008 have slightly fluctuating values. But on the average, petroleum retail prices have increased during the year 2003-2008.

Table 24. Average Price of Petrol per Year.

Year	Average Price		
	Unleaded Petrol (ULP)	Diesel	Dual Purpose Kerosene (domestic)
2003	149.88	144.5	131.83
2004	172.8	167.11	157.93
2005	200.78	204.04	193.4
2006	233.34	239.48	228.71
2007	239.62	241.47	227.18
2008	294.29	318.44	300.8

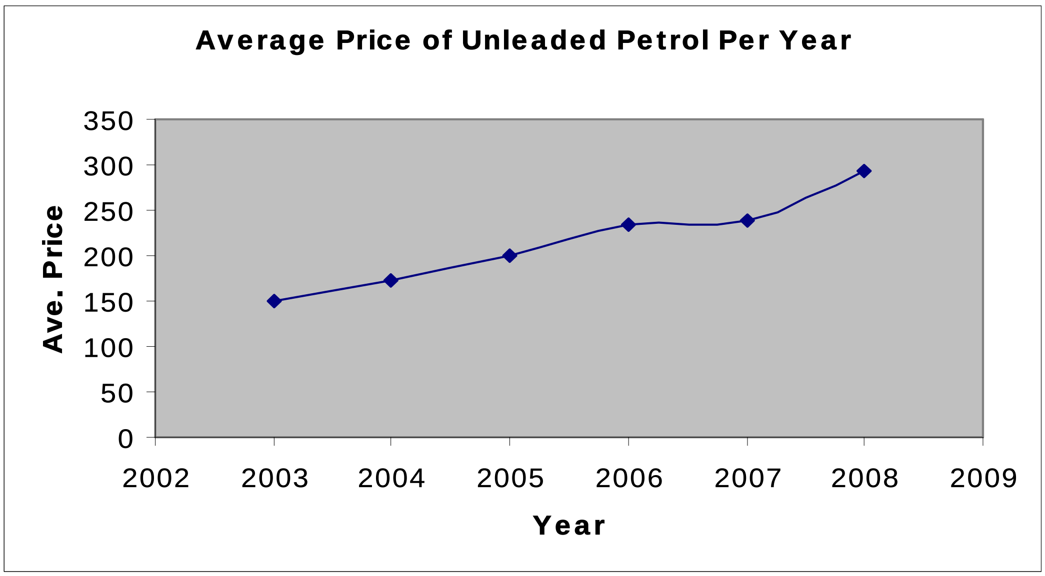


Figure 24. Average Price of ULP per Year.

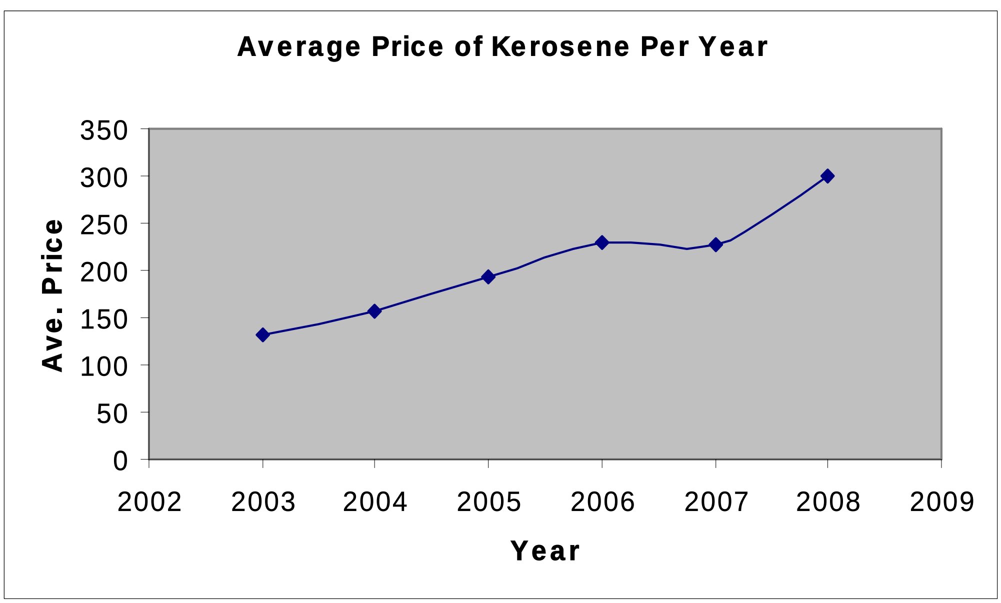


Figure 25. Average Price of Kerosene per Year.

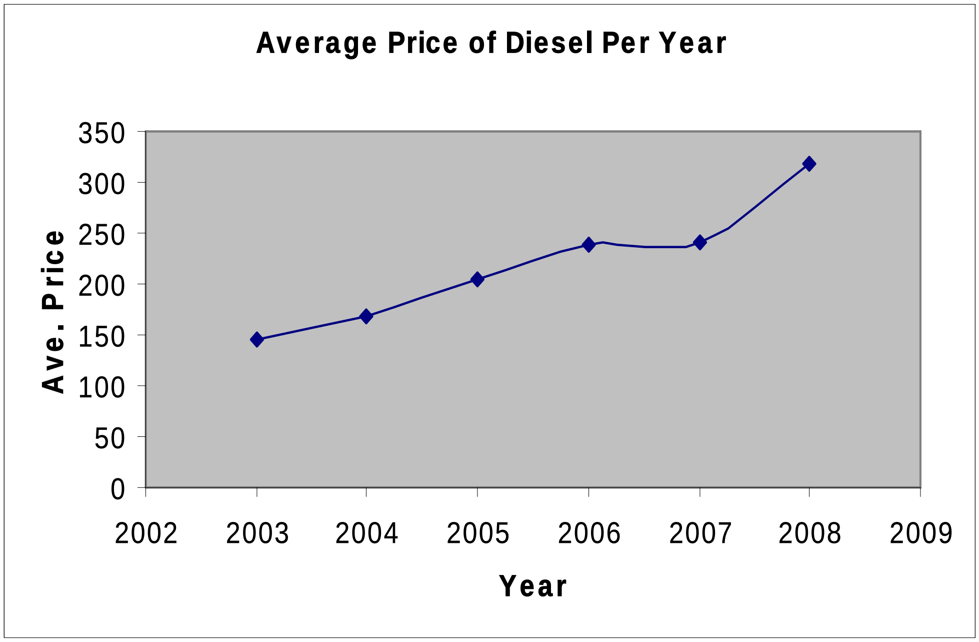


Figure 26. Average Price of Diesel per Year.

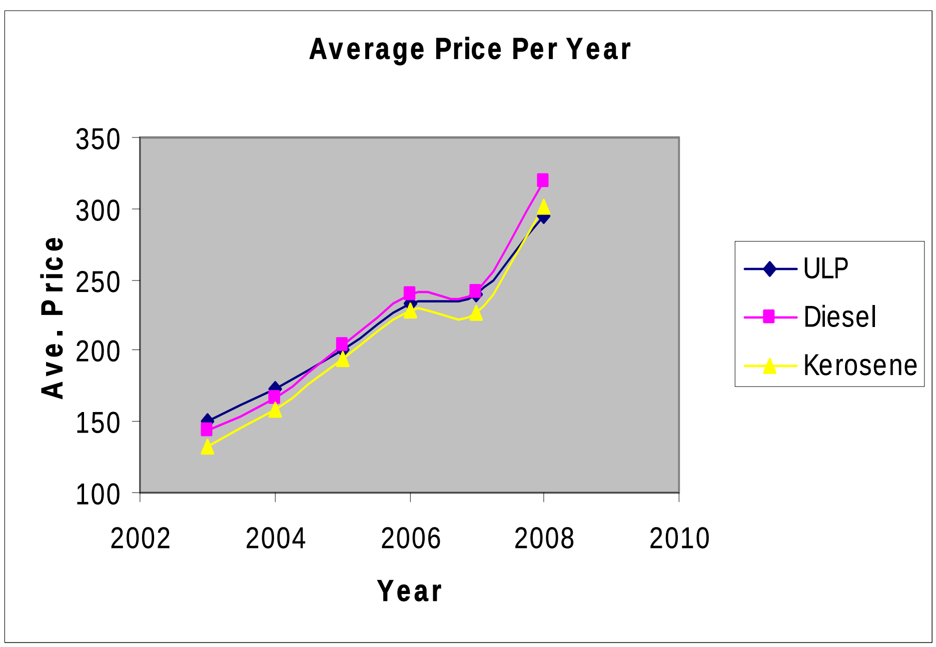


Figure 27. Average Price of ULP, Diesel and Kerosene per Year.

Table 25: GDP by industry - percentage distribution*

	2002	2003	2004	2005	2006	Average 2002:2006	Mar-02	Jun-02	Sep-02	Dec-02	Mar-03	Jun-03
At current prices												
Agriculture	7.0	6.7	7.9	7.6	6.3	7.1	7.6	7.7	6.9	6.0	6.4	6.6
Fishing	7.7	6.1	5.8	5.2	5.1	5.9	7.6	8.0	7.6	7.4	6.6	6.1
Food & Beverages manufacturing	3.4	3.5	3.3	3.5	3.2	3.4	3.2	3.3	3.3	3.6	3.5	3.4
Other manufacturing	12.2	13.4	12.0	10.9	9.7	11.5	11.5	11.9	12.5	12.7	12.7	14.3
Construction	6.1	6.2	8.2	9.0	9.0	7.8	6.2	6.2	6.1	5.9	5.9	5.9
Electricity and water	4.8	4.6	4.5	4.6	4.7	4.6	5.0	4.8	4.8	4.4	4.9	4.7
Commerce	19.9	19.4	19.2	19.7	21.3	20.0	19.7	19.8	19.9	20.3	20.1	19.7
Hotels, restaurants	2.3	2.6	2.6	2.7	3.0	2.7	2.3	2.3	2.3	2.4	2.5	2.5
Transport, Communication	11.8	12.4	12.3	12.5	12.3	12.3	11.8	10.8	12.0	12.6	12.3	11.4
Public administration	8.0	7.8	7.3	7.5	8.4	7.8	8.2	8.2	7.9	7.8	8.0	7.9
Finance and business services	8.6	9.0	9.1	9.1	9.4	9.1	8.5	8.7	8.7	8.5	8.6	9.0
Less: Enterprise share of FISIM	-1.2	-1.2	-1.3	-1.2	-1.2	-1.2	-1.2	-1.2	-1.1	-1.1	-1.2	-1.3
Ownership of dwellings	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.8	3.7	3.8	3.9	3.9
Personal and other services	5.7	5.7	5.5	5.3	5.2	5.4	5.7	5.7	5.6	5.7	5.8	5.9
Total GDP	100.0	100.0	100.0	100.0	100.0	100.0	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
At constant 2002 prices												
Agriculture	7.0	7.4	6.7	7.4	6.7	7.0	7.2	6.8	7.0	7.0	7.7	7.1
Fishing	7.7	6.3	5.6	4.9	4.8	5.8	7.6	8.0	7.6	7.5	6.6	6.4
Food & Beverages manufacturing	3.4	3.3	3.2	3.4	3.1	3.3	3.2	3.3	3.3	3.5	3.4	3.2
Other manufacturing	12.2	12.5	11.3	10.1	8.9	10.9	11.7	12.2	12.4	12.3	11.9	13.4
Construction	6.1	6.0	7.9	8.5	8.6	7.5	6.3	6.2	6.0	5.7	5.8	5.7
Electricity and water	4.8	4.6	4.6	4.5	4.6	4.6	4.9	4.9	4.9	4.4	4.7	4.8
Commerce	19.9	19.5	19.3	19.4	19.9	19.6	19.7	19.9	19.8	20.3	20.4	20.1
Hotels, restaurants	2.3	2.6	2.6	2.7	2.9	2.6	2.3	2.4	2.3	2.4	2.5	2.5
Transport, Communication	11.8	12.4	12.8	12.8	12.9	12.6	11.9	10.9	12.0	12.5	12.2	11.3
Public administration	8.0	8.2	8.4	9.1	9.9	8.8	8.1	8.2	8.0	7.9	8.2	8.3
Finance and business services	8.6	9.1	9.6	9.6	10.1	9.4	8.5	8.8	8.7	8.4	8.5	9.0
Less: Enterprise share of FISIM	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.1	-1.1	-1.2	-1.2
Ownership of dwellings	3.8	3.7	3.7	3.6	3.5	3.6	3.8	3.8	3.7	3.6	3.8	3.8
Personal and other services	5.7	5.6	5.7	5.4	5.4	5.5	5.9	5.8	5.6	5.4	5.6	5.7
Total GDP	100.0	100.0	100.0	100.0	100.0	100.0	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Selected measures of production:												
At current prices-												
Non-monetary	14.1	13.6	14.4	13.8	12.9	13.7	14.8	15.0	13.9	12.8	13.6	13.8
Monetary - total	85.9	86.4	85.6	86.2	87.1	86.3	85.2	85.0	86.1	87.2	86.4	86.2
Monetary - restricted scope	77.0	76.4	77.1	78.9	80.8	78.2 76.0	76.8	76.3	76.9	77.7	76.8	75.5
At constant 2002 prices-												
Non-monetary	14.1	13.8	13.1	13.1	12.6	13.3	14.6	14.3	13.9	13.6	14.0	13.9
Monetary - total	85.9	86.2	86.9	86.9	87.4	86.7	85.4	85.7	86.1	86.4	86.0	86.1
Monetary - restricted scope	77.0	76.9	78.9	80.1	81.7	79.0	76.9	76.8	77.0	77.2	77.0	76.0

*Source: The Gross Domestic Product Report 2006 (Quarterly Economic Review for December quarter 2006)

12. Cost of Biofuel Production Based on New Plantation in Samoa

12.1. Bioethanol

The following cost of bioethanol production is based on a standard minimum economic production capacity of 30 million liters per year. This capacity is too large for Samoa but if found profitable then it could be exported to other countries. Since suitable lands are not contiguous, a consolidator supply approach is assumed. The consolidator will buy the fresh cassava tuber at SAT 0.25/kg then process it to cassava chips and sell it to the ethanol plant at SAT0.8/kg.

12.1.1. Consolidator

A financial analysis on the consolidator's side was first done in order to provide basis for the cassava chips cost to be sold to the ethanol plant which requires cassava chips as their raw material. The chips will then be milled by the plant to powder, which is now the starting material for the secondary processing of cassava to produce anhydrous ethanol. The basic assumptions are presented below:

Table 26. Basic assumptions.

HECTARAGE	10,000 Ha
AVERAGE HARVEST	20 tons/Ha
TOTAL YIELD	20,000 kg
HARVESTING PERIOD	300 days
OPERATING DAYS PER YEAR	300 days
OPERATING HOURS	8 hrs
INPUT PER DAY (tubers)	17 tpd
FUEL FOR DRYING	Diesel
Cassava Tuber Cost	0.25 Tala/kg
Salvage Value	10% of FCI
Chips per day	13.21 tpd
Chips Selling Price	0.80 Tala

The projected cashflow and income statement are presented in Table 28 and 29, respectively. According to the financial analysis, the project at 0.25 SAT per kilogram cassava tuber will be profitable if the consolidators will sell the dried cassava chip at 0.80 SAT per kilogram. A summary of the financial indicators for this case is given below:

Table 27. Financial indicators at 0.80 SAT per kilogram dried cassava chip.

Return on Investment	25.78%
Average Net Income (SAT)	148,267
Internal Rate of Return	23.43%
Payback Period	4.21
Net Present Value (SAT)	217,933

Table 28. Projected Cash Flow Statement - Primary Processing from cassava tubers to dried chips (Case 2).

Particulars	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CASH INFLOWS											
Loan	460,107										
Equity	115,027										
Sales		3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370
Salvage Value											53,792
Total Cash Inflows	**575,134**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,224,162**
CASH OUTFLOWS											
Fixed Capital Investments:	330,534										
Cost of Sales - Ethanol:											
Direct Materials		1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530
Direct Labor		27,360	27,360	27,360	27,360	27,360	27,360	27,360	27,360	27,360	27,360
Factory Overhead less Depreciation		1,648,668	1,648,668	1,665,195	1,665,195	1,665,195	1,665,195	1,665,195	1,665,195	1,665,195	1,665,195
Corporate Taxes	-	-	-	-	-	62,493	64,323	66,332	68,537	70,956	73,612
Total Cash Outflows	**330,534**	**2,917,558**	**2,917,558**	**2,934,085**	**2,934,085**	**2,996,578**	**2,998,408**	**3,000,417**	**3,002,622**	**3,005,041**	**3,007,697**
NET CASHFLOW											
BEFORE DEBT SERVICE	**244,600**	**252,812**	**252,812**	**236,285**	**236,285**	**173,792**	**171,962**	**169,953**	**167,748**	**165,329**	**216,465**
Less: Debt Service:											
Payment of Principal			-	-	48,872	53,637	58,866	64,606	70,905	77,818	85,405
Payment of Interest	-	44,860	44,860	44,860	44,860	40,095	34,866	29,126	22,827	15,914	8,327
Total Debt Service	**-**	**44,860**	**44,860**	**44,860**	**93,732**	**93,732**	**93,732**	**93,732**	**93,732**	**93,732**	**93,732**
NET CASHFLOW											
AFTER DEBT SERVICE		**207,952**	**207,952**	**191,425**	**142,553**	**80,060**	**78,230**	**76,221**	**74,016**	**71,597**	**122,733**
CASH BALANCE, Beginning		**244,600**	**452,551**	**660,503**	**851,928**	**994,481**	**1,074,541**	**1,152,771**	**1,228,992**	**1,303,008**	**1,374,605**
CASH BALANCE, Ending	**244,600**	**452,551**	**660,503**	**851,928**	**994,481**	**1,074,541**	**1,152,771**	**1,228,992**	**1,303,008**	**1,374,605**	**1,497,339**

Internal Rate of Return (IRR)	**23.43%**
Net Present Value (NPV)	**217,933**
Payback, yrs	**4.21**
Discount Rate	**12%**

TABLE 29. PROJECTED INCOME STATEMENT - PRIMARY PROCESSING FROM CASSAVA TUBERS TO DRIED CHIPS (CASE 2)

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
SALES										
Cassava Chips	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370	3,170,370
Gross Sales	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**	**3,170,370**
Less: Cost of Sales										
Cost of Sales - Cassava Chips										
Direct Materials	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530	1,241,530
Direct Labor	27,360	27,360	27,360	27,360	27,360	27,360	27,360	27,360	27,360	27,360
Factory Overhead										
Indirect Labor	38,016	38,016	38,016	38,016	38,016	38,016	38,016	38,016	38,016	38,016
Fringe Benefits	8,755	8,755	8,755	8,755	8,755	8,755	8,755	8,755	8,755	8,755
Repair & Maintenance			16,527	16,527	16,527	16,527	16,527	16,527	16,527	16,527
Depreciation	17,638	17,638	17,638	17,638	17,638	17,638	17,638	17,638	17,638	17,638
Processing Utilities	1,601,897	1,601,897	1,601,897	1,601,897	1,601,897	1,601,897	1,601,897	1,601,897	1,601,897	1,601,897
Total Cost of Sales	**2,935,196**	**2,935,196**	**2,951,723**	**2,951,723**	**2,951,723**	**2,951,723**	**2,951,723**	**2,951,723**	**2,951,723**	**2,951,723**
NET INCOME BEFORE INTEREST	**235,174**	**235,174**	**218,647**	**218,647**	**218,647**	**218,647**	**218,647**	**218,647**	**218,647**	**218,647**
Less: Interest on Loan	44,860	44,860	44,860	44,860	40,095	34,866	29,126	22,827	15,914	8,327
NET INCOME BEFORE TAX	190,313	190,313	173,787	173,787	178,552	183,781	189,521	195,820	202,733	210,320
Less: Corporate Taxes	-	-	-	-	62,493	64,323	66,332	68,537	70,956	73,612
NET INCOME/(LOSS) AFTER TAX	190,313	190,313	173,787	173,787	116,059	119,458	123,188	127,283	131,776	136,708

Average Net Income	148,267
Return on Investment (ROI)	25.78%

12.1.2. Bioethanol distillery

From the consolidators, the dried cassava chips will be transported to the ethanol plant to be milled and processed for ethanol production. The assumptions for the base case (3.34 SAT ethanol selling price and 0.80 SAT cassava chip buying price) are presented in the table below:

Table 30. Basic assumptions for base case.

