A REPORT ON THE POSSIBILITY OF PRODUCING POWER ALCOHOL IN NEW GUINEA.

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Introduction.

Petroleum deposits are irreplaceable and, at the present rate of petrol consumption (300,000,000 tons per annum), will not last indefinitely. Because of this, and the paramount importance of motor fuels in modern civilization, especially at the present time, numerous efforts have been made in recent years to develop substitute motor fuels with which to supplement petrol. Quite a number of chemical compounds and mixtures of these compounds have been successfully employed in the modern type of internal combustion engine but the most successful and widely used of all these compounds is ethyl alcohol which, when used for industrial purposes, is usually termed "industrial" or "power" alcohol.

The value of power alcohol as a substitute fuel has been widely recognized for many years and many national efforts aiming at the establishment of power alcohol industries have been made. In Great Britain during the Great War, an Inter-departmental Committee was formed to report on the production and utilization of power alcohol and related problems. It is interesting to note that the committee came to the conclusion that, so far as vegetable sources of raw material and the manufacture of power alcohol were concerned, Great Britain must rely mainly, if not entirely, on increased production in tropical and sub-tropical countries.

Power alcohol is a fuel of particular merit in that its supply is *absolutely inexhaustible*.

Petrol and Power Alcohol Compared.

On the basis of available combustible matter, petrol is a better fuel for engines of the present-day design than alcohol, since high-grade petrol may contain 135,000 B.t.u. per gallon whereas power alcohol only contains approximately 84,450 B.t.u. The low absorption of water by petrol, in contrast to the miscibility of water and alcohol in all proportions, is perhaps a further disadvantage although not in the case of accidental fire. Nevertheless, there are certain physical characteristics of power alcohol which are much more favorable than those of petrol.

It has been claimed that the use of power alcohol or power alcohol blended with petrol results in a lower relative mileage and power output, as compared with straight petrol. Because of the lower calorific value of alcohol, the claim is undoubtedly true for unadulterated alcohol, and would be true for alcohol blends, if the efficiency of the internal combustion engine depended solely upon the potential energy of the fuel. This, however, is not the case. The actual power and mileage of which an engine is capable, is the result of compression, carburetor setting, spark adjustment, engine temperature, volatility of fuel, speed, acceleration and design, all of which are complicated by other factors such as method of driving, load, grade of road, &c. It is the total effect of all these factors which determines the mileage and power a fuel is capable of producing.

Much data has been published on the subject of mileage and Bridgeman (1936) has summarized the results of various findings as follows:—

"When used in the same engine, particularly with the carburetor and spark set for the mean of the optimum values for the two types of fuels, little difference in power, acceleration, or fuel consumption is observed with a 10 per cent. blend, or even with a 20 per cent. blend under many operating conditions."

He also states—

"If suitably designed engines are used for the two types of fuels, equal or better power and acceleration per gallon of fuel consumed may be obtained from the blend when comparing a petrol and the same petrol blended with ethyl alcohol, within the range of present-day petrols."

In a recent publication on "Effects of Different Carburetor Settings on the Performance Characteristics of some makes of Automobile Engines using Alcohol as Motor Fuel", Teodoro (1940) summarizes the results of his findings as follows:—

"1. With petrol as fuel the differences in fuel consumption between optimum economical carburetor setting and maximum power setting are approximately 5 to 8 per cent. at full throttle and 1 to 3 per cent. at fractional loads. The difference in power developed hardly exceeds 3 per cent. Detonation was more evident in adjustments giving lean mixtures than those giving rich.

2. Maximum power setting with nearly straight alcohol gave about 10 per cent. more power than the maximum that could be developed with petrol. This was done at the expense of a fuel consumption ratio (compared with petrol by weight) varying from 1.4: 1 to 1.7: 1. It was easily possible to double the consumption of alcohol without increasing the power developed when a certain maximum load was reached.

The most economical adjustment that could be obtained was one giving a fuel consumption ration of 1.27: 1 (compared with petrol by weight) and a maximum load of about 5 per cent. less than the standard set by the engine manufacturer.

There was no evidence of detonation when nearly straight alcohol was used.