Primary Processing Assumptions	
Operating Days per Year (days)	300
Operating Hours (hrs)	24
Cassava Chips Input per Day (tpd)	245.7
Secondary Processing Assumptions	
Stoichiometric Gravimetric Factor (Starch to Ethanol)	0.57
Starch to Ethanol Conversion Efficiency (%)	85
Distillation Efficiency (%)	98.5
Dehydration Efficiency (%)	99
Carbon Dioxide (Kg)/ L Ethanol	0.73
Ethnanol Density at Ambient Temperature (kg/L)	0.786
Revenue Assumptions (Base Case)	
Ethanol Price (SAT/L)	3.34
CDM	
Biogas Substitution of Bunker Oil (SAT/L)	0.03
Biogas Substitution of Gasoline (SAT/L)	0.02
Biogas Utilization (SAT/L)	0.03
Carbon Dioxide Price (SAT/kg)	0.40
Cost Assumptions (Base Case)	
Cassava (at 14% MC) Buying Price per kg (SAT)	0.8
Assets Life (Years)	
Mobile Equipments	10
Stationary Equipments	15
Buildings	25
Depreciation Method (Straight Line Method)	
Maintenance and Repairs (SAT/ L ethanol)	
Year 4-10	0.11
Licenses, Fees and Insurance (SAT/L ethanol)	0.08
Salaries and Fringe Benefits (Monthly Total)	
Total Salaries (SAT)	
Direct Labor	510,840
Indirect Labor	501,547
Sales Force	4,020
Administrative Labor	39,720
Admin Fringe Benefits (32% of admin labor)	13,997
Financing	
Ethanol Production Capital (L/day)	100,000
Plant Cost (Php)	72,580,067
Loan Financing, 80% (SAT)	58,064,054
Equity Financing, 20% (SAT)	14,516,013
Interest Rate on Loan (%)	9.75
Tsx Holiday (Years)	5

The costs per liter of ethanol of the different cost components are also presented below. Whereas, the projected cashflow and income statement are presented in Tables 32 and 33, respectively.

Table 31. Unit cost per liter of ethanol.

Core Enterprise	Ethanol Processing
Business Concerns	chips buying, chips processing, ethanol processing
Capacity	30 million liters per year
Final Product	Ethanol
Associated Costs	per liter
1. Cost of Sales	
Tuber	-
Primary Processing	2.34
Secondary Processing	0.68
Total Cost of Sales	3.02
2. Selling & Administrative Cost	0.03
3. Interest Expense	0.07
4. Corporate Taxes (5 yrs TH)	0.17
TOTAL	3.29
TOTAL PROJECT COST:	72,580,067
Fixed Capital Investments	63,703,435
Working Capital	8,876,632
FINANCING:	
Loan (9.75%i, 3 yrs GP, 10yrsPmt)	58,064,054
Equity	14,516,013
BUYING COST OF RAW MATERIALS	0.80 per kg chips
PRICING SCHEME:	3.34
Cost of Sales Per Unit	3.02
Mark-up Per Unit	0.32
% Mark-up	11%
MINIMUM UNIT SELLING PRICE:	3.34
Financial Indicators:	
ROI	15.51%
IRR	12.10%
NPV	236,432
Payback Period (years)	7.00
SUGGESTED UNIT SELING PRICE:	3.40
Financial Indicators:	
ROI	17.31%
IRR	15.48%
NPV	8,384,051
Payback Period (years)	5.86
Farmer's Income Share Per Hectare	-

Table 32. Projected cash flow statement - Ethanol processing from cassava (Case 2).

Particulars	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
SALES										
Ethanol		100,200,000	100,200,000	100,200,000	100,200,000	100,200,000	100,200,000	100,200,000	100,200,000	100,200,000
CDM										
Biogas Substitution of Bunker oil		800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000
Etoh substitution of gasoline		700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000	700,000
Biogas Utilization		920,000	920,000	920,000	920,000	920,000	920,000	920,000	920,000	920,000
Carbon Dioxide		5,760,000	5,760,000	5,760,000	5,760,000	5,760,000	5,760,000	5,760,000	5,760,000	5,760,000
Gross Sales		**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**
Less: Cost of Sales										
Cost of Sales – Ethanol										
Direct Materials										
Cost of Primary Processing:										
Direct Materials	-	58,379,200	58,379,200	58,379,200	58,379,200	58,379,200	58,379,200	58,379,200	58,379,200	58,379,200
Direct Labor	-	5,749,920	5,749,920	5,749,920	5,749,920	5,749,920	5,749,920	5,749,920	5,749,920	5,749,920
Factory Overhead										
Indirect Labor	-	5,670,720	5,670,720	5,670,720	5,670,720	5,670,720	5,670,720	5,670,720	5,670,720	5,670,720
Repair and Maintenance	-			187,910	187,910	187,910	187,910	187,910	187,910	187,910
Depreciation	-	176,937	176,937	176,937	176,937	176,937	176,937	176,937	176,937	176,937
Total Cost of Direct Materials		**69,976,777**	**69,976,777**	**70,164,687**	**70,164,687**	**70,164,687**	**70,164,687**	**70,164,687**	**70,164,687**	**70,164,687**
Direct Labor	-	380,160	380,160	380,160	380,160	380,160	380,160	380,160	380,160	380,160
Factory Overhead										
Indirect Labor	-	347,846	347,846	347,846	347,846	347,846	347,846	347,846	347,846	347,846
Indirect Materials - Chemicals	-	298,284	298,284	298,284	298,284	298,284	298,284	298,284	298,284	298,284
Repair & Maintenance	-	-	-	2,973,092	2,973,092	2,973,092	2,973,092	2,973,092	2,973,092	2,973,092
Depreciation	-	2,545,560	2,545,560	2,545,560	2,545,560	2,545,560	2,545,560	2,545,560	2,545,560	2,545,560
Processing Utilities	-	12,033,431	12,033,431	12,033,431	12,033,431	12,033,431	12,033,431	12,033,431	12,033,431	12,033,431
Total Cost of Sales - Ethanol		**85,582,058**	**85,582,058**	**88,743,060**	**88,743,060**	**88,743,060**	**88,743,060**	**88,743,060**	**88,743,060**	**88,743,060**
Add: Cost of Sales - CO2	-	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000
Total Cost of Sales		**87,382,058**	**87,382,058**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**
Increase in Cost of Sales	-	-	-	-	-	-	-	-	-	-
Total Cost of Sales		**87,382,058**	**87,382,058**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**	**90,543,060**
		20,997,942	**20,997,942**	**17,836,940**	**17,836,940**	**17,836,940**	**17,836,940**	**17,836,940**	**17,836,940**	**17,836,940**
Less: Selling & Administrative Expenses										
Administrative Expenses	423,878	488,506	692,842	692,842	692,842	692,842	692,842	692,842	692,842	692,842
Repairs and Maintenance	-	-	-	24,170	24,170	24,170	24,170	24,170	24,170	24,170
Administration Utilities	11,270	12,988	18,420	18,420	18,420	18,420	18,420	18,420	18,420	18,420
Communications	44,049	50,765	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000
Office Supplies	1,835	2,115	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Depreciation	16,803	16,803	16,803	16,803	16,803	16,803	16,803	16,803	16,803	16,803
Total Selling & Administrative Expenses	**497,836**	**571,177**	**803,065**	**827,235**	**827,235**	**827,235**	**827,235**	**827,235**	**827,235**	**827,235**
NET INCOME BEFORE INTEREST	**(497,836)**	**20,426,764**	**20,194,876**	**17,009,705**	**17,009,705**	**17,009,705**	**17,009,705**	**17,009,705**	**17,009,705**	**17,009,705**
Less: Interest on Loan	2,540,807	2,540,807	2,602,136	2,602,136	2,332,257	2,036,065	1,704,480	1,340,565	941,169	502,831
NET INCOME BEFORE TAX	**(3,038,643)**	**17,885,957**	**17,592,741**	**14,407,569**	**14,677,448**	**14,973,640**	**15,305,225**	**15,669,140**	**16,068,536**	**16,506,873**
Less: Corporate Taxes	-	-	-	-	-	5,240,774	5,356,829	5,484,199	5,623,988	5,777,406
NET INCOME/(LOSS) AFTER TAX	**(3,038,643)**	**17,885,957**	**17,592,741**	**14,407,569**	**14,677,448**	**9,732,866**	**9,948,396**	**10,184,941**	**10,444,548**	**10,729,468**
Average Net Income	**11,256,529**									

Return on Investment (ROI)	**15.51%**

Table 33. Projected income statement – Ethanol processing from cassava (Case 2).

Particulars	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
CASH INFLOWS											
Loan	26,059,560	31,375,484	629,010								
Equity	6,514,890	7,843,871	157,252								
Sales	-	-	108,380,000	108,380,000	108,380,000	108,380,000	108,380,000	108,380,000	108,380,000	108,380,000	108,380,000
Salvage Value	-	-	-	-	-	-	-	-	-	-	27,564,215
Total Cash Inflows	**32,574,450**	**39,219,355**	**109,166,262**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**108,380,000**	**135,944,215**
CASH OUTFLOWS											
Fixed Capital Investments:											
Primary Processing	1,879,098	1,879,098									
Secondary Processing	29,730,920	29,730,920	-	-	-	-	-	-	-	-	-
Administration	483,399	-	-	-	-	-	-	-	-	-	-
Total Fixed Capital Investments	**32,093,417**	**31,610,018**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Cost of Sales - Ethanol:											
Direct Materials less Depreciation		-	69,799,840	69,799,840	69,987,750	69,987,750	69,987,750	69,987,750	69,987,750	69,987,750	69,987,750
Direct Labor		-	380,160	380,160	380,160	380,160	380,160	380,160	380,160	380,160	380,160
Factory Overhead less Depreciation	-	-	12,679,562	12,679,562	15,652,654	15,652,654	15,652,654	15,652,654	15,652,654	15,652,654	15,652,654
Total Cost of Sales - Ethanol	**-**	**-**	**82,859,562**	**82,859,562**	**86,020,563**	**86,020,563**	**86,020,563**	**86,020,563**	**86,020,563**	**86,020,563**	**86,020,563**
Cost of Sales - CO2	-	-	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000
Selling & Admin Expenses less Depreciation	-	481,033	554,374	786,262	810,432	810,432	810,432	810,432	810,432	810,432	810,432
Corporate Tax	-	-	-	-	-	-	5,240,774	5,356,829	5,484,199	5,623,988	5,777,406
Add: Increase in Cost of Sales	-	-	-	-	-	-	-	-	-	-	-
Total Cash Outflows	**32,093,417**	**32,091,051**	**85,213,936**	**85,445,823**	**88,630,995**	**88,630,995**	**93,871,769**	**93,987,824**	**94,115,194**	**94,254,983**	**94,408,401**
NET CASHFLOW BEFORE DEBT SERVICE	**481,033**	**7,128,305**	**23,952,326**	**22,934,177**	**19,749,005**	**19,749,005**	**14,508,231**	**14,392,176**	**14,264,806**	**14,125,017**	**41,535,814**
Less: Debt Service:											
Payment of Principal		-	-	-	2,767,989	6,370,502	7,058,438	7,746,636	8,501,933	9,330,871	10,240,631
Payment of Interest	-	2,540,807	2,540,807	2,602,136	2,602,136	2,332,257	2,036,065	1,704,480	1,340,565	941,169	502,831
Total Debt Service	**-**	**2,540,807**	**2,540,807**	**2,602,136**	**5,370,124**	**8,702,759**	**9,094,503**	**9,451,115**	**9,842,498**	**10,272,040**	**10,743,463**
NET CASHFLOW AFTER DEBT SERVICE	**481,033**	**4,587,498**	**21,411,519**	**20,332,041**	**14,378,880**	**11,046,246**	**5,413,728**	**4,941,061**	**4,422,308**	**3,852,977**	**30,792,352**
CASH BALANCE, Beginning		**481,033**	**5,068,530**	**26,480,050**	**46,812,091**	**61,190,971**	**72,237,217**	**77,650,945**	**82,592,006**	**87,014,314**	**90,867,291**
CASH BALANCE, Ending	**481,033**	**5,068,530**	**26,480,050**	**46,812,091**	**61,190,971**	**72,237,217**	**77,650,945**	**82,592,006**	**87,014,314**	**90,867,291**	**121,659,643**

Internal Rate of Return (IRR)	**12.10%**
Net Present Value (NPV)	**236,432**
Payback, yrs	**6.49**

Discount Rate	**12%**

A sensitivity analysis was prepared to determine the effect of cassava chips purchase cost, ethanol selling price and percent increase in production cost on the financial indicators namely return on investment, average net income, internal rate of return, payback period, and net present value.

A financial analysis on the consolidator was first done in order to obtain a basis for the cassava chips purchase cost. It was found out that the consolidators will gain profit at a minimum suggested price of 0.80 SAT per kilogram of chips. The sensitivity analysis therefore considered 0.60 SAT as the lowest possible cassava chips cost and 1.00 SAT per kilogram of chips as the upper limit of the sensitivity analysis. The financial analysis obtained 3.34 SAT per liter of ethanol as the minimum ethanol selling price and the suggested ethanol selling price is 3.40 SAT so that the business venture will be attractive to investors. The sensitivity, therefore, considered ethanol selling price from 3.20 SAT until 3.60 SAT per liter ethanol.

Table 34 shows the effect of the ethanol selling price on the financial indicators at different cassava chips cost. The trend shows that the return on investment, average net income, internal rate of return, and net present value increase as the ethanol selling price increases but decrease as the cassava chips cost increase. The payback period shows opposite trend from the previous. At a base case of 3.40 SAT ethanol selling price and 0.80 SAT cassava chips cost with no expected increase in processing cost, the return on investment is 17.3%, average net income 12.6M, internal rate of return 15.5%, payback period 5.4 years, and net present value equal to 8.38M. Also according to the table, at an ethanol selling price of 3.40 SAT, the venture will not be attractive if the cassava chip cost increased from 0.80 SAT to 0.90 SAT. In order for the project to be profitable at 0.90 SAT, the ethanol price should be increased to at least 3.60 SAT. The venture, however, will not be feasible at 1.00 SAT at any ethanol price since the net present value for any case is negative. The sensitivity figures for this case are presented in Appendix Figures 1 to 5.

Table 35 shows that if the cassava chip cost increases at a certain ethanol selling price, the return on investment, average net income, internal rate of return and net present value decreases whereas, the payback period is longer for the same case. However, the trend is opposite for increasing ethanol prices at a certain cassava chip cost. It can be deduced from the table that if the cassava chip cost increased from 0.80 SAT to 0.90 SAT, the ethanol price should be at 3.60 SAT. Moreover, the business venture is not attractive at 1.00 SAT cassava chip cost. The sensitivity figures for this case are presented in Appendix Figures 6 to 10.

Table 36 shows the response of the financial indicators to the change in processing cost at different cassava chip cost. It is observed that the return on investment, average net income, internal rate of return and net present value decreases at increasing processing cost, whereas, the payback period is longer for this case. The same trend was also observed for increasing cassava chip cost. In order for the project to be profitable if the processing cost increased by 5%, the cassava chip cost should be lowered to 0.70 SAT assuming that the ethanol price for this case is 3.34 SAT. The sensitivity figures for this case are presented in Appendix Figures 11 to 15.

Table 34. Effect of ethanol price.

Financial Indicators	Base Case 0% 3.34	Effect of Ethanol Price 3.20	3.30	3.40	3.50	3.60
		Chips Price at 0.60/kg				
Return on Investment	30.6%	26.3%	29.4%	32.4%	35.5%	38.5%
Average Net Income (SAT)	21,837,759	18,792,759	20,967,759	23,142,759	25,317,759	27,492,759
Internal Rate of Return	38.8%	31.6%	36.7%	41.8%	46.7%	51.5%
Payback Period	4.0	4.4	4.1	3.9	3.8	3.6
Net Present Value (SAT)	67,889,883	48,878,858	62,458,162	76,037,466	89,616,769	103,196,073
		Chips Price at 0.70/kg				
Return on Investment	22.99%	18.8%	21.8%	24.8%	27.8%	30.8%
Average Net Income (SAT)	16,547,144	13,502,144	15,677,144	17,852,144	20,027,144	22,202,144
Internal Rate of Return	25.79%	18.2%	23.7%	28.9%	34.1%	39.1%
Payback Period	4.72	5.5	4.9	4.5	4.2	4.0
Net Present Value (SAT)	34,063,158	15,052,132	28,631,436	42,210,740	55,790,044	69,369,348
		Chips Price at 0.80/kg				
Return on Investment	15.5%	11.3%	14.3%	17.3%	20.3%	23.3%
Average Net Income (SAT)	11,256,529	8,211,529	10,386,529	12,561,529	14,736,529	16,911,529
Internal Rate of Return	12.1%	3.9%	9.8%	15.5%	21.0%	26.3%
Payback Period	7.0	10.5	8.4	5.4	5.1	4.7
Net Present Value (SAT)	236,432	(18,774,593)	(5,195,289)	8,384,015	21,963,319	35,542,622
		Chips Price at 0.90/kg				
Return on Investment	8.2%	4.0%	7.0%	9.9%	12.9%	15.9%
Average Net Income (SAT)	5,965,914	2,920,914	5,095,914	7,270,914	9,445,914	11,620,914
Internal Rate of Return	-2.9%	-12.2%	-5.5%	0.9%	6.9%	12.7%
Payback Period	11.4	12.7	11.7	10.9	10.1	6.7
Net Present Value (SAT)	(33,590,293)	(52,601,319)	(39,022,015)	(25,442,711)	(11,863,407)	1,715,897
		Chips Price at 1.00/kg				
Return on Investment	0.9%	-3.2%	-0.3%	2.7%	5.6%	8.6%
Average Net Income (SAT)	675,299	-2,369,701	(194,701)	1,980,299	4,155,299	6,330,299
Internal Rate of Return	-	-	-	-	-8.6%	-2.1%
Payback Period	14.0	16.1	14.6	13.3	12.2	11.3
Net Present Value (SAT)	(67,417,019)	(86,428,044)	(72,848,740)	(59,269,436)	(45,690,132)	(32,110,828)

Table 35. Effect of cassava chip cost.

Financial Indicators	Base Case 0% 0.80	Effect of Cassava Chip Cost Cost 0.60	0.70	0.80	0.90	1.00
		Ethanol Price at 3.20/L				
Return on Investment	11.3%	26.3%	18.8%	11.3%	4.0%	-3.2%
Average Net Income (SAT)	8,211,529	18,792,759	13,502,144	8,211,529	2,920,914	(2,369,701)
Internal Rate of Return	3.9%	31.6%	18.2%	3.9%	-12.2%	-
Payback Period	10.5	4.4	5.5	10.5	12.7	16.1
Net Present Value (SAT)	(18,774,593)	48,878,858	15,052,132	(18,774,593)	(52,601,319)	(86,428,044)
		Ethanol Price at 3.30/L				
Return on Investment	14.3%	29.4%	21.8%	14.3%	7.0%	-0.3%
Average Net Income (SAT)	10,386,529	20,967,759	15,677,144	10,386,529	5,095,914	(194,701)
Internal Rate of Return	9.8%	36.7%	23.7%	9.8%	-5.5%	-
Payback Period	8.4	4.1	4.9	8.4	11.7	14.6
Net Present Value (SAT)	(5,195,289)	62,458,162	28,631,436	(5,195,289)	(39,022,015)	(72,848,740)
		Ethanol Price at 3.40/L				
Return on Investment	17.3%	32.4%	24.8%	17.3%	9.9%	2.7%
Average Net Income (SAT)	12,561,529	23,142,759	17,852,144	12,561,529	7,270,914	1,980,299
Internal Rate of Return	15.5%	41.8%	28.9%	15.5%	0.9%	-
Payback Period	5.9	3.9	4.5	5.9	10.9	13.3
Net Present Value (SAT)	8,384,015	76,037,466	42,210,740	8,384,015	(25,442,711)	(59,269,436)
		Ethanol Price at 3.50/L				
Return on Investment	20.3%	35.5%	27.8%	20.3%	12.9%	5.6%
Average Net Income (SAT)	14,736,529	25,317,759	20,027,144	14,736,529	9,445,914	4,155,299
Internal Rate of Return	21.0%	46.7%	34.1%	21.0%	6.9%	-8.6%
Payback Period	5.1	3.8	4.2	5.1	10.1	12.2
Net Present Value (SAT)	21,963,319	89,616,769	55,790,044	21,963,319	(11,863,407)	(45,690,132)
		Ethanol Price at 3.60/L				
Return on Investment	23.3%	38.5%	30.8%	23.3%	15.9%	8.6%
Average Net Income (SAT)	16,911,529	27,492,759	22,202,144	16,911,529	11,620,914	6,330,299
Internal Rate of Return	26.3%	51.5%	39.1%	26.3%	12.7%	-2.1%
Payback Period	4.7	3.6	4.0	4.7	6.7	11.3
Net Present Value (SAT)	35,542,622	103,196,073	69,369,348	35,542,622	1,715,897	(32,110,828)

Table 36. Effect of percent increase in processing cost.

Financial Indicators	Base Case 0% 3.34	Effect of Percent Increase in Processing Cost -10%	-5%	0%	5%	10%	15%	20%
		Chips Price at 0.60/kg						
Return on Investment	30.6%	38.0%	34.3%	30.6%	26.9%	23.2%	19.5%	15.8%
Average Net Income (SAT)	21,837,759	27,128,662	24,483,211	21,837,759	19,192,307	16,546,856	13,901,404	11,255,953
Internal Rate of Return	38.8%	50.6%	44.7%	38.8%	32.6%	26.3%	19.8%	12.9%
Payback Period	4.0	3.7	3.8	4.0	4.3	4.7	5.3	6.7
Net Present Value (SAT)	67,889,883	100,783,367	84,336,625	67,889,883	51,443,141	34,996,400	18,549,658	2,102,916
								Chips Price at 0.70/kg
Return on Investment	23.0%	31.1%	27.0%	23.0%	18.9%	14.9%	10.9%	6.8%
Average Net Income (SAT)	16,547,144	22,367,109	19,457,126	16,547,144	13,637,162	10,727,179	7,817,197	4,907,215
Internal Rate of Return	25.8%	39.3%	32.7%	25.8%	18.6%	11.1%	3.1%	-5.6%
Payback Period	4.7	4.0	4.3	4.7	5.4	7.5	10.6	11.7
Net Present Value (SAT)	34,063,158	70,259,762	52,161,460	34,063,158	15,964,856	(2,133,446)	(20,231,748)	(38,330,050)
								Chips Price at 0.80/kg
Return on Investment	15.5%	24.3%	19.9%	15.5%	11.1%	6.8%	2.4%	-2.0%
Average Net Income (SAT)	11,256,529	17,605,555	14,431,042	11,256,529	8,082,016	4,907,503	1,732,990	(1,441,523)
Internal Rate of Return	12.1%	27.8%	20.2%	12.1%	3.5%	-5.8%	-	-
Payback Period	7.0	4.6	5.2	7.0	10.6	11.8	13.3	15.3
Net Present Value (SAT)	236,432	39,736,157	19,986,295	236,432	(19,513,430)	(39,263,292)	(59,013,154)	(78,763,016)
								Chips Price at 0.90/kg
Return on Investment	8.2%	17.5%	12.9%	8.2%	3.5%	-1.2%	-5.9%	-10.6%
Average Net Income (SAT)	5,965,914	12,844,002	9,404,958	5,965,914	2,526,870	(912,174)	(4,351,218)	(7,790,261)
Internal Rate of Return	-2.9%	15.8%	6.8%	-2.9%	-	-	-	-
Payback Period	11.4	5.8	10.2	11.4	12.9	15.0	17.8	21.9
Net Present Value (SAT)	(33,590,293)	9,212,552	(12,188,871)	(33,590,293)	(54,991,715)	(76,393,138)	(97,794,560)	(119,195,983)
								Chips Price at 1.00/kg
Return on Investment	0.9%	11.0%	5.9%	0.9%	-4.1%	-9.1%	-14.1%	-19.2%
Average Net Income (SAT)	675,299	8,082,448	4,378,874	675,299	(3,028,276)	(6,731,850)	(10,435,425)	(14,138,999)
Internal Rate of Return	#NUM!	2.9%	-7.9%	-	-	-	-	-
Payback Period	14.0	10.6	12.1	14.0	16.7	20.5	26.8	38.4
Net Present Value (SAT)	(67,417,019)	(21,311,053)	(44,364,036)	(67,417,019)	(90,470,001)	(113,522,984)	(136,575,966)	(159,628,949)

B. Biodiesel

1. Jatropha Biodiesel Production.

Table 37. Annual* cost of items for the 1,000 L daily production of JME.

Daily Seed Requirement: 4,000 kg seeds

Assumptions:

Oil in Seed	33%
Extraction Oil Recovery	80%
Transesterification Recovery	85%

ITEM	DESCRIPTION	COST (SAT)
A. Fixed Capital Investment Cost		
1. Land	1,000 sq. meter @10 SAT/sq. m	10,000.00
2. Building	Floor area requirement of 200 sq. m (warehouse-type)	96,000.00
3. Machinery		711,750.00
a. Hulling machine	500 kg/hr capacity, powered by 5 KW motor	4,550.00
b. Oil expeller	85 kg/hr capacity, powered by 5 KW electric motor	78,000.00
c. Conveyor	Flat belt, powered by 1 KW electric motor	3,250.00
d. Settling tank & storage tanks	(6 cu. m. capacity, made of lined steel = 100,000 each) 1 tank; 1 for 2-month storage of JME which requries 48 cu.m. capacity	52,000.00
e. Pump	2 gear pumps powered by ½ KW motor	325.00
f. 0.5 □m Filter		52,000.00
g. Filter Press		18,200.00
h. Methanol recovery facility		39,000.00
i. Glycerin recovery facility		39,000.00
j. Transesterification system including pretreatment		182,000.00
k. Cooker		16,900.00
l. Cake bin		52,000.00
m. Wastewater treatment facility		130,000.00
n. Miscellaneous	screw conveyor, spare shaft, etc.	44,525.00
4. Electrical component	Magnetic switches and transformer	5,000.00
5. Office equipment	Computers, cabinets, weighing scale, moisture meter, etc.	7,500.00
	TOTAL	**830,250.00**
B. Annual Processing Cost		
a. Energy consumption, P/year	500 kWh/day, allowance included.	150,000.00
b. Personnel Services, P/yr.	See Table 2.	94,013.28
c. Analysis and Others		36,000.00
d. Repair and maintenance of equipment	2% of acquistion cost of machinery & equipment alloted annually for repair and maintenance	11,100.00
e. Depreciation	Salvage value is 10% of acquisition cost for machinery & equipment, 0% for building; computed using straight-line method	-
e.1. Building	service life is 30 years	2,880.00
e.2. Machinery and office equipment	service life is 15 years	37,333.33
f. Raw Material Cost	See Table 3.	1,288,444.54
	TOTAL	**1,619,771.15**
C. Production Cost/L JME	**5.40**	

*300 operating days in 1 year

Table 38. Personnel requirement of the plant and their corresponding remunerations.

POSITION	NO.	ANNUAL SALARY (SAT)	TOTAL (SAT)
1. Plant Supervisor (Chemical Engineer)	1	10,759.68	10,759.68
2. Mechanical Engineer	1	10,759.68	10,759.68
3. Machine Operators	6	9,033.12	54,198.72
4. Utility Persons	5	3,659.04	18,295.20
			94,013.28

Table 39. Daily* energy consumption of the plant.

EQUIPMENT	QUANTITY	POWER CONSUMPTION (kW)	kWh/day	Daily Power Cost (SAT)**	Daily Power Cost (SAT)
1. Dehuller	1	5	40	40	2.00
2. Expeller	4	5	160	160	8.00
3. Conveyor	1	1	8	8	0.40
4. Pump	2	0.75	12	12	0.60
5. Reactor	1	2.24	17.92	17.92	0.90
6. Heater	1	15	120	120	6.00
7. Filter Press***	1	5.73	22.92	22.92	1.15
8. Lights	10	0.05	4	4	0.20
9. Others	1	2	16	16	0.80
TOTAL			400.84	400.84	20.04
			500	500	25.00

Table 40. Annual* costing of raw materials.
*300 operating days in a year

	Capacity	Unit (per day)	Annual Cost (SAT)
Jatropha seeds	4,000	kg	1,200,000.00
Methanol	147	L	71,442.00
Sodium hydroxide	8	kg	3,708.00
Salt	22	kg	11,697.44
Water**	2,347	kg	1,597.10
			1,288,444.54

Table 1 presents the yearly breakdown of fixed capital investment and processing costs for village-scale Jatropha biodiesel or methyl ester (JME) production. With daily target of 1,000 L JME, the production cost is SAT 5.40/ L at 4,000 kg daily seed requirement and SAT 1/kg seed cost. The seed requirement in achieving the target production of 1,000 L for village-scale setting may vary upon the oil yield of the seeds to be used.

Jatropha seeds vary in prices depending on their oil yield, variety, and origin. Some seed varieties that come from far places can have higher value due to transportation, and usually are imported for high quality or oil yield, or simply for the bulk availability in these places. For seed costs less than SAT 1/ kg seeds, the breakeven production costs are given in Appendix Figure 16. Obviously, if the seeds to be used are cheaper, the breakeven price becomes lower and more profit can be attained at a certain market selling price of JME. If the seeds to be used are of less quality or have low oil yield, then the seed requirement to produce 1,000 L of JME should increase and this results to higher breakeven price.

The rate of return of investment and payback time are presented in Appendix Figures 17, 18, 20 and 21. At 4,000-kg daily Jatropha seed requirement and SAT 0.33/kg seed cost, the selling price of JME is from SAT 3 to 3.5/L with at most 10 years payback period.

The changing prices of raw materials and services due to the country's economic performance need to be considered in the study of JME village-scale production. Appendix Figure 19 gives the breakeven price of JME at different seed costs.

2. Refined Jatropha Oil Production

Add-on Table. Fixed capital investment cost.

Item	Description	Cost (SAT)
Land	1,000 sq.m. at SAT 10/ sq.m.	10,000
Warehouse building	120 sq. m.	57,600
Machinery		297,750
Wastewater treatment facility		50,000
Office equipment & electrical components		12,500
		427,850

Table 41. Annual* cost of items for the 1,176 L daily production of refined Jatropha oil.
Daily Seed Requirement: 4,000 kg seeds

ITEM	DESCRIPTION	COST (SAT)
A. Annual Fixed Capital Investment Cost		
1. Land	1,000 sq. meter @10 SAT/sq. M	10,000.00
2. Building	Floor area requirement of 120 sq. m (warehouse-type)	57,600.00
3. Machinery		347,750.00
a. Hulling machine	500 kg/hr capacity, powered by 5 KW motor	4,550.00
b. Oil expeller	85 kg/hr capacity, powered by 5 KW electric motor	78,000.00
c. Conveyor	Flat belt, powered by 1 KW electric motor	3,250.00
d. Settling tank		13,000.00
e. Pump	2 gear pumps powered by ½ KW motor	325.00
f. 0.5 □m Filter		52,000.00
g. Filter Press		18,200.00
h. Cooker		16,900.00
i. Cake bin		52,000.00
j. Wastewater treatment facility	(no 30% adjustment for SAT)	50,000.00
k. Miscellaneous	screw conveyor, spare shaft, etc.	44,525.00
4. Electrical component	Magnetic switches and transformer	5,000.00
5. Office equipment	Computers, cabinets, weighing scale, moisture meter, etc.	7,500.00
	TOTAL	427,850.00
B. Annual Processing Cost		-
a. Energy consumption	260 kWh/day at SAT 1/ kWh	78,000.00
b. Personnel Services	See Table 2.	57,000.00
c. Analysis and Others		10,000.00
d. Repair and maintenance of equipment	2% of acquistion cost of machinery & equipment alloted annually for repair and maintenance	7,105.00
e. Depreciation	Salvage value is 10% of acquisition cost for machinery & equipment, 0% for building; computed using straight-line method	
e.1. Building	service life is 30 years	1,728.00
e.2. Machinery and office equipment	service life is 15 years	24,017
f. Raw Material Cost	See Table 3.	1,207,017.00
	TOTAL	1,384,866.67
C. Production Cost/L Refined Jatropha Oil		4.62

*300 operating days in 1 year

Table 42. Personnel requirement of the plant and their corresponding remunerations.

POSITION	NO.	ANNUAL SALARY (SAT)	TOTAL (SAT)
1. Plant Supervisor (Agricultural or Mechanical Engineer)	1	27,000.00	27,000.00
3. Machine Operators	2	9,000.00	18,000.00
4. Utility Persons	2	6,000.00	12,000.00
			57,000.00

Table 43. Annual* costing of raw materials.
*300 operating days in a year

	Daily Requirement	Unit (per day)	Unit Price (SAT/unit)	Annual Cost (SAT)
Jatropha seeds	4,000	Kg	1.00	1,200,000.00
				-
Sodium hydroxide	8	Kg	1.625	4,017.00
				-
Water**	5	cu.m.	2.00	3,000.00
				1,207,017.00

Considering refined Jatropha oil only for village-scale production, about 1,176 L prior to 1,000-L JME production, Appendix Figure 22 compares the breakeven production costs at different seed requirement and cost.

At 4,000-kg seed requirement, the breakeven production costs are given in Appendix Figure 25 and compared at different seed costs and increasing processing costs.

The return of investment and payback period are presented in Appendix Figures 23, 24, 26, 27, 28 and 29.

3. Refined Coconut Oil Production

Table 44. Annual* cost of items for the 1,000 L daily production of refined coconut oil.

Assumptions:

Copra Oil Extraction Recovery 85%
Oil in Copra 60%
Refining Oil recovery 95%
2000 Kg Copra produces 1,077 li Oil

Daily Copra Requirement: 2,000 kg

ITEM	DESCRIPTION	COST (SAT)
A. Fixed Capital Investment Cost		
1. Land	1,000 sq. meter @10 SAT/sq. m	10,000.00
2. Building	Floor area requirement of 120 sq. m (warehouse-type)	57,600.00
3. Machinery		347,750.00
a. Desheller machine	500 kg/hr capacity, powered by 5 KW motor	4,550.00
b. Oil expeller	85 kg/hr capacity, powered by 5 KW electric motor	78,000.00
c. Conveyor	Flat belt, powered by 1 KW electric motor	3,250.00
d. Settling tank		13,000.00
e. Pump	2 gear pumps powered by ½ KW motor	325.00
f. 0.5 □m Filter		52,000.00
g. Filter Press		18,200.00
h. Cooker		16,900.00
i. Cake bin		52,000.00
j. Wastewater treatment facility		50,000.00
k. Miscellaneous	screw conveyor, spare shaft, etc.	44,525.00
4. Electrical component	Magnetic switches and transformer	5,000.00
5. Office equipment	Computers, cabinets, weighing scale, moisture meter, etc.	7,500.00
	TOTAL	**427,850.00**
B. Annual Processing Cost		-
a. Energy consumption	260 kWh/day at SAT 1/ kWh	78,000.00
b. Personnel Services	See Table 2.	57,000.00
c. Analysis and Others		10,000.00
d. Repair and maintenance of equipment	2% of acquistion cost of machinery & equipment alloted annually for repair and maintenance	7,105.00
e. Depreciation	Salvage value is 10% of acquisition cost for machinery & equipment, 0% for building; computed using straight-line method	
e.1. Building	service life is 30 years	1,728.00
e.2. Machinery and office equipment	service life is 15 years	24,016.67
f. Raw Material Cost	See Table 4.	787,017.00
	TOTAL	**964,866.67**
C. Production Cost/L Refined Coconut Oil		3.22

*300 operating days in 1 year

Table 45. Personnel requirement of the plant and their corresponding remunerations.

POSITION	NO.	ANNUAL SALARY PER PERSON (SAT)	TOTAL (SAT)
1. Plant Supervisor (Agricultural or Mechanical Engineer)	1	27,000.00	27,000.00
2. Machine Operators	2	9,000.00	18,000.00
3. Utility Persons	2	6,000.00	12,000.00
			57,000.00

Table 46. Annual* costing of raw materials.