3. The 10 per cent. alcohol-petrol mixture gave as efficient running as petrol and developed about 5 per cent. more power with the same economical adjustment. With medium setting, the engine not only developed 10 per cent. more power but also consumed 5 to 7 per cent. less fuel than petrol.

4. The 20 per cent. alcohol-petrol mixture gave less fuel consumption than petrol at economical setting but developed about 3 per cent. less power. The difference in fuel economy varied from 3 per cent. to as high as 20 per cent. depending upon the jet used.

5. There was no evidence of detonation when the alcohol-petrol mixtures were used under any carburetor settings. Acceleration was slightly sluggish when the 20 per cent. mixture was tested with the most economical jet.

6. Better results in fuel economy and power were obtained with alcohol and alcohol-petrol mixtures at a high compression ratio. Petrol, on the other hand, detonated badly, developed less maximum power, but gave slightly better fuel economy at certain loads with a high compression ratio than with low.

7. The present trend of compression ratio used in automobile engines favours the utilization of alcohol and alcohol-petrol mixtures as fuel."

Comparing petrol with straight alcohol, Cook (1927) writes—

"By the use of high compression engines, therefore, it is possible to obtain from alcohol about the same work and hence about the same mileage per gallon as it is possible to obtain with petrol in lower compression engines."

It is thus seen that, in present day engines with the carburetor suitably adjusted, a 10 per cent. alcohol-petrol blend is superior to straight petrol. With a 20 per cent. blend there is a small loss of power with a slightly higher petrol consumption. There is no detonation when either mixtures is used. If straight alcohol is used, a high compression engine will give more power than a low compression engine.

Some investigators have reported poor starting in cold weather from certain alcohol-petrol blends. On this point Bridgeman (*loc. cit.*) wrote—

"When comparing petrols with the same petrols containing 10 per cent. alcohol, engine starting will be easier with the blend at temperatures above 0° F. and will be more difficult with the blend at temperatures below —10° F., with little difference in the intermediate range. The conclusions are not changed when the blend has the same vapour-locking tendency as petrol."

Bridgeman concludes—

"When used in the same engine, a 10 per cent. blend is more likely to give trouble from vapour lock than the petrol (alone) with which the alcohol is blended. Little difference would be expected with a 20 per cent. blend, and the situation would be reversed with a 40 per cent. blend, since there is greater freedom from vapour lock difficulties with the blend than with the petrol, from which the 40 per cent. blend was prepared. Addition of alcohol in increasing quantities first increases and later decreases the Reid vapour pressure. The same (comparative) freedom from vapour lock may be obtained for a 10 per cent. blend and petrol if the vapour pressure of the petrol used (for blending) is lower than that of the petrol with which the blend is compared."

According to Cook (*loc. cit.*) and others, the use of power alcohol or alcohol-petrol blends, calls for the use of a higher compression ratio than the same unblended petrol.

It is Bridgeman's (*loc. cit.*) opinion that—

"No material gain in engine performance is obtained by the increase in octane number on blending unless the compression ratio of an engine is sufficiently high to take advantage of the increased octane number."

Ogston (1937) and Nash and Howes (1935) concur in the above opinion.

The effect on the octane rating of petrol resulting from the addition of power alcohol is summarized in the following statement by Bridgeman (*loc. cit.*) :—

"The octane number of pure ethyl alcohol is about 90 (on the basis of present test methods) while that of petrol varies from about 74 to 80 for the first grade; about 65 to 70 for the second grade; and usually below 65 for the third grade. Accordingly, blending ethyl alcohol with petrol will improve the octane number by amounts which cannot be stated quantitatively but which depend upon the percentage of alcohol used and upon the octane number of the petrol. In general, addition of 10 per cent. of ethyl alcohol to a second or regular grade of petrol will increase the octane number about three to five units, while the increase will be less when blending with the first or premium grade, and may be as high as 10 octane units when blending with a low, third grade petrol. As a result of this increase in octane number, it is possible to use for blending, a petrol of lower octane number than would be used unblended."

Ogston (*loc. cit.*) states—

"It can, no doubt, be accepted that, at any rate with fuels between 65 and 85 octane numbers, an increase of one octane number will permit an increase of about 1 per cent. engine efficiency, always provided that the engine has been properly designed to take full advantage of the higher antiknock value. Now, although the alcohol response of different petrols varies a good deal, as a general rule it can be accepted that when ratings between 65 and 85 octane are being dealt with, the addition of 1 per cent. ethyl alcohol increases the knock rating of the petrol by at least 0.7 octane number. Thus a 15 per cent. blend results in a loss of 5 per cent. calorific value, but the octane rating would have been increased by at least 10, which will accordingly permit an increase in efficiency of about 10 per cent. It is evident from this that alcohol therefore, more than 'pays its way', since its lower calorific value is offset by the higher efficiency which it is possible to obtain by better octane rating in the ratio of loss to gain of about 1 to 2. The inclusion of benzol, of course, still further improves the picture."

Nash and Howes (*loc. cit.*) state—

"The antiknock value of ethyl alcohol has been recognized for some years and has not been disputed."

The latent heat of vaporization of ethyl alcohol is 209 calories per gram, as compared with 75 calories per gram for petrol. The boiling temperature of ethyl alcohol is approximately 173° F., whilst that of petrol ranges from 100° to 400° F. It is thus seen that when using a fuel containing ethyl alcohol, an engine operates at a cooler temperature than when using ordinary petrol and thus operates more efficiently.

In conclusion, we may quote the words of Cole (1922), who gave the matter much consideration:—

"Alcohol mixtures to-day are being used on a large scale in the present type of petrol engine with simple alterations. These mixtures offer many advantages and no disadvantages over petrol and are more efficient than petrol."

Magnitude of Possible Markets.

Recent communications from Canberra indicate that, at present, there is a good market for power alcohol in Australia. Support is given to this statement by the recent introduction of a petrol rationing scheme. However, this may be only a temporary, war-time market, and it would be irrational to invest capital in a plant for the production of power alcohol to satisfy a temporary market unless the need were most urgent.

An indication of the market, which is likely to exist at the termination of the war, is best obtained by investigating the market which existed before the present disturbed state of affairs. The amounts of petrol imported into New Guinea and Australia during the five years preceding the commencement of the war, are given in Table I.:—

TABLE I.—PETROL CONSUMPTION IN NEW GUINEA AND AUSTRALIA.

——	1934–35.	1935–36.	1936–37.	1937–38.	1938–39.
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
New Guinea	823,920	1,060,078	870,279	1,087,440	937,708
Australia..	267,632,864	319,336,547	341,547,869	402,979,165	399,517,906

From Table I., it is seen that the normal petrol consumption in New Guinea is approximately 1,000,000 gallons, and in Australia over 300,000,000 gallons per annum. It is thus considered that 300,000,000 gallons per annum may be taken as a conservative estimate of the petrol requirements in New Guinea and Australia in normal times.

Alcohol has been successfully blended not only with petrol but with many other substances, notably ether and benzol, for use as a fuel in the modern type of automobile engine. The constituents of the more popular blends are given in Table II. together with the approximate amounts of alcohol which would be required if legislation were to enforce their use in New Guinea and Australia.

TABLE II.—PETROL BLENDS AND ALCOHOL REQUIREMENTS.

Blend.			Where Marketed or First Used.	Approximate Market in Australia and New Guinea.
No.	Constituents.	Per cent.		
				Gallons.
1	Alcohol	5	Alcohol-petrol blends are marketed in practically every country in the world	15,000,000
	Petrol	95		
2	Alcohol	10		30,000,000
	Petrol	·90		
3	Alcohol	15		45,000,000
	Petrol	85		
4	Alcohol	20		60,000,000
	Petrol	80		
5	Alcohol	40	United States	120,000,000
	Petrol	35		
	Benzol	25		
6	Alcohol	40	United States	180,000,000
	Petrol	35		
	Ether	25		
7	Alcohol	70	Australia	230,000,000
	Petrol or Benzol ..	20		
	Ether	10		
8	Alcohol	55.55	Hawaii	300,000,000
	Ether	42.78		
	Kerosene	1.11		
	Pyridine	.56		
9	Alcohol	55	South Africa	300,000,000
	Ether	44.9		
	Ammonia	.1		
10	Alcohol	80 gals.	.. .. ..	240,000,000
	Benzol	20 gals.		
	Naphthalene	2 lb.		