*300 operating days in a year

	Daily Requirement	Unit (per day)	Unit Price (SAT/unit)	Annual Cost (SAT)
Copra	2,000	Kg	1.30	780,000.00
Sodium hydroxide	8	Kg	1.625	4,017.00
Water**	5	cu.m.	2.00	3,000.00
				787,017.00

To compare with refined oil from another biodiesel substrate which is coconut, in equivalent village-scale production, Appendix Figure 30 shows the breakeven production costs at different copra requirement and costs. At 2,000-kg daily copra requirement, Appendix Figure 33 compares the breakeven production cost of refined coconut oil.

The return of investment and payback period graphs (Appendix Figures 31, 32, 34-37) show the economic analysis of this village-scale refined coconut oil production.

13. COMPARATIVE PRICE AND ANALYSIS

Estimated Production and Conversion Yields and Cost of Production of Recommended Biofuel Feedstock.

FEEDSTOCK	$\frac{Ton}{Ha-Yr}$	$\frac{EnergyYield}{Ton}\left(\frac{Li}{Ton}\right)$	$\frac{LiterFuel\,Produced}{Ha-Yr}$	$\frac{Production\ Cost*}{Liter}(SAT)$
A. Bioethanol Production				
Cassava	30 (fresh tuber)	178	5,357	3.02
B. Biodiesel Production				
Jatropha	1-5 (seeds)	250 – 300	250 – 1,503	5.4 (JME) 4.62 (RJO)
Coconut	2.76 (copra)	476	1,314	3.22 (RCO)

* Includes only direct cost such as feedstock, energy, personnel, depreciation, repair and maintenance and analysis.

13.1. Bioethanol Production

At cassava chips price of SAT 0.8 per Kg from a fresh tuber price of $\frac{SAT\,0.25}{Kg}$, the cost of production of ethanol from cassava at SAT 3.02 per liter, is higher than the pump price of gasoline in Samoa at SAT 2.625 per liter (December 2007 price). The total administrative and selling expenses for this case amount to SAT 0.03 per liter ethanol and interest on loan of SAT 0.07 per liter. At the minimum selling price of SAT 3.34 per liter ethanol, the company's unit mark-up amounts to SAT 0.32 per liter ethanol, which is equal to 10.60% mark-up. On the other hand, at the suggested selling price of SAT 3.40 per liter ethanol, the company's unit mark-up amounts to SAT 0.38 per liter ethanol, which is equal to 13.00% mark-up (See Table 31). This production was already based on the standard minimum plant capacity where below this production capacity, cost per liter increases. The hope of producing ethanol at the lower cost and export the excess to other countries in South Pacific seems impossible if it is compared against gasoline price. Although the use of bioethanol, especially sourcing the feedstock from new plantation will bring about job employment and environmental benefits in terms of reduction in toxic and greenhouse gas emission, policy-wise it would be hard to justify because it is not economically viable. To reap the benefits on the environmental aspects without producing bioethanol in Samoa, the use of bioethanol for gasoline blending maybe done through importation of bioethanol from Brazil at US $480 per ton, equivalent to SAT 1.2 per liter only. Due to corresponding reduced gasoline importation , blending of imported bioethanol would result to an annual positive net Foreign Exchange Saving in the amount of SAT 3.7 Million (based on 10% ethanol to gasoline blending and December 2007 price index 2007 and volume of 26M Li). This scheme will not require huge investment, yet it could test the social acceptability of bioethanol blending in Samoa and when time comes that bioethanol production in Samoa will be economically feasible, acceptability is already in place and investment fund availability would be the only problem to hurdle.

To have bioethanol production in Samoa comparable to gasoline price at SAT $\frac{2.62}{Li}$, cassava chips should be priced at SAT $\frac{0.51}{Kg}$ (against SAT 0.8 previous computed price). In this pricing scheme, the ethanol distillery investment will have a Return of Investment of 15.45% and Payback Period of 7 years. However, at SAT $\frac{0.51}{Kg}$ cassava chip, fresh cassava tuber must be sold at $\frac{SAT\,0.034}{Kg}$ for the consolidator to have a mark-up of 8.51%.

13.2. Biodiesel and Refined Oil Production

At Jatropha seed priced at $\frac{SAT\,1.0}{Kg}$ and Copra at $\frac{SAT\,1.3}{Kg}$, the cost of production per liter of Jatropha Biodiesel, Jatropha Refined Oil and Coconut Refined Oil are, SAT 5.4, 4.62 and 3.22, respectively. These prices are all higher than the diesel price of $\frac{SAT\,2.718}{Li}$ (Based on December 2007 price). These computed production costs were based on the cost of establishing new plantation areas for both coconut and Jatropha. Blending of biodiesel to diesel in Samoa at these price levels would be difficult to justify in all types of biofuels. Feedstock cost contributes approximately 80%, 85% and 82% for the production of Jatropha biodiesel, Jatropha Refined Oil and Coconut Refined Oil respectively. For the biodiesel and refined Jatropha and coconut oil to be comparable to the price of diesel, price of a kilo Jatropha seed should be at SAT 0.4 and SAT 0.53, and price of a kilo copra should be SAT 1.063, respectively.

14. REFINED COCONUT OIL PRODUCTION SOURCED FROM EXISTING COCONUT PLANTATIONS

Data:

Copra price @ SAT 0.84, 0.88 and 1.0 (Based on Pacific Oil buying price)

Oil Extraction Recovery @ 85%
Oil in Copra @ 60%
Refining Oil Recovery @ 95%
2,000 Kg Copra produces 1,077 liters of refined coconut oil

Using Copra price at SAT 0.84, 0.88 and 1.0 per kilo

Production cost per liter oil = SAT 2.30(@ SAT 0.84 per Kg Copra)
SAT 2.38 (@ SAT 0.88 per Kg Copra)
SAT 2.62 (@ SAT 1.0 per Kg Copra)

While the use of biofuel from new plantation areas (i.e. both Jatropha biodiesel and Refined Jatropha and Coconut Oil), is not economically attractive, the use of refined coconut oil sourced from existing coconut plantation maybe beneficial. Report of Cocogen Project on 15% coconut oil blended diesel test for 2,041 hours using 106,988 li (mixed fuel) showed no special engine trouble. However, the Cumming Engine KTTA 1963 with a 400 KW maximum generation capacity showed decreased in fuel consumption generation from 3.33 to 2.98 $\frac{kwh}{li}$. The power generation reduced to 89% only , or an increase in fuel consumption by 11%. Factoring in this reduced power generation, cost adjustments will be as follows:

Copra Price (SAT/Kg)	Production Cost (SAT/li)	Increase in Value due to decrease in power generation (+11%)	Potential Maximum Savings Against Diesel's SAT 2.718/li (SAT/li)	Percent Potential Maximum Savings against Diesel's SAT 2.718/li
0.84	2.30	2.55	0.168	6.59%
0.88	2.38	2.64	0.078	2.95%
1.0	2.62	2.91	-0.192	(-6.6%)

A potential maximum savings of 0.168 per liter or 2.718% could be obtained if copra price is at SAT 0.84/kg. On the average buying price of copra at SAT 0.88, potential maximum savings is SAT 0.078 per liter of refined coconut oil.

Case of Pacific Oil Extraction Performance

Oil in Copra @ 68%
1.6 Kg Copra contains 1 Kg oil or produced 1 Liter of extracted oil
4.5 Nuts produce 1 Kg copra (or 7.2 nuts produced 1 liter extracted oil)

Expected cost of oil and production cost are as follows:

Copra Price	Cost per Liter Oil $\left(\frac{SAT}{Li}\right)$	Production Cost Per Liter Oil $\left(\frac{SAT}{Li}\right)$	Increase in Value due to decrease in Power Generation	Potential Maximum Savings $\left(\frac{SAT}{Li}\right)$ Against Diesel's 2.718 Li	Potential Maximum Savings in Percentage
0.84	1.344	1.94	2.15	0.568	26.42%
0.88	1.408	2.0	2.22	0.498	22.43%
1.0	1.6	2.19	2.43	0.288	11.85%

At oil extraction recovery of 88% on 68% oil containing copra, the potential maximum savings per li refined coconut oil is SAT 0.568, 0.498 and 0.288 for copra prices at SAT 0.84, 0.88 and 1.0, respectively.

15. SUMMARY AND CONCLUSION

AGRONOMIC SUITABILITY

Based on existing agro-ecological conditions of Samoa, Cassava and Jatropha could be sources of bioethanol and biodiesel respectively. They can be planted in Upolu and Savaii in soils that are clay loam, deep, and free of boulders and big rocks. The types of soils suitable for the crops are defined in the report, However, the current knowledge about the production and processing of jathropa being a new crop in the island has not been thoroughly research. Varietal selection and development of site specific management practices for the crop should be conducted. Furthermore, production of coconut must be improved through the introduction of new varieties from the Philippines and application of recommended production technologies. Rehabilitation of existing groves through replanting using high yielding varieties should be instituted.

E*CONOMIC VIABILITY*

Biofuel production in Samoa sourced from the establishment of new plantation is not competitive against gasoline and biodiesel prices (December, 2007 pricing). To reap the environmental benefits and Foreign Exchange Savings on the use of biofuel, bioethanol maybe imported from Brazil at US $\$\frac{480}{T}$, generating an annual FOREX Savings of SAT 3.7 million (based on 10% blending, December 2007 price and 2007 volume).

On the other hand, blending of refined oil to diesel sourced from coconut oil from existing plantation could be viable. Potential maximum savings ranges from SAT 0.168 to 0.568 per liter of refined coconut oil used. An estimated SAT 427,850 investment is needed for every 300,000 liter per year refinery plant.

16. RECOMMENDATIONS

BIOETHANOL BLENDING FOR TRANPORT VEHICLE APPLICATION

- Blend at least 10% bioethanol to all gasoline sold in Samoa for transport vehicle use. 10% blending is widely use as the minimum blend to gasoline
- Import bioethanol from Brazil at USD 480/Ton, the cheapest source.
- PPS will take charge of bioethanol importation, similar to its role on petroleum products importation. With this arrangement, the importation, handling, storage and volume requirement would be well coordinated and established.
- Blending should be done at PPS depot only using recommended procedure to ensure controlled quality of ethanol blended gasoline in Samoa.

USE OF REFINED COCONUT OIL FOR POWER GENERATION

- Blend at least 15% refined coconut oil on diesel used for EPC's power generation
- EPC may establish its own copra procurement and coconut oil refinery plant for its consumption
- Only refined coconut oil should be used for blending on diesel
- EPC and/or government may look at initially investing or subsidizing on new plantation, replanting and rehabilitation of coconut trees to complement existing coconut plantation to assure a sustainable supply of coconut oil in Samoa.

FUTURE REVIEW

- The economic viability of biofuel production from new plantation in Samoa maybe reviewed when the cost of imported petroleum will be exceedingly high again. With petroleum price went up as high as USD147 per barrel last July, 2008, the current price at USD 46 per barrel is artificially low.

17. LITERATURE CITED

O.J. Alamu, M.A. Waheed, S.O. Jekayinfa and T.A. Akintola. "Optimal Transesterification Duration for Biodiesel Production from Nigerian Palm Kernel Oil". Agricultural Engineering International: the CIGR Ejournal. Manuscript EE 07 018. Vol. IX. December, 2007.

Lalita Attanatho, Sukunya Magmee and Peesamai Jenvanitpanjakul. 2004. "Factors Affecting the Synthesis of Biodiesel from Crude Palm Kernel Oil". The Joint International Conference on "Sustainable Energy and Environment (SEE)", December 1-3, 2004, Hua Hin, Thailand.

Anonymous, 2002. Growing and marketing of breadfruit as a commercial crop. MAFFM Fruit Tree Development Project. Samoa, May 2002.

Anonymous. Undated. Ano ang oil palm. MPOIDCSI. Technoguide no 1. Mindanao, Philippines.

Anonymous. Undated. Growing cassava in Nigeria. Information Agricultural Support for Agricultural Growth in Nigeria. www.les-nigeria.org.

Adepomala, T. 2004. Cassava. In" Report on Survey of Selected Raw Materials in Nigeria. RMCDC Abuja, Nigeria.

ANZDEC and Department of Scientific and International Research (DSIR). 1990. Land resource planning study: Western Samoa. Final Report Asian Development Bank no 1065-SAM. Lower Hutt: DSIR Division of Land and Soil Science. Samoa

Atherton, J. 2004. GIS design and development. FAO-Sub Regional Office for the Pacific Islands, Apia, Samoa.

Biofuel News. March 20, 2008.

S. Chongkhong, C. Tongursi, P. Chetepattananondh and C. Bunyakan, 2007 Elseiver Ltd.

Cock, J.H. 1983. Cassava. In: Symposium on potential productivity of field crops under different environments. International Rice Research Institute. Los Banos, Laguna, Philippines.

Coronel, R E. 1983. Promising fruits in the Philippines, College of Agriculture, UP Los Banos College, Laguna

Curry, L. 1955. The physical geography of Western Samoa. New Zealand Geographer 11(1): 28-52.

Curry, L. 1962. Weather and climate In: Fox and Cumberland 48-62.

Darnoko and Munir Cheryan. 2000. Kinetics of Palm Oil Transesterification in a Batch Reactor. JAOCS 77 (12). (also: http://www.fineprint.com).

Demafelis, R.B., Movillon, J.L., Badayos, R.B. and Bataller, B.G. 2008. Opportunities and Challenges of Interphasing the Biofuels Program with the Sugarcane Industry. 2008 Annual Convention of the Philippine Sugarcane Technologists Association, Inc. Waterfront Hotel, Cebu City.

Demafelis, R.B. 2008. Biodiesel Processing from *Jatropha curcas* under Philippine Conditions. The Philippine Journal of Crop Science. Vol. 32. No. 4.

Department of Agriculture. Undated. Guide on cassava production. Northern Mindanao Integrated Agricultural Research Center. Dalwangan, Malaybalay City, Philippines.

Del Rosario, E.J., Demafelis, R.B. and T. Cabagay. 2007. Pre-feasibility Study of Bioethanol Production from Corn in the Philippines. DAR. Philippines.

Garcia, E. undated. Experience of oil palm production. Mindanao, Philippines.

Gonzalves, J.B. 2006. An assessment of the biofuel industry in Thailand. United Nations Conference on Trade and Development.

Hazelman, S. 1997. Cassava evaluation: a trial programme linking farmers, extensionists and researchers. Agricultural Extension Service, Savaii, Samoa.

Lian, T.S. undated. Cassava breeding and agronomy research in Malaysia during the past 15 years. Food and Industrial Crops Research Center. MARDI Kuala Lumpur.

Macedo, I.C., Leal, M.R.L.V. and J.E.A.R. da Silva. 2004. Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil. Department of Environment, Government of the State of Saō Paulo. April, 2004.

MAFFM Fruit Tree Development Project, May 2002 (Samoa).

Ministry of Finance. 2008. Strategy for the Development of Samoa 2008-2012. Apia, Samoa.

Ministry of Agriculture and fisheries 2008. The local coconut situation. Market Link. 2(4) Jan-Feb 2008.

Madya Dr. Noor Azian Morad, Madya Mustafa Kamal Abd Aziz and Rohani Binti Mohd Zin. Process Design in Degumming and Bleaching of Palm Oil. Research Vote No: 74198. Centre of Lipids Engineering and Applied Research. Universiti Teknologi Malaysia. November, 2006.

Morton, J. 1987. Fruits of Warm Climates, Miami, Florida.

Movillon, J.L. and M.G. Borines. 2008. Fruit Wastes as Potential Feedstocks for Bioethanol Production. National Fruit Conference, November 1-5, 2008, Splash Mountain, Los Baños, Laguna, Philippines.

Nguyen, Thu Lan Thi, Shabbir H. Gheewala and Savitri Garivait. Full Chain Energy Analysis of Fuel Ethanol from Cassava in Thailand. The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand. March 7, 2007.

Nguyen, Thu Lan Thi, Shabbir H. Gheewala and Savitri Garivait. Life Cycle Cost Analysis of Fuel Ethanol Produced from Cassava in Thailand. The 2nd Joint International Conference on "Sustainable Energy and Environment (SEE 2006)". November 21-23, 2006, Bangkok, Thailand.

Onwueme, I.C. Cassava in Asia and Pacific. In: p 55-66. R.J. Hillocks, J.M. Thresh and A.C. Bellotti (eds). Cassava: Biology, Production and Utilization. CABI Publishing, Oxon, UK.

Panaka, Petrus. New Developments of Ethanol Industry in Indonesia. Presentation during the Asian Science and Technology Seminar, Jakarta. March 7, 2007.

Pauzan, I. undated. Effect of planting and rainfall distribution on the yield of five common varieties in Lumpang, Indoensia. Umas Jaya Farm, Great Giant Pineapple Co., Lumpang, Indonesia.

PCARRD, 1983. Philippines recommends for coconut. Los Banos, Laguna Philippines

PHILSUTECH. 1997. Official Chemical Handbook for Philippine Sugarcane Industries. Bacolod City, Philippines: NALCO Press, Inc. 221 pp.

Planning Commission, Government of India. 2003. Report on the Committee on Development of Bio-fuel. April 6, 2003. http://planning commission.nic.in/reports/genrep/cmtt_bio.pdf.

Ragone, D. *Artocarpus altilis*. Species Profiles for Pacific Island Agroforestry. April 2006. www.traditional tree.org.

Rojanaridpiched, C. V. Vichukir, E. Sorobol, and P Changlek. Undated. Dept of Agronomy Kastsart University, Bangkok, Thailand.

Rajendran, R. 1991. *Artocarpus altilis* (Parkinson) Forsberg. In: Verheij, E.W.M. and E. Coronel 1991. Plant resources of Southeast Asia 2 Edible Fruits and Nuts PROSEA Bogor, Indonesia.

Rañola, R.F.Jr., Demafelis, R.B., Elepaño, A.R., Del Rosario, E.J. and E. Del Rosario. Feasibility of Bioethanol Production from Cassava in the Philippines. CDSF. Philippines.

Schaffert, R.E. Development of Cultivars for Industrial Processing/Ethanol Production in Brazil. Paper presented during the International Conference on Sorghum for Fuels. August 19-22, 2008. Houston, Texas.

Sesega, S. 2005. Deforestation and forest degradation in Samoa. FAO/SAPA/SAM DEFOR 01/05. Nov 2005 FAO.Apia, Samoa.

Statistics Department, Ministry of Finance. Tabulation report population and housing census 2006. Apia, Samoa.

Suthipong Sthiannopkao. Asian J. Energy Environ., Vol. 3 Issues 1-2, (2002), pp. 27-51.

M.M. Rahman Taluteder, K.L. Min Beatrice, O. Puay Song, S. Puah, J. Chuan Wu, C. Jae Won, and Y. Chow. 2008. "Improved Method for Efficient Production of Biodiesel from Palm Oil". Energy and Fuels 22: 141-144.

Verheij, E.W.M. and R. E. Coronel 1991. Plant resources of Southeast Asia 2 Edible Fruits and Nuts PROSEA Bogor, Indonesia.

Villancio, G. *Jatropha curcas* seed production for biodiesel. Tubang Bakod Series 1(1):1-9. PLB College, Laguna.

Ward, R. G. and P. Ashcroft. 1998. Samoa" mapping the diversity. Institute of Pacific Studies, University of South Pacific. Suva, Samoa.

Wright, A.C.S. 1963. Soils and land use of Western Samoa. Soil Bureau Bulletin no 2. New Zealand Department of Scientific and Industrial Research.

APPENDIX 1

The following persons were consulted and the specific issues and information discussed:

Date	Time	Persons consulted	Purpose of the meeting
June 18, 2008	1:30-4:30 pm	Mr Aru Mathias	Conducted an ocular inspection of the island of Upolu to determine its soils potential, existing land use and cropping systems and vegetation
June 19, 2008	9:00 am	Mr Austalia Titimoea Assistant CEO, Meteorology, MNREM	Consulted him about the climate of Samoa and requested for information of the most recent climatic data such as rainfall, temperature and relative humidity
June 19, 2008	1:00-2:00 pm 3:30 pm	Mr Solomone Fifita, Program Manager of Pacific Islands Greenhouse Gas Abatement Through Renewable Energy Project (PIGGAREP) Mr Anare Matakavit, Energy Program Coordinator, International Union for the Conservation of Nature (Based in Fiji) Mr Pau Inoue, Senior Draftsman, Ministry of Natural Resources	Discussed the biofuel project in relation to what the Pacific Island countries sees as part of a regional thrust on renewable energy. Inquired if there is a regional policy framework into which the biofuel project can be situated. Mr Fifita mentioned of a Joint Communique issued and signed in 2006 by senior energy officials of Pacific Island countries Briefed me on GIS assisted soil, topographic, and land use mapping system of Samoa including the measurements of the total area in the two main islands covered by each land use. Requested copy of map for inclusion in site assessment.
June 20, 2008	9:00am	Dr Hitofume Abe Chief Advisor on Renewable Energy, JICA	Inquired from him about his presentation in which he cited biofuel as part of renewable energy program. I was briefed on his much vouched thermal energy project through biomass gassification
Date	**Time**	**Persons consulted**	**Purpose of the meeting**

	10:00am	Mr David Hunter Registrar and Professor of soils science, University of Samoa Mr Mareko Tofinga Associace Professor in Crop Science, USP	Provided me with a glimpse of existing agricultural practices in Samoa, crop use and adaptation, their programs on crop production, propagation and protection and their staff complement for research and training programs. Provided me with insights on existing crops raised in Samoa and their cropping systems
June 20, 2008 June 23, 2008	11:20am Whole day	Mr Asuao Kirifi Pouono CEO, Ministry of Agriculture With Aru Mathias of FAO, Edward Langham of EPC and Paul Inoue of MNRE	Discussed with me his views about biofuel in relation to food security thrusts of the government of Samoa. His views were clear. He doesn't see the biofuel program to clash with food security. Cassava is not being grown for food but feed. Volume of production of coconut and breadfruit is in excess of local demand. What the program should look at is how to move away from traditional to commercial production. Conducted an ocular assessment of the existing vegetation, accessibility topography, water availability and soil conditions of Savaii. Soil map of Savaii was provided was provided courtesy of MNRE. The ocular visit provided as a first hand information on places in the island having suitable and unsuitable sites based on predominance of shallow rocky soils.
June 24, 2008	3:00	Mr Jeff Affoa Secretary, Farmers Association	Discuss with him the biofuel study. The grower provided me an insight of the production of breadfruit and other fruit crops in the island including the cost of production and income potentials of various crops

Date	Time	Persons consulted	Purpose of the meeting
June 25, 2008	10:00	Mr Lemalu Samau Tate Simi CEO, Ministry of Commerce, Industry	Briefed me about the excellent investment environment in Samoa. Labor cost is not competitive. SAT2/hr is relatively high

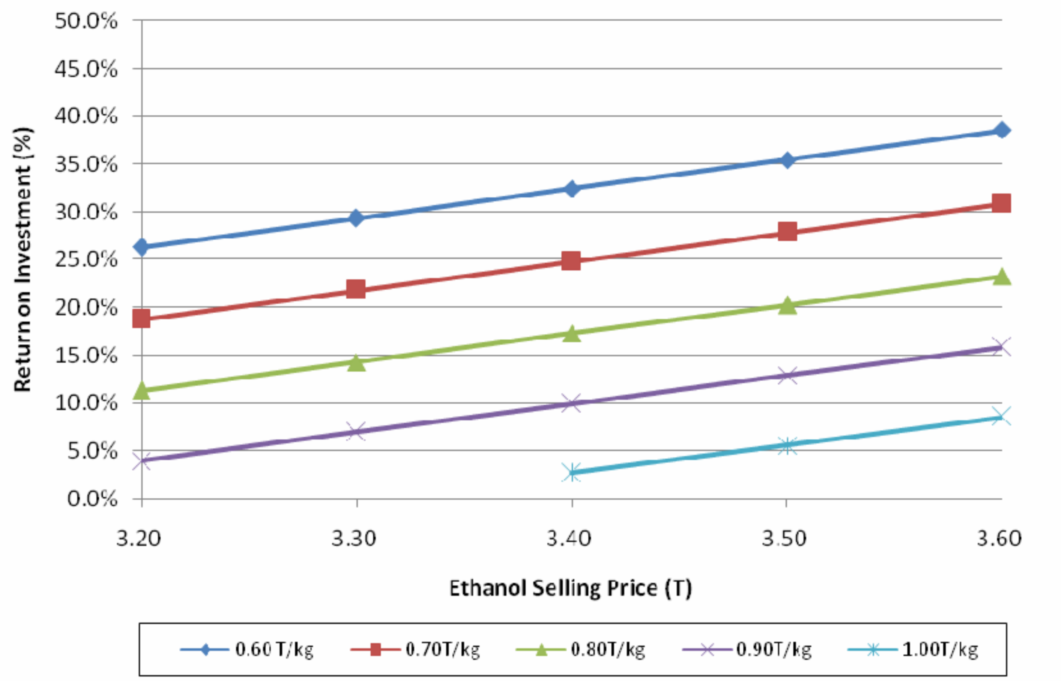
		and Labor	compared to other South Pacific Countries. The country implements value added tax of 15%. It exempts however investments with gross income of SAT 78,000/yr. The government also provides incentives to foreign investors by extending tax exemption for raw materials and infrastructures to be used for export
June 26, 2008	8:00 10:00 11:30 1:00 2:30	Mr , Vegetable Grower, Member, Farmers association in Samoa, Afiamalu, Samoa 5 officials of Crops Section Ms Lasa Aiono Mr Parate Matalavea, Principal Research Official of Crops Division, MOA Papali I Grant Percival Managing Director Natural foods International	Briefed me about the production and export potentials of high value vegetable crops. He grows lettuce, head cabbage, tomato among others Presented the current work and programs on breadfruit production, varietal evaluation of coconut, cassava production and tissue culture of taro Briefed her about the biofuel mission and is willing to participate in case Samoa will venture into biofuel crop production. Has been planting vegetable, fruit crops and ornamental crops The Research Section pursues research on propagation, farming systems, crop protection and postharvest handling of vegetable and fruit crops He is involved in the processing of nonu juice and banana chips. He plans to establish 100 acres of oil palm plantation in Savaii to produce oil for his manufacturing business. His monthly requirement of palm oil reaches 20 tons/6 month.

DATE	PERSONS MET	PURPOSE OF MEETING
July 7, 2008 (Monday)	Visit the office of EPC and met RAPA	Discussed the current status of biofuel feedstock plantation in SAMOA such as cassava and breadfruit. ------ the planned plantation of Jatropha and Palm in Samoa.
July 8, 2008 (Tuesday)	Engr. Siloma Tago Asst. Generation Manager of EPC	Discussed EPC test conducted on Isuzu and Toyota Hilux

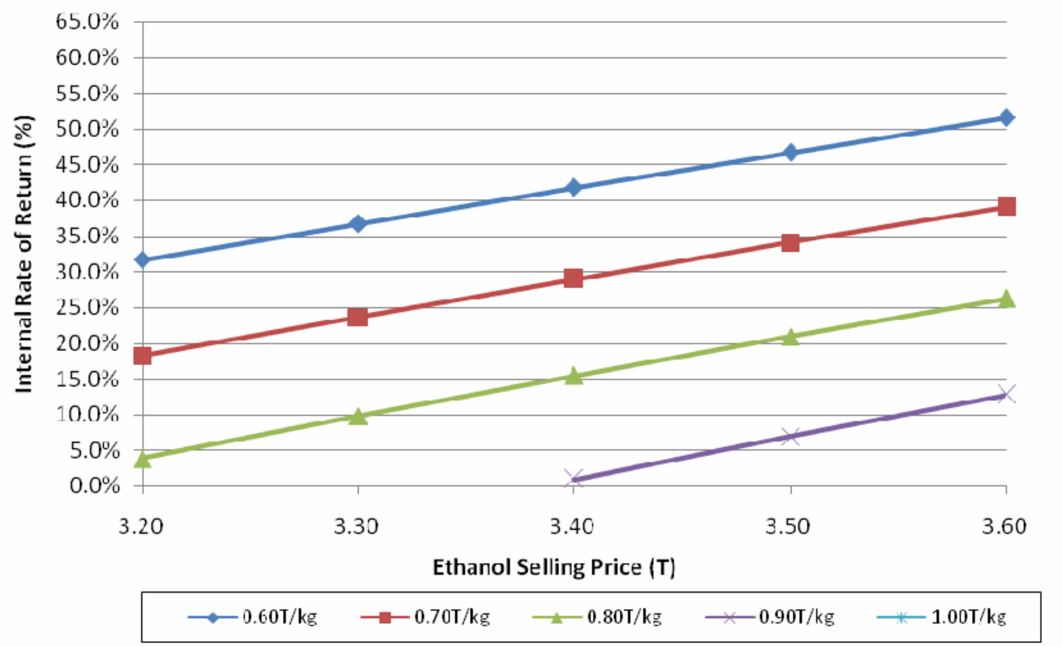
		vehicles using different blends of coconut oil.
July 9, 2008 (Wednesday)	Hon. Lusia Seto Leau Deputy CEO Ministry of Finance and Mr. Benjamin Pereiora Assistant CEO Eco Policy and Planning Division Ministry of Finance Ms. Silia Kilepoa Energy Coordinator, Min. of Finance	Discussed existing coconut oil processing plants and just recently government approved 600 acre Jatropha plantation project in Samoa.
July 10, 2008 (Thursday)	Meeting with Mr. Faamatuainu Amosa Powoa and Associate Assistant CEO Ministry of Works, Transportation and Inftrastucture Meeting with Hon. Tuun IeTi Taulealo, CEO, Ministry of Natural Resources and Environment and with Mr. Mataia Uaine Silailai Assistant CEO, Ministry of Natural Resources and Environment Meeting with Mr. Saman Eluale Seto Managing Director, Petroleum Products Supplies	Discussed existing petroleum depot, road network. Discussed on land use policy and government permitting requirement Discussed bulk liquid transportation and shipping costing and pier.
	Mr. Tupuola Plant Supervisor Pacific Oil	Visited Pacific Oil discussed coconut oil extractor yield and costings of copra.
July 14, 2008 (Monday)		Conducted field inspection of potential biofuel feedstock plantation areas around Upolu island.

APPENDIX FIGURES

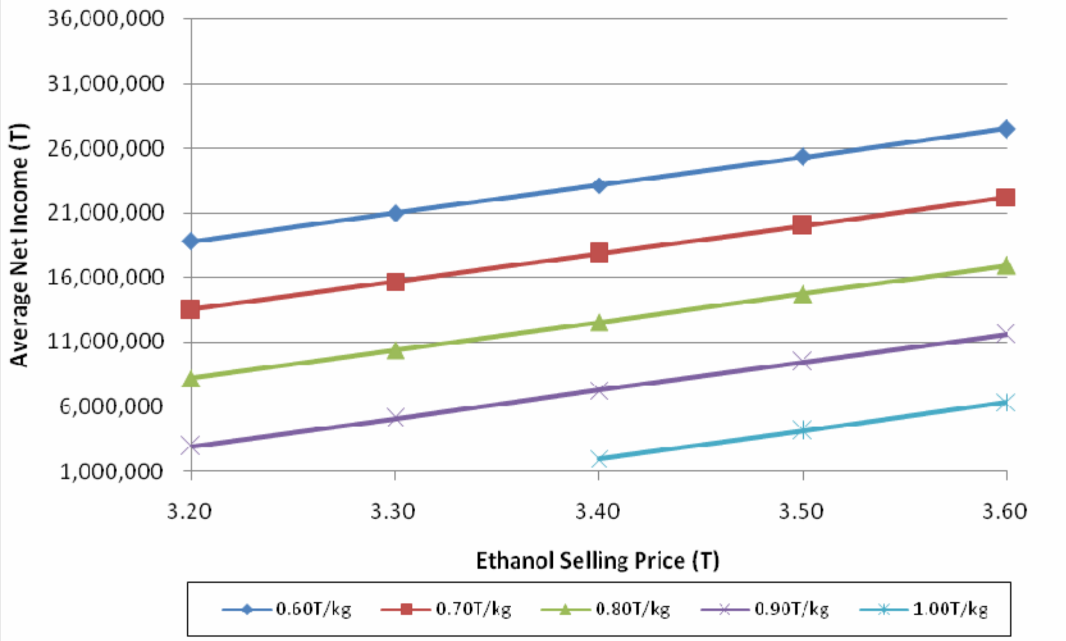
Effect of Ethanol Price



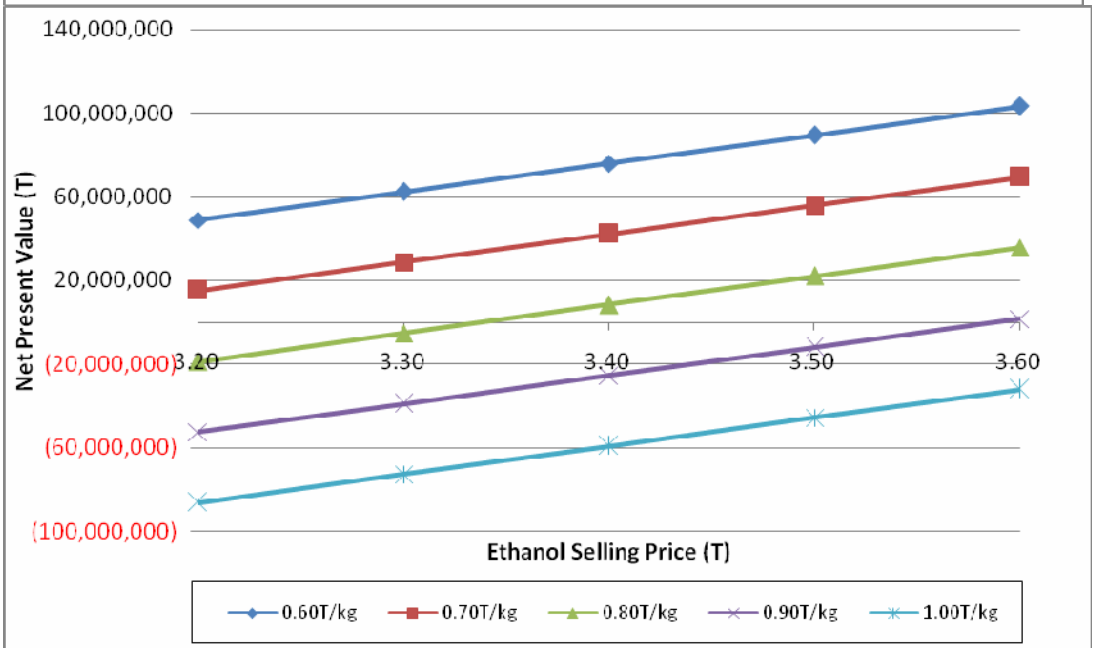
Appendix Figure 1. The Effect of Ethanol Selling Price on Return on Investment at Different Cassava Chip Cost at Zero Percent Increase in Processing Cost



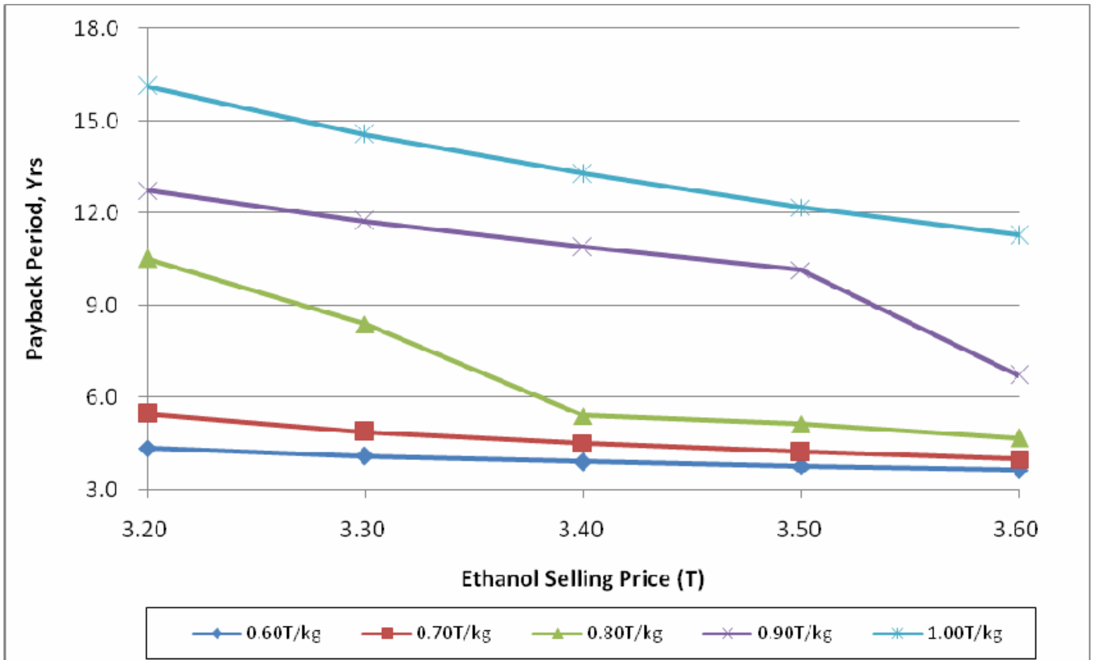
Appendix Figure 2. The Effect of Ethanol Selling Price on Internal Rate of Return at Different Cassava Chip Cost at Zero Percent Increase in Processing Cost



Appendix Figure 3. The Effect of Ethanol Selling Price on Average Net Income at Different Cassava Chip Cost at Zero Percent Increase in Processing Cost