Blends 6, 7, 8 and 9 contain ether. Ether can be readily and cheaply manufactured from alcohol by what is known as the "continuous etherification process". The alcohol is mixed with sulphuric acid and heated, an alkyl hydrogen sulphate being formed. On addition of more alcohol, the latter is decomposed, forming ether and regenerating sulphuric acid. The sulphuric acid then forms more of the alkyl hydrogen sulphate, which with more alcohol again forms ether, and were it not for the destruction and dilution of the acid by the products of side reactions, a given quantity of sulphuric acid could transform an unlimited quantity of alcohol into ether.

Ricardo (1924) has investigated the effect of small amounts of ether in alcohol fuel mixtures from the point of view of their behaviour in a Leyland lorry engine at various positions of the throttle. His general conclusions in this connexion are as follows:—

"1. Both at half load and at quarter load there is a definite advantage as regards power, economy, and range of combustion due to the addition of small proportions of ether in alcohol mixtures.

2. These advantages become well marked for the 10 and 15 per cent. ether mixtures. The increase in range of combustion giving increased "responsiveness" in acceleration is clearly shown.

3. Between alcohol alone and a mixture containing 10 per cent. ether the improvement in efficiency was measured as 7.5 per cent. both for half-load and for quarter-load conditions.

4. At half-load the efficiency on petrol was no less than 12 per cent. higher than for the most economical of the alcohol-ether mixtures."

It is pointed out, howover, that the above results apply to an engine running at a constant speed whereas ordinarily the speed of the engine would be by no means constant.

In blends 6 and 9, benzol is a constituent. Benzol (benzene) is manufactured from coal-tar, about 2.5 gallons of rectified benzol being obtained from the high temperature carbonization of 1 ton of coal; naphthalene is also manufactured from coal-tar.

Pyridine or ammonia is added to blends 8 and 9 to neutralize any acid which might be formed in the fuel or in the combustion of the fuel. It also serves as a denaturant.

In a consideration of the amount by which petrol importations should be reduced, consideration must not only be given to technical aspects but to matters of national defence, international trade and internal economics. From Table II. it is seen that blends 8 and 9, neither of which contain petrol, would open up the largest market for power alcohol. Such blends would be a considerable help in conserving petrol supplies, would give employment to a large number of people, would make Australia less dependent on other countries, but would however upset our international trade somewhat. On the other hand, a petrol blend containing only a small percentage of alcohol (e.g. No. 1 blend) would result in a very small conservation of resources, would give little extra employment, and it would still be necessary to import large quantities of petrol. When, after consideration of all these factors, a figure has been decided upon, it would then be necessary to establish a market. With the present shortage of petrol in Australia, this would not be difficult although, as a safeguard, it would probably be advisable to introduce legislation compelling importers to purchase power alcohol amounting to a definite fraction of the petrol they import. With constant and regular supplies of power alcohol available and this alcohol blended to produce a fuel cheaper and equal, if not superior to petrol, it is unlikely that there would be trouble in retaining a market for the product.

In Queensland, all petrol companies are required by law to purchase a quantity of pure alcohol equal to 1.5 per cent. of the volume of petrol brought into the State. There is no law or regulation requiring the use of alcohol as a constituent part of the petrol sold, but the petrol companies, in order to dispose of the alcohol they are forced to purchase use it for blending with petrol to make distinct grades of motor fuel. It is reported that some time ago there was an organized effort to have the Government compel the petrol companies to use alcohol to the extent of 15 per cent. of the volume of imported petrol.

In Victoria, at least one independent oil company has been marketing an alcohol-petrol blend for over four years during which time millions of gallons have been sold. Similar blends are also probably sold in all other States of the Commonwealth. The blends are particularly popular with motor cycle and car racing experts.

In England, alcohol blends can be sold at the same market price as first-class petrol. The methylated spirit regulation of 1930, ruled that alcohol used in internal-combustion engines should be tax-free, provided that it was blended with a minimum of 25 per cent. petrol or benzol, whereas straight petrol paid a tax of 8d. per gallon. In addition, under the Revenue Act of 1906, motor fuel alcohol received a Government allowance of 5d. per proof gallon, or 8¾d. per Imperial gallon. In May, 1938, the tax on petrol was increased to 9d., and this also became effective on alcohol blends. In 1934, Government factories in the Irish Free State were authorized to produce motor fuel from potatoes. This alcohol is exempt from tax if used in motor fuel blends (10 per cent.).

Summing up, the foregoing information indicates that a large market awaits development in Australia, and possibly Great Britain for cheap power alcohol. The extent and ultimate success with which such a market could be established, however, would probably depend on suitable legislation fostering its initial stages of development, otherwise, there would be a chance of the market never becoming properly established and collapsing at the termination of the war. Such legislation, besides stimulating industrial activity and giving employment, would foster the local production of an essential commodity for which Australia is, at present, largely dependent upon foreign countries.

Sources of Alcohol.

In evaluating the economic possibility of successfully making power alcohol from agricultural products, it is necessary not only to know the extent of the possible market which could be developed but the amount and distribution of suitable raw material which is available or could be made available when required. Problems of planting, harvesting, collecting, transporting and storing without serious deterioration, especially in the case of perishable materials, would have to be investigated. Technical problems of processing would also have to be solved. The net price that could be paid for the raw material, its value in comparison with other raw materials, the cost of producing the alcohol and the selling price such a product could command on the basis of comparative efficiency as a motor fuel, are other essential factors in the undertaking which should be considered. Above all, it must be remembered that the situation is continually changing and that a consideration of the problem should include future as well as present conditions.

Power alcohol may be derived from three classes of agricultural products—

(1) Saccharine materials (molasses, sugar beet, nipa palm, &c.).

(2) Starchy materials (grains, potatoes, cassava, sago palm, &c.).

(3) Cellulosic materials (wood, sulphite liquor from paper pulp mills, &c.).

At present, the chief source of ethyl alcohol is sugar-cane molasses, which are the waste syrup remaining after the commercial extraction of crystallized sugar from evaporated sugar-cane juice. This material has been the main source of ethyl alcohol for a great many years. It has an advantage over starchy materials in that its carbohydrate is already in a suitable form for transformation into alcohol by the action of yeast, whereas starch-bearing products must be treated with diastase or dilute acids to convert the starch into sugar before fermentation can take place. The feasibility of producing power alcohol from other products largely depends on the availability and suitability of each raw material.

In New Guinea and Papua, there are three good sources of raw material for the large-scale production of power alcohol. They are cassava (*Manihot utilissima*), the sago palm (*Metroxylon sagus* and *M. rumphii*) and the nipa palm (*Nipa fruticans*).

In 1922, it was shown by Cole that the sap of the nipa palm was the cheapest source of alcohol in the world, namely, .027 dollars per litre of 180 proof or 90 per cent. alcohol, estimating the raw material as delivered at the distillery. Cassava was the second cheapest source, being .034 dollars per litre. Prices have changed considerably since these costs were computed, but the list of available raw materials is practically the same, and by giving the materials present-day prices it is seen that nipa palm sap and cassava roots are still probably [illegible]est source of power alcohol. No reference can be found in the literatur[illegible] sago palm for the production of alcohol.

In some countries the coco-nut palm (*Cocos nucifera*) is cultivated for its sap, from which an alcoholic beverage is made. There is more labour involved in obtaining the sap from the coco-nut palm than from the nipa because of the height of the palms. To facilitate collection, bamboo poles are usually attached from palm top to palm top, forming bridges upon which the collector can travel without descending to the ground until his receptacle is full.

Since the coco-nut palm blossoms throughout the year, the sap-collecting season is continuous, and when one stalk is exhausted another is tapped. The average daily yield per palm is approximately one-sixth of a gallon. The sap has approximately the same sugar content as nipa palm sap, so that, volume for volume, the yield of alcohol would be approximately the same. It is thus seen that the coco-nut palm is a possible source of power alcohol. However, such a source would be most undesirable in this territory, for once the native learnt to tap coco-nut palms, which are to be found everywhere, he would soon acquire a taste for the fermented sap and intoxication would be difficult to prevent in the villages. On the other hand, the restricted growth of the nipa palm makes control measures a comparatively simple matter.

Cassava (Manihot Utilissima).

Cassava or tapioca, although now grown throughout the tropics, is indigenous to South America. It grows in many parts of this territory, although there are no records indicating when it was first introduced here.