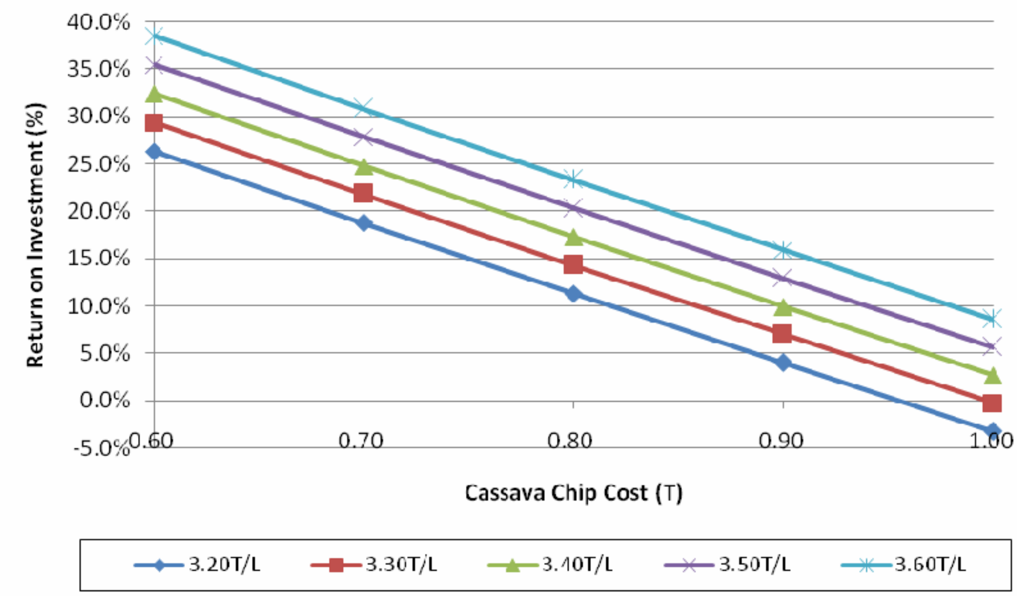


Appendix Figure 4. The Effect of Ethanol Selling Price on Net Present Value at Different Cassava Chip Cost at Zero Percent Increase in Processing Cost

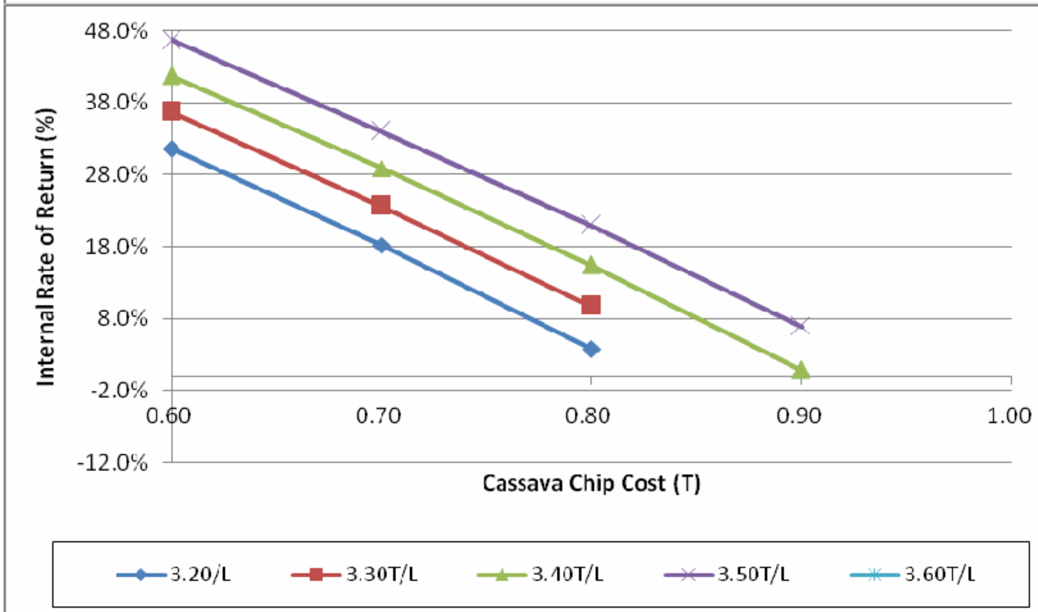


Appendix Figure 5. The Effect of Ethanol Selling Price on Payback Period at Different Cassava Chip Cost at Zero Percent Increase in Processing Cost

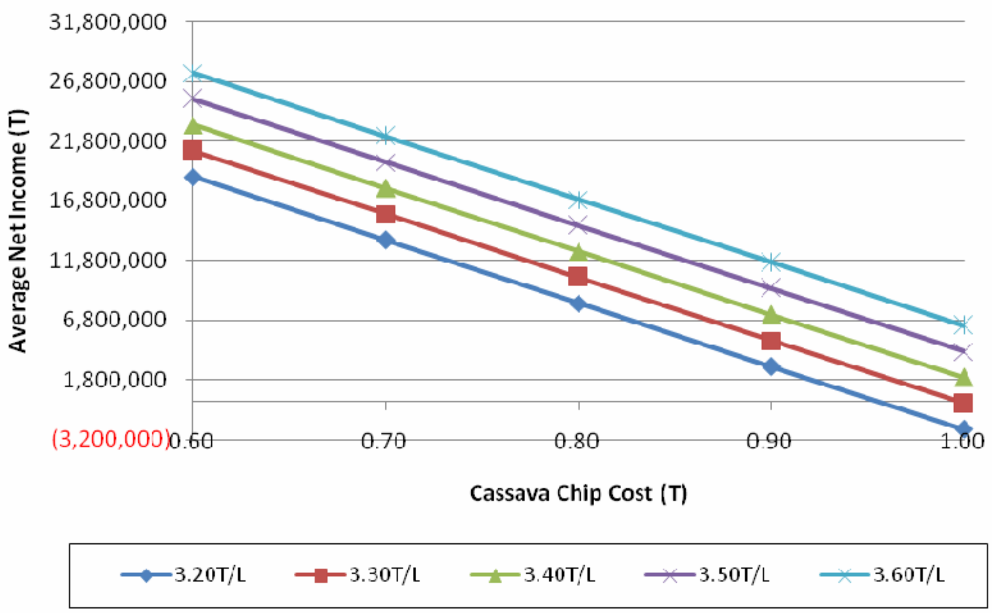
Effect of Cassava Chip Cost



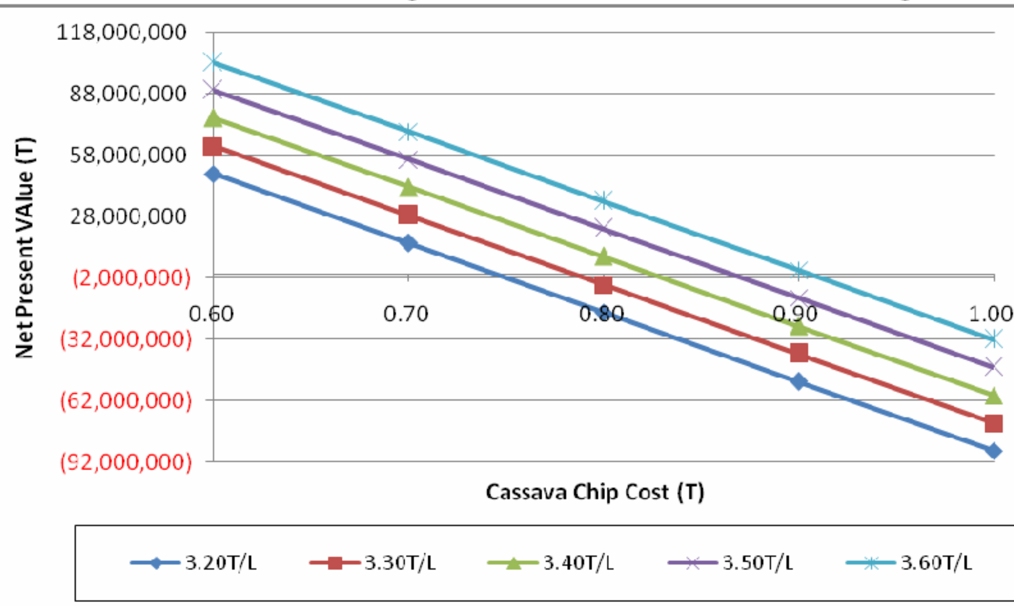
Appendix Figure 6. The Effect of Cassava Chip Cost on Return on Investment at Different Ethanol Selling Prices at Zero Percent Increase in Processing Cost



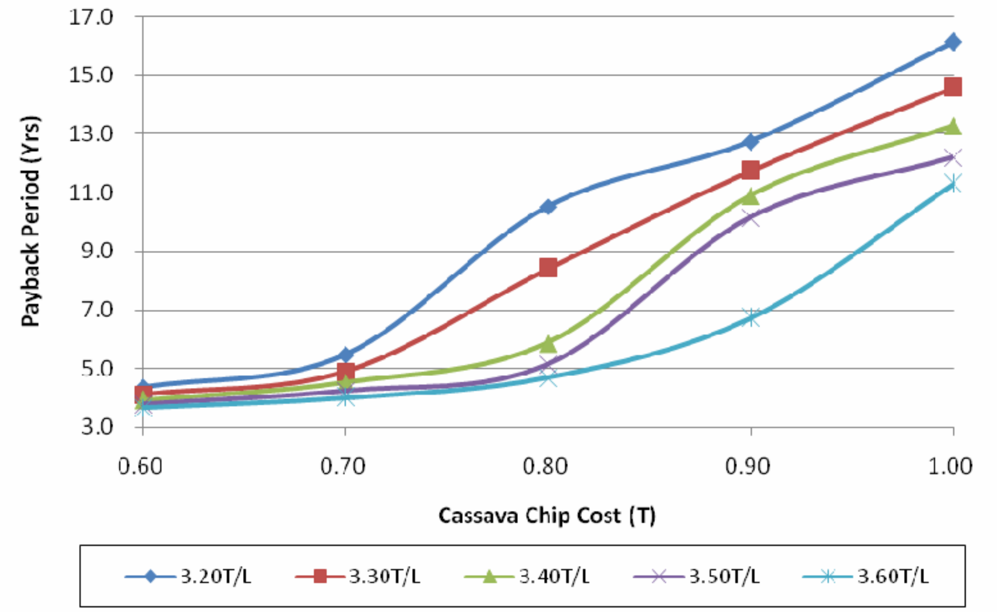
Appendix Figure 7. The Effect of Cassava Chip Cost on Internal Rate of Return at Different Ethanol Selling Prices at Zero Percent Increase in Processing Cost



Appendix Figure 8. The Effect of Cassava Chip Cost on Average Net Income at Different Ethanol Selling Prices at Zero Percent Increase in Processing Cost

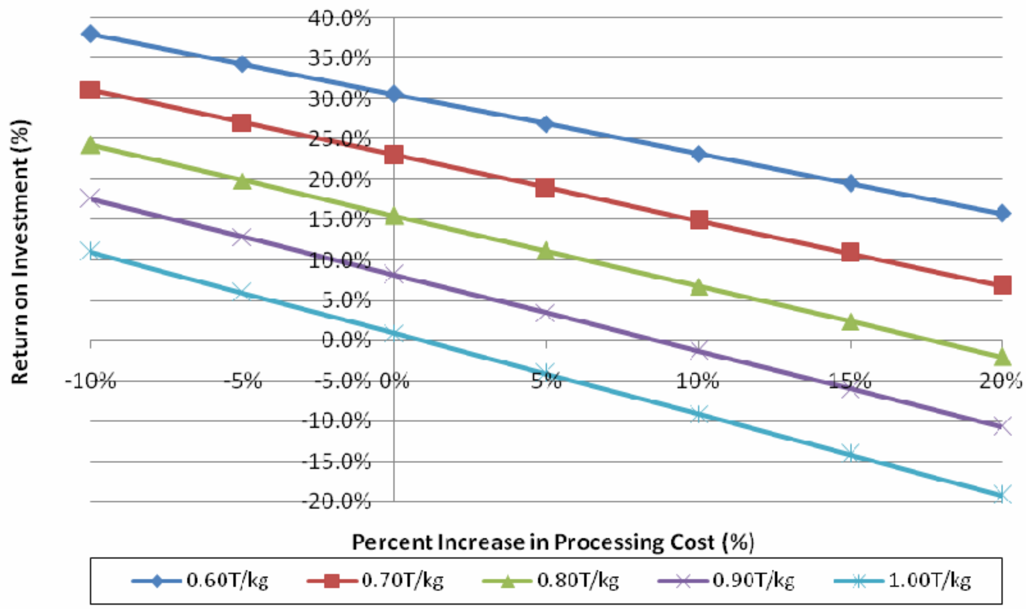


Appendix Figure 9. The Effect of Cassava Chip Cost on Net Present Value at Different Ethanol Selling Prices at Zero Percent Increase in Processing Cost

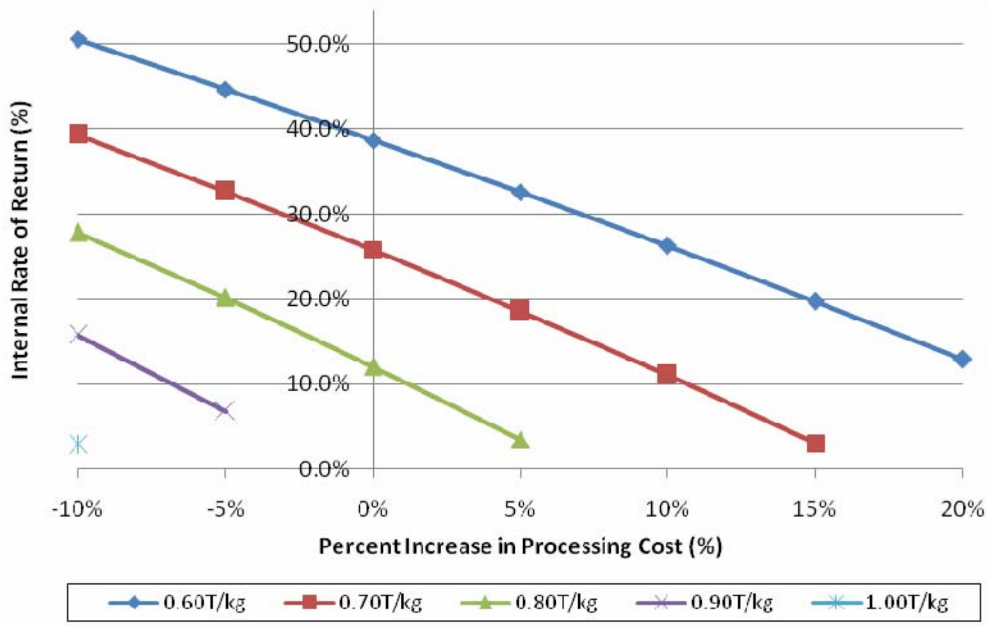


Appendix Figure 10. The Effect of Cassava Chip Cost on Payback Period at Different Ethanol Selling Prices at Zero Percent Increase in Processing Cost

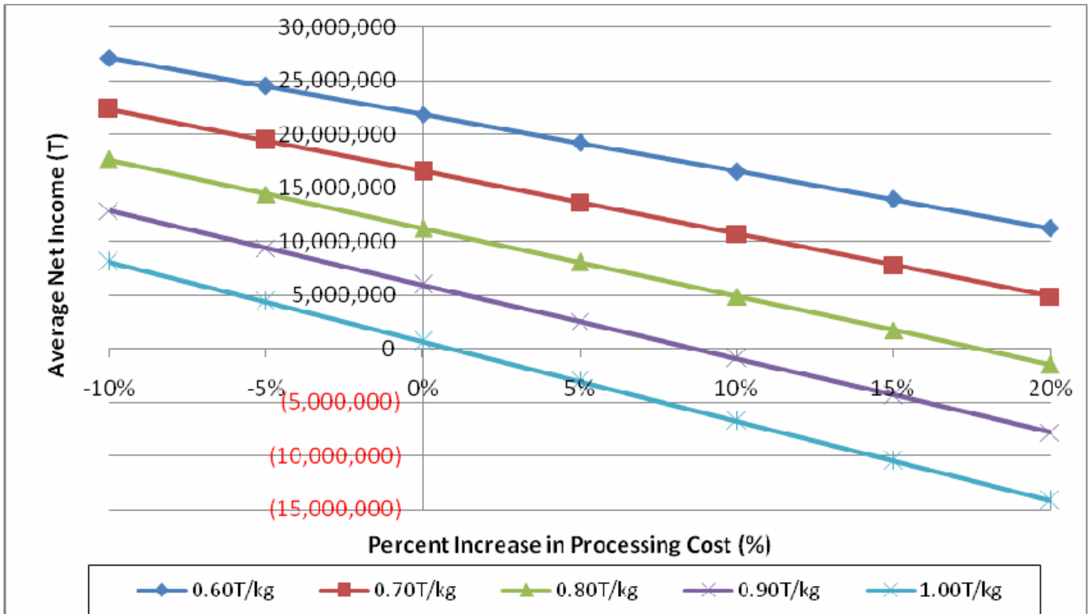
Effect of Percent Increase in Processing Cost



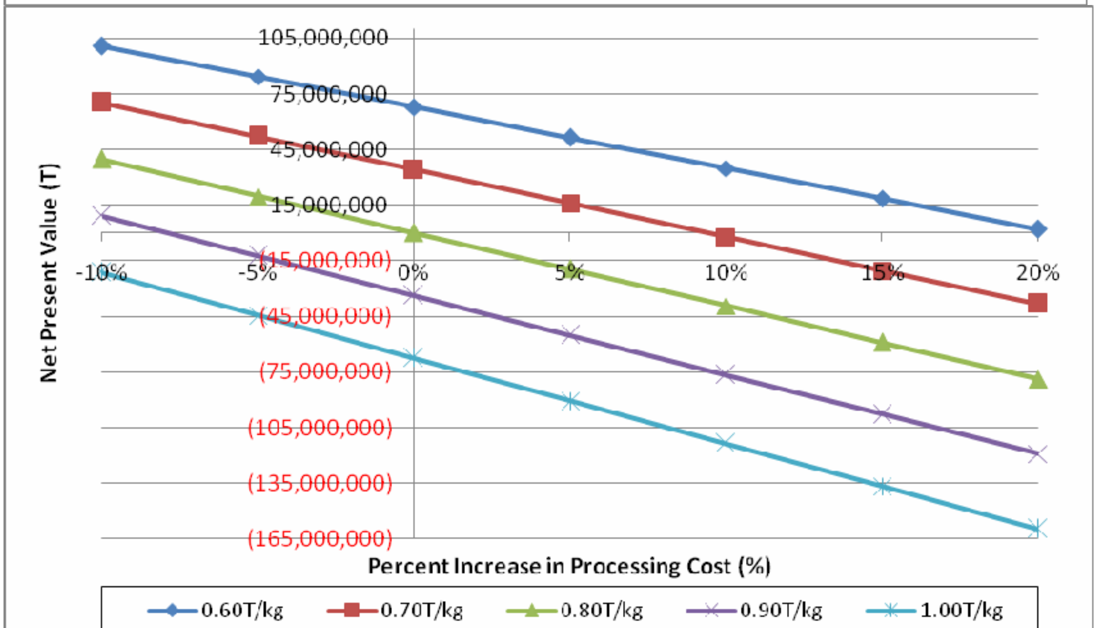
Appendix Figure 11. The Effect of Percent Increase in Processing Cost on Return on Investment at Different Cassava Chip Cost at 3.34 T/L Ethanol Selling Price



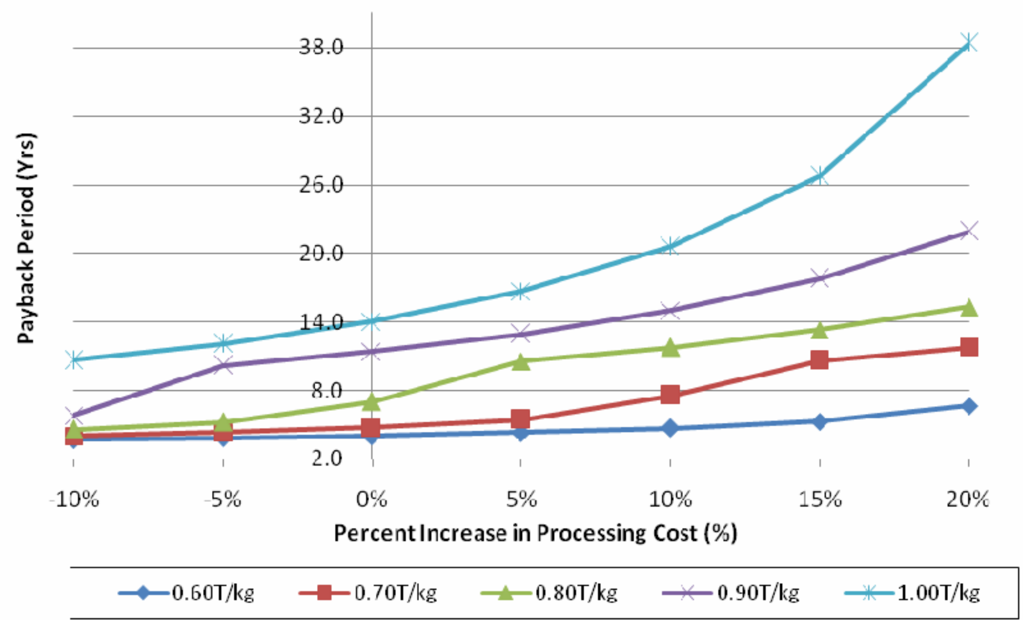
Appendix Figure 12. The Effect of Percent Increase in Processing Cost on Internal Rate of Return at Different Chip Cost at 3.34 T/L Ethanol Selling Price



Appendix Figure 13. The Effect of Percent Increase in Processing Cost on Average Net Income at Different Cassava Chip Cost at 3.34 T/L Ethanol Selling Price

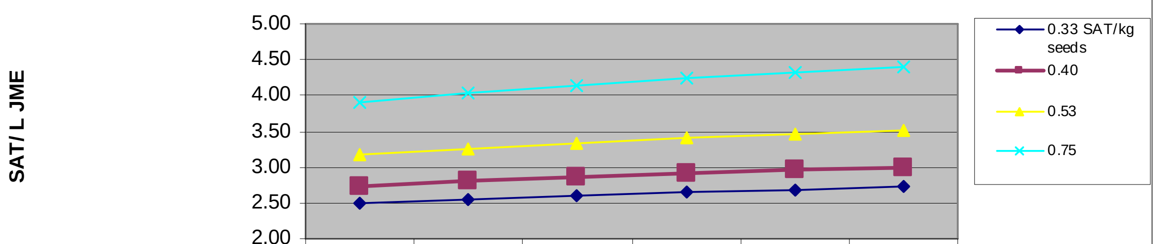


Appendix Figure 14. The Effect of Percent Increase in Processing Cost on Net Present Value at Different Cassava Chip Cost at 3.34 T/L Ethanol Selling Price



Appendix Figure 15. The Effect of Percent Increase in Processing Cost on Payback Period at Different Chip Cost at 3.34 T/L Ethanol Selling Price

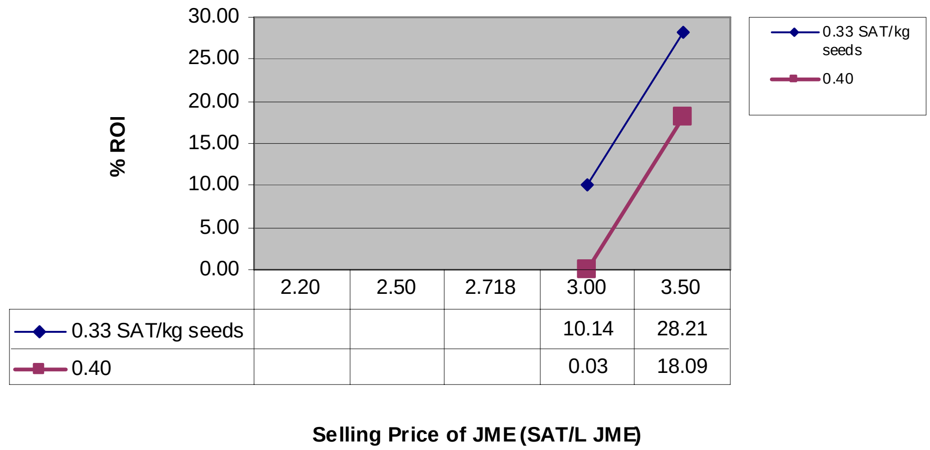
Jatropha Methyl Ester or Biodiesel



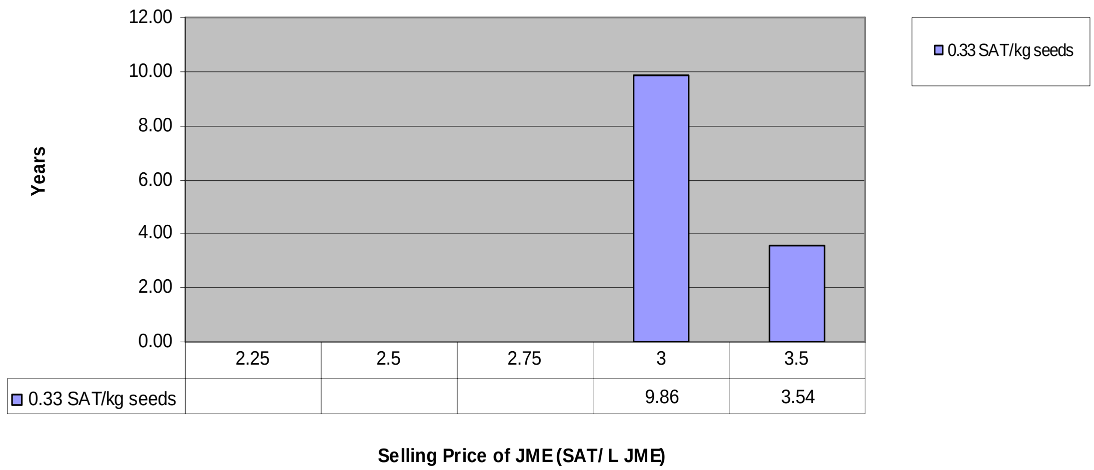
	3,350	3,500	3,650	3,800	3,900	4,000
0.33 SAT/kg seeds	2.50	2.55	2.60	2.65	2.69	2.72
0.40	2.74	2.80	2.86	2.92	2.96	3.00
0.53	3.17	3.25	3.33	3.41	3.47	3.52
0.75	3.91	4.02	4.14	4.25	4.32	4.40

kg seeds/ day

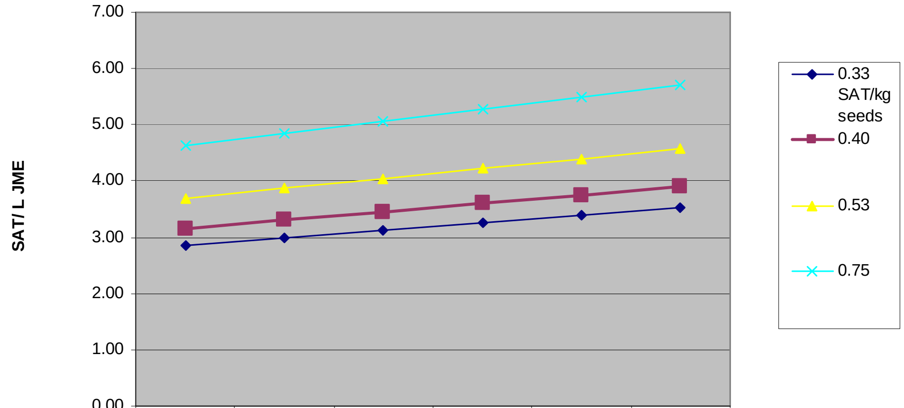
Appendix Figure 16. Breakeven Production Costs at Different Seed Requirement (depending on Oil Yield of Seeds) at Different Seed Costs at Constant Costs of Other Raw Materials)



Appendix Figure 17. Return of Investment (ROI) at Constant Daily Seed Requirement



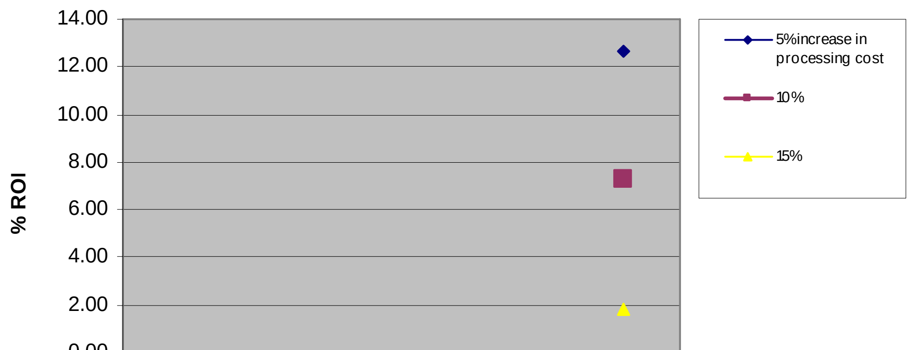
Appendix Figure 18. Payback Period at Constant Daily Seed Requirement of 4,000 kg



	5	10	15	20	25	30
0.33 SAT/kg seeds	2.86	2.99	3.13	3.26	3.40	3.54
0.40	3.15	3.30	3.45	3.60	3.75	3.90
0.53	3.70	3.87	4.05	4.22	4.40	4.58
0.75	4.62	4.84	5.06	5.28	5.50	5.72

% Increase in Processing Cost

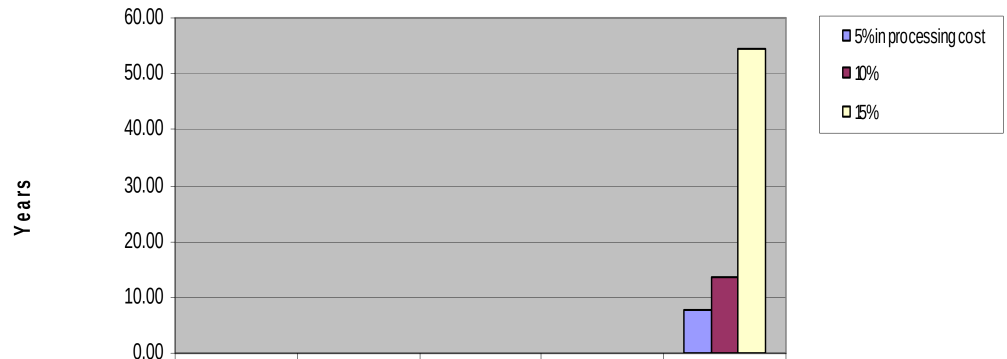
Appendix Figure 19. Breakeven Production Costs at Increasing Processing Costs at 4,000 kg Daily Seed Requirement



	2.20	2.50	2.72	3.00	3.50
5% increase in processing cost					12.68
10%					7.26
15%					1.84

Selling Price of JME (SAT/ L)

Appendix Figure 20. Return of Investment (ROI) at 4,000 kg Daily Seed Requirement at SAT 0.40/ kg Seed Cost

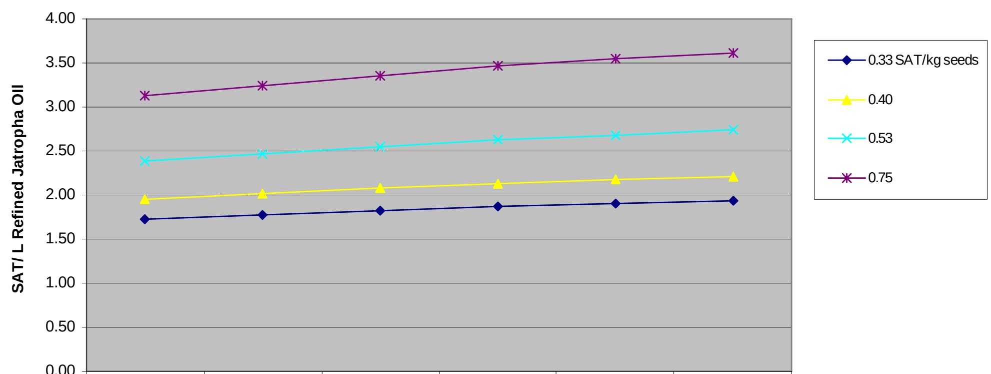


	2.20	2.50	2.72	3.00	3.50
5% in processing cost					7.89
10%					13.78
15%					54.40

Selling Price of JME (SAT/ L JME)

Appendix Figure 21. Payback Period at Constant 4,000 kg Daily Seed Requirement at SAT 0.40/kg Seed Cost

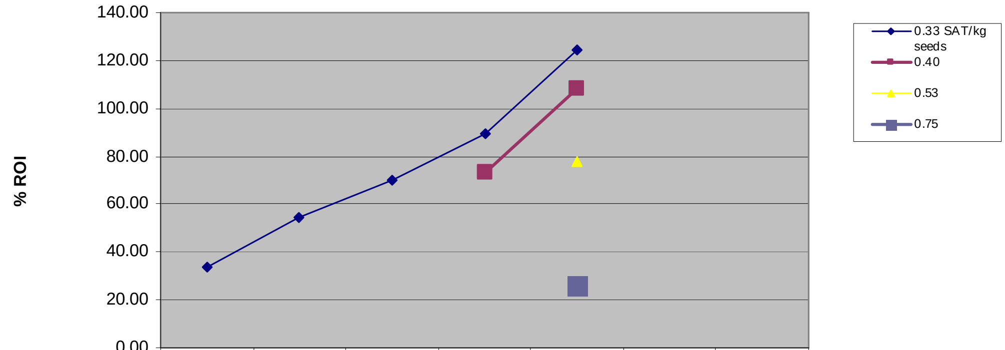
Refined Jatropha Oil



	3,350	3,500	3,650	3,800	3,900	4,000
0.33 SAT/kg seeds	1.72	1.77	1.82	1.87	1.90	1.94
0.40	1.96	2.02	2.08	2.14	2.18	2.22
0.53	2.39	2.47	2.55	2.63	2.68	2.74
0.75	3.13	3.24	3.35	3.47	3.54	3.62

kg seeds/ day

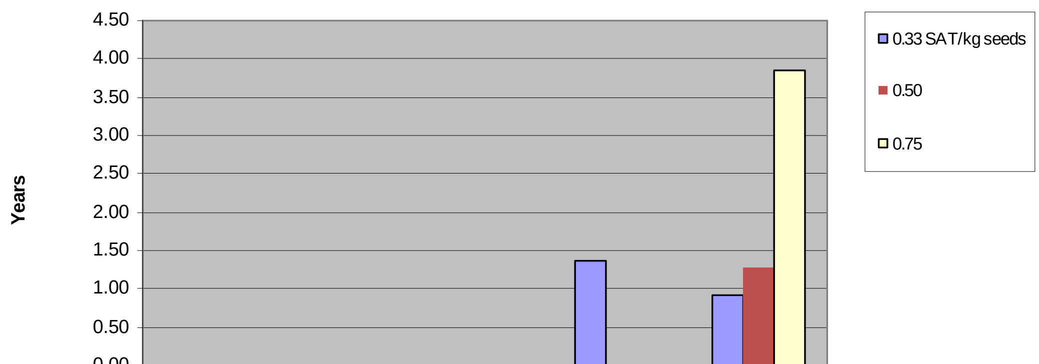
Appendix Figure 22. Production Costs at Different Seed Requirement (depending on Oil Yield of Seeds) at Different Seed Costs at Constant Costs of Other Raw Materials)



	2.20	2.50	2.718	3.00	3.50		
0.33 SAT/kg seeds	33.54	54.57	69.86	89.63	124.69		
0.40				73.19	108.25		
0.53					77.71		
0.75					26.03		

Selling Price of Refined Jatropha OIl (SAT/L)

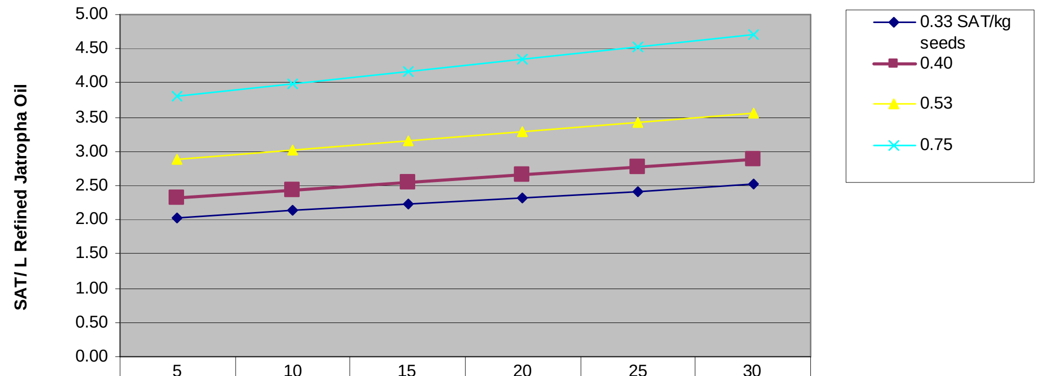
Appendix Figure 23. Return of Investment (ROI) at Constant Daily Seed Requirement



	2.20	2.50	2.72	3.00	3.50
0.33 SAT/kg seeds				1.37	0.92
0.50					1.29
0.75					3.84

Selling Price of Refined Jatropha Oil (SAT/ L)