Description.—The cassava plant is a small, shrubby perennial, attaining a height of 6 to 8 feet, and has large tuberous roots which contain a high percentage of starch. There are said to be at least 40 varieties, falling into two groups—"bitter" and "sweet". The roots of bitter cassava contain a cyanogenetic substance, which, on decomposition, yields prussic acid. This is rendered inert by cooking. Sweet cassava, generally supposed to be free from this poison, actually contains small quantities in the rind and outer layers of the tubers.

Habitat and Available Areas.—Although cassava is to be found growing in many parts of the territory, it is generally grown as a native food crop, and if large quantities were required for the production of power alcohol, fresh areas would have to be planted up.

The best soil for growing cassava is a light, rich, sandy loam and many growers prefer that such a soil should be underlaid by a hard pan, which will prevent the roots from going too deep into the ground. The soil should be dry rather than wet and fair yields can be secured from soils too dry for many other crops. Recently-cleared land appears to be preferred by the natives, as it is rich in plant food and the crop can be grown on it continuously for several years with good yields. Swampy soils and heavy black soils, excessively rich in humus, should be avoided, for in the latter case the plant makes much top growth but the tubers are small. Heavy clay soils are also unsuitable, as they give low yields and the roots are difficult to dig.

The cassava plant is always propagated commercially by means of stem cuttings. In some varieties seeds are never or rarely formed, but even when available, they should never be used, as the plants raised from them always give low yields of roots. Only the middle portions of well-matured, vigorous stems should be used for propagation—the basal, woody part and the extremities of the branches being discarded. Cuttings should not be made until they are required for pl[illegible] [illegible]out 8 or 10 inches long. Only living stems, distinguished by their plump appearance, fresh-looking bark, sound pith and plump buds, should be used. Stems which appear shrivelled, are bleached or darkened in colour, have discoloured or dry pith and shrunken buds, should be rejected. The ends of the cuttings must be cut cleanly. This may be done with a sharp, heavy knife.

Before planting, the soil must be brought into a fine state of tilth. This may be done by hoeing, ploughing or harrowing. It is advisable not to plough too deeply so that the roots may be kept nearer the surface and be easier to dig.

Newly-cleared land will not, as a rule, require manuring, but land which has been under cultivation may have to be enriched by this means. Potash is the chief food constituent taken up by the cassava roots, and as potash salts favour the formation of starch and sugar, it is essential that this constituent be present in sufficient quantity. Large quantities of available nitrogen in the soil induce an excessive growth of stems and leaves without a corresponding increase in the yield of roots. If a leguminous crop, such as velvet beans or cowpeas, has preceded cassava, a practice to be much recommended, a nitrogenous manure will not be necessary and a mixture consisting of 200 lb. of kainit and 300 lb. of superphosphate per acre may be used. The exact amount to be applied will depend upon the nature of the soil; more should be used on poor soils, whilst on calcareous soils the amount of superphosphate may be less. If nitrogen is to be added, it may be applied conveniently in the form of nitrate of soda at the rate of 250 lb. per acre. The potassic and phosphatic manures should be added before the crop is planted and the nitrogenous manure just after growth has commenced. If chemical manures are not available, about 8 to 10 tons of animal manure per acre, preferably mixed with wood or coco-nut shell ashes, may be used.

Copeland (1931) regards cassava as the best catch crop for planting with coco-nuts until the latter begin to bear. It is also used as a catch crop with young rubber and as a temporary shade for young coffee and cocoa.

Yields.—The yield of cassava roots is dependent upon the variety, fertility of the soil, climate, cultivation, vitality of the cuttings, number of plants per acre, and the age of the plants. Typical annual yields in New Guinea are about 10 tons to the acre, although yields of nearly 25 tons have been obtained.

Table III., compiled by Galang (1931) in the Philippines, gives reported yields per acre of tubers in different countries.

Taking the mean of the figures in this table, it is seen that the yield varies from about 10 to 38 tons per acre. The New Guinea figure (10 tons) is on the lower limit of this range and could undoubtedly be increased.

TABLE III.—CASSAVA YIELDS IN DIFFERENT COUNTRIES.