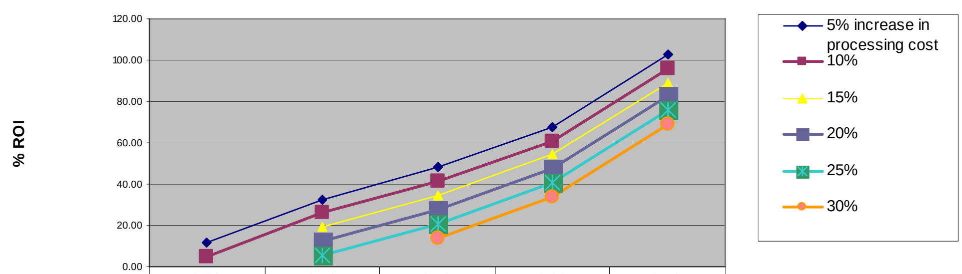
Appendix Figure 24. Payback Period at Constant Daily Seed Requirement of 4,000 kg



% Increase in Processing Cost	5	10	15	20	25	30
0.33 SAT/kg seeds	2.03	2.13	2.23	2.32	2.42	2.52
0.40	2.33	2.44	2.55	2.66	2.77	2.88
0.53	2.87	3.01	3.15	3.28	3.42	3.56
0.75	3.80	3.98	4.16	4.34	4.52	4.70

% Increase in Processing Cost

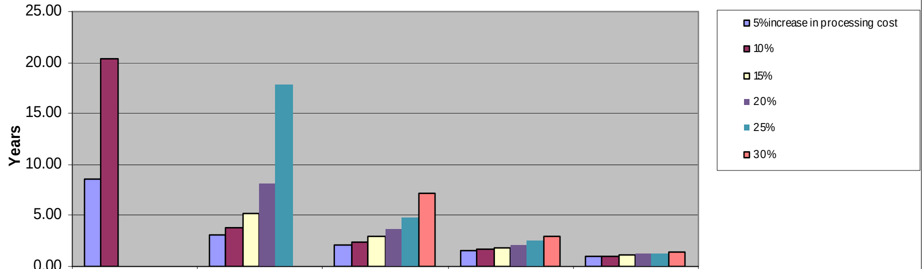
Appendix Figure 25. Breakeven Production Costs at Increasing Processing Costs at 4,000 kg Daily Seed Requirement



Selling Price of Refined Jatropha Oil (SAT/ L)	2.20	2.50	2.72	3.00	3.50
5% increase in processing cost	11.71	32.74	48.03	67.80	102.86
10%	4.92	25.95	41.24	61.01	96.07
15%		19.17	34.45	54.23	89.28
20%		12.38	27.66	47.44	82.50
25%		5.59	20.88	40.65	75.71
30%			14.09	33.86	68.92

Selling Price of Refined Jatropha Oil (SAT/ L)

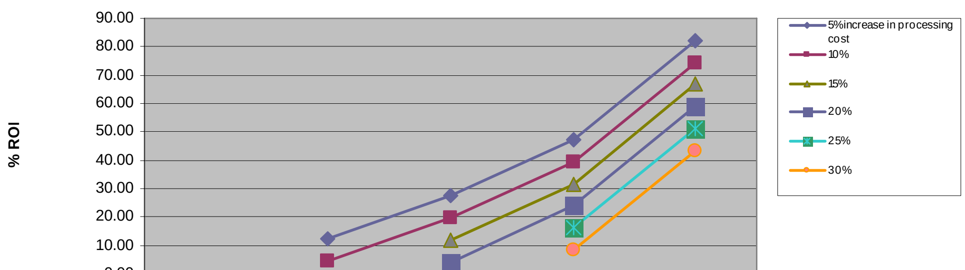
Appendix Figure 26. Return of Investment (ROI) at 4,000 kg Seed Requirement at SAT 0.33/ kg Seed Cost



	2.20	2.50	2.72	3.00	3.50
5% increase in processing cost	8.54	3.05	2.08	1.47	0.97
10%	20.33	3.85	2.42	1.64	1.04
15%		5.22	2.90	1.84	1.12
20%		8.08	3.61	2.11	1.21
25%		17.89	4.79	2.46	1.32
30%			7.10	2.95	1.45

Selling Price of Refined Jatropha OIl (SAT/ L)

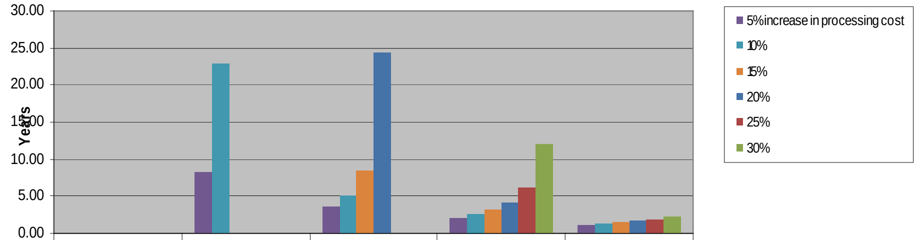
Appendix Figure 27. Payback Period at SAT 0.33/kg Seed Cost and 4,000 kg Daily Seed Requirement



	2.20	2.50	2.72	3.00	3.50
5% increase in processing cost		12.13	27.41	47.19	82.25
10%		4.36	19.64	39.42	74.48
15%			11.87	31.65	66.71
20%			4.10	23.88	58.94
25%				16.11	51.17
30%				8.34	43.40

Selling Price of Refined Jatropha OIl (SAT/ L)

Appendix Figure 28. Return of Investment (ROI) at 4,000 kg Daily Seed Requirement at SAT 0.50/ kg Seed Cost

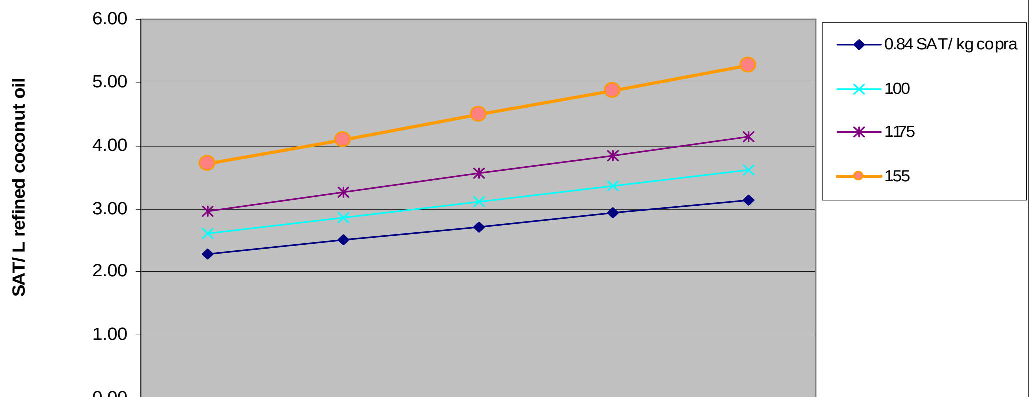


	2.20	2.50	2.72	3.00	3.50
5% increase in processing cost		8.25	3.65	2.12	1.22
10%		22.95	5.09	2.54	1.34
15%			8.42	3.16	1.50
20%			24.37	4.19	1.70
25%				6.21	1.95
30%				11.99	2.30

Selling Price of Refined Jatropha Oil (SAT/ L)

Appendix Figure 29. Payback Period at Constant 4,000 kg Daily Seed Requirement at SAT 0.50/kg Seed Cost

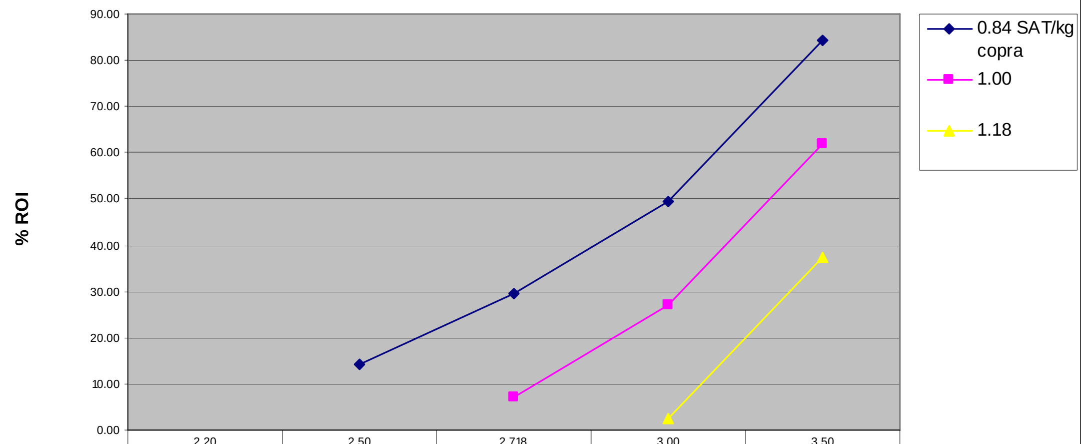
Refined Coconut Oil



	2,000	2,250	2,500	2,750	3,000
0.84 SAT/ kg copra	2.30	2.51	2.72	2.93	3.14
1.00	2.62	2.87	3.12	3.37	3.62
1.175	2.97	3.26	3.55	3.85	4.14
1.55	3.72	4.10	4.49	4.88	5.27

kg copra/ day

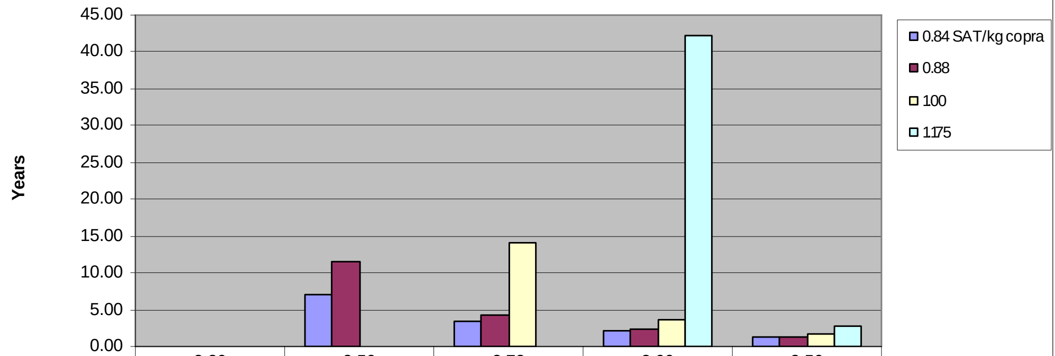
Appendix Figure 30. Breakeven Production Costs at Different Copra Requirement (depending on Oil Yield of Seeds) at Different Copra Costs at Constant Costs of Other Raw Materials)



	2.20	2.50	2.718	3.00	3.50
0.84 SAT/kg copra		14.29	29.57	49.35	84.41
1.00			7.14	26.91	61.97
1.18				2.37	37.43

Selling Price of refined coconut oil (SAT/L)

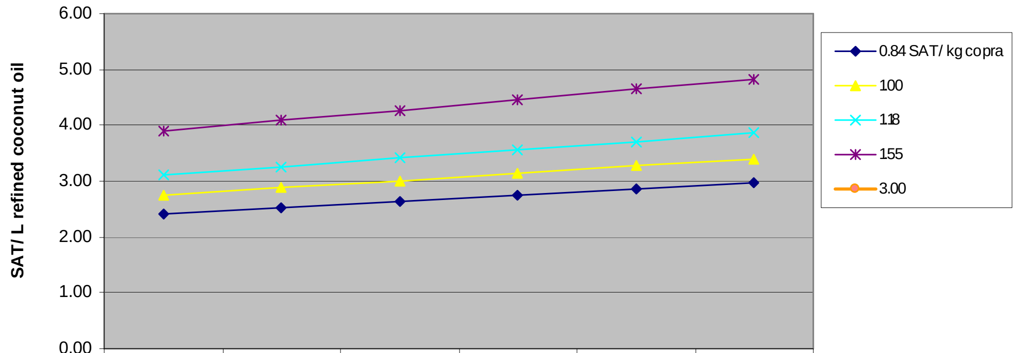
Appendix Figure 31. Return of Investment (ROI) at 2,000 kg Daily Copra Requirement



	2.20	2.50	2.72	3.00	3.50
0.84 SAT/kg copra		7.00	3.38	2.03	1.18
0.88		11.52	4.17	2.29	1.27
1.00			14.01	3.72	1.61
1.175				42.22	2.67

Selling Price of refined coconut oil (SAT/ L)

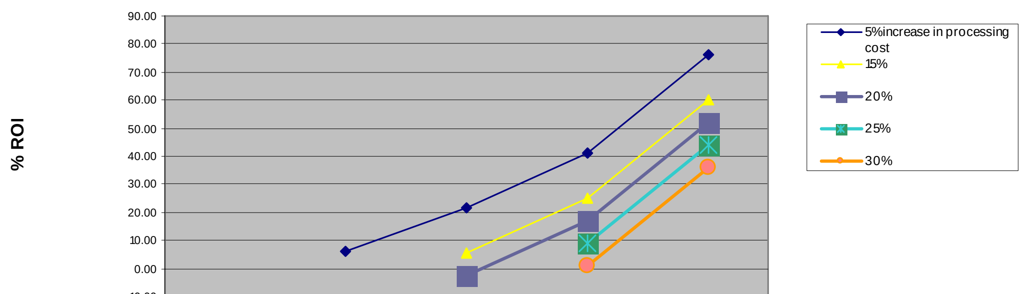
Appendix Figure 32. Payback Period at 2,000 kg Daily Copra Requirement



	5	10	15	20	25	30
0.84 SAT/ kg copra	2.41	2.53	2.64	2.76	2.87	2.99
1.00	2.75	2.88	3.01	3.14	3.27	3.40
1.18	3.11	3.26	3.41	3.56	3.71	3.86
1.55	3.90	4.09	4.27	4.46	4.65	4.83
3.00						

% Increase in Processing Cost

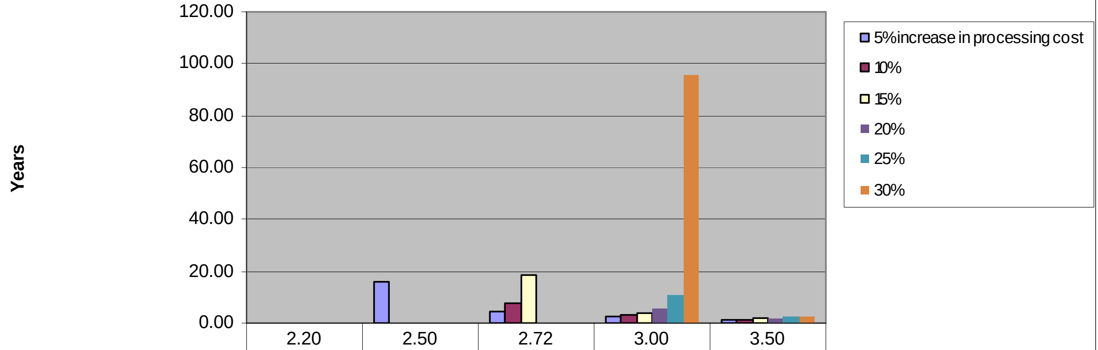
Appendix Figure 33. Breakeven Production Costs at Increasing Processing Costs at 2,000 kg Daily Copra Requirement



	2.20	2.50	2.718	3.00	3.50
5% increase in processing cost		6.24	21.52	41.30	76.36
15%			5.42	25.20	60.26
20%			-2.63	17.15	52.21
25%				9.10	44.15
30%				1.05	36.10

Selling Price of Refined Coconut Oil (SAT/ L)

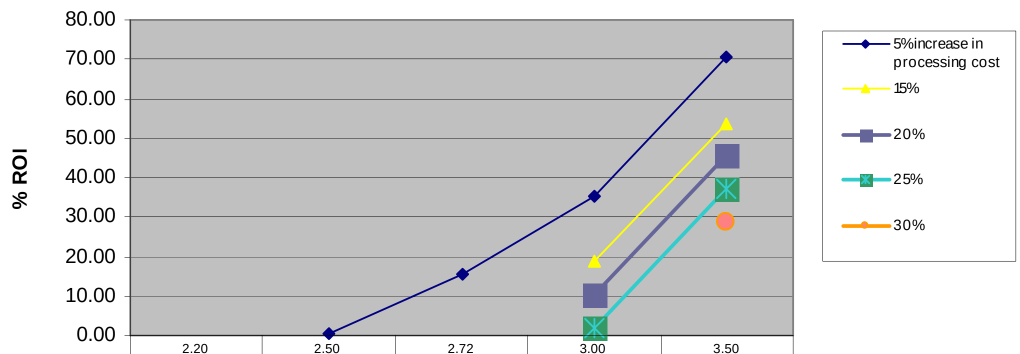
Appendix Figure 34. Return of Investment (ROI) at 2,000 kg Copra Requirement at SAT 0.84/ kg Copra Cost



	2.20	2.50	2.72	3.00	3.50
5% increase in processing cost		16.03	4.65	2.42	1.31
10%			7.42	3.01	1.46
15%			18.44	3.97	1.66
20%				5.83	1.92
25%				10.99	2.26
30%				95.64	2.77

Selling Price of Refined Coconut Oil (SAT/ L)

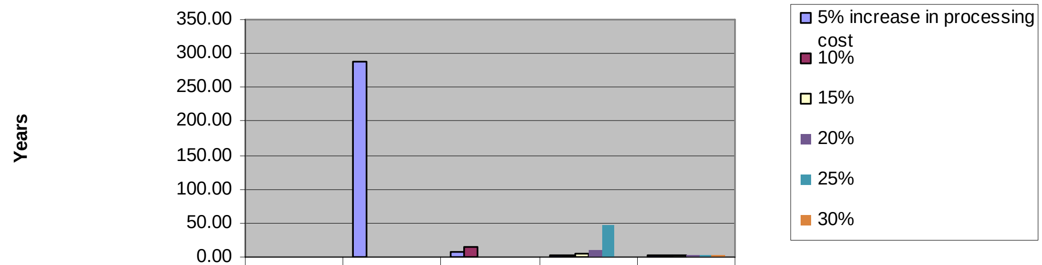
Appendix Figure 35. Payback Period at SAT 0.84/kg Copra Cost and 2,000 kg Daily Seed Requirement



	2.20	2.50	2.72	3.00	3.50
5%increase in processing cost		0.35	15.63	35.41	70.47
15%				18.75	53.80
20%				10.41	45.47
25%				2.08	37.14
30%					28.81

Selling Price of Refined Coconut Oil (SAT/ L)

Appendix Figure 36. Return of Investment (ROI) at 2,000 kg Copra Requirement at SAT 0.88/ kg Copra Cost



	2.20	2.50	2.72	3.00	3.50
5% increase in processing cost		287.15	6.40	2.82	1.42
10%			13.69	3.69	1.61
15%				5.33	1.86
20%				9.60	2.20
25%				47.98	2.69

Selling Price of Refined Coconut Oil (SAT/ L)

Appendix Figure 37. Payback Period at SAT 0.88/kg Copra Cost and 2,000 kg Daily Seed Requirement