Country.	Tons per Acre.
Caledonia	10 to 100
East Africa	1 to 90
Florida	30 to 40
Jamaica	3 to 13
Java and Ceylon	10
Virgin Islands	8 to 46
Hawaii	16 to 30
Trinidad and Tobago ..	3 to 10
Barbodos	6 to 10
Laguna	12 to 35

The results given in Table IV. were obtained from a series of experiments carried out at the Hope Agricultural Station in Jamaica and give the yields of different varieties of cassava at different stages of maturity. It appears to be advantageous to harvest the crop at 21 months—

TABLE IV.—CASSAVA ROOT YIELDS.

Variety.	Yield of Roots.			Quantity of Starch in Roots.		
	At Twelve Months.	At Fifteen Months.	At Twenty-one Months.	At Twelve Months.	At Fifteen Months.	At Twenty-one Months.
	Tons per acre.	Tons per acre.	Tons per acre.	Lb. per acre.	Lb. per acre.	Lb. per acre.
Blue Top	8.25	14.2	21.9	5,636	9,733	15,818
Black Stick	6.5	6.5	18.0	4,878	5,197	15,433
Smalling	7.5	11.1	19.3	5,494	8,553	13,883
Mullings	5.75	11.1	18.0	4,160	8,180	13,277
Long Leaf—Blue Bud ..	9.0	15.4	15.4	6,552	12,857	13,187
White Top	10.5	11.0	11.6	7,902	7,638	8,753
Luana Sweet	6.75	8.1	9.0	5,322	6,540	7,102
Rodney	7.5	9.7	10.3	5,337	6,931	6,547

Cousins (1915) has determined the starch content of a number of bitter and sweet varieties of cassava grown in Jamaica and the average results calculated from his figures are given in Table V. There is little difference in the starch contents of the two varieties.

TABLE V.—STARCH CONTENT OF BITTER AND SWEET VARIETIES OF CASSAVA.

—	Bitter Varieties.		Sweet Varieties.	
	Moisture.	Starch.	Moisture.	Starch.
	Per cent.	Per cent.	Per cent.	Per cent.
After twelve months' growth—				
Fresh	58.4	32.9	58.4	31.8
Dry	..	79.1	..	76.4
After fifteen months' growth—				
Fresh	60.9	32.5	61.0	32.6
Dry	..	83.1	..	83.6
After twenty-one months' growth—				
Fresh	59.4	34.2	60.2	34.7
Dry	..	84.2	..	87.3

In Table VI. typical figures are given for the composition of cassava roots and potatoes. Potatoes are used extensively for the production of power alcohol in Germany and other European countries. It is seen that cassava contains considerably more fermentable material than potatoes. A high-grade root would contain over 30 per cent. starch and 6 per cent. sugar. Even if the average content of total fermentable matter be taken as 25 per cent., which is a very conservative estimate, this amount would be much greater than that in potatoes. The dry roots contain about 90 per cent. of fermentable substances and are a much more valuable source of alcohol, weight for weight, than any other material mentioned in Table VII.

TABLE VI.—COMPOSITION OF CASSAVA ROOTS AND POTATOES.

Constituent.	Cassava Roots.		Potatoes.	
	Fresh.	Dry.	Fresh.	Dry.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	65.25	..	75.80	..
Protein	1.12	3.22	2.08	8.59
Fat	0.41	1.18	0.20	0.83
Starch	26.45	76.08	19.90	82.23
Sugar	5.13	14.76		
Fibre	1.11	3.22	1.10	4.55
Ash	0.54	1.54	0.92	3.80

In *Motor Fuels from Farm Products* (1938), a recent publication of the United States Department of Agriculture, information is given on the quantity of alcohol obtainable from various raw materials. This information is embodied in Table VII.

TABLE VII.—ALCOHOL YIELDS FROM VARIOUS CROPS.

Order.	Material.	Fermentable Matter.		Yield of 99.5 per cent. alcohol/ton in gallons.	Approximate yield of 99.5 per cent. alcohol/acre in gallons.
		Per cent.	Pounds/ton.*		
1	Cassava	30.0	672	48.7	487
2	Sugar beet	16.0	358	24.8	321
3	Sugar cane	11.0	246	17.0	300
4	Jerusalem artichoke ..	15.2	340	22.4	202
5	Potatoes	15.6	349	25.6	199
6	Sweet potato	23.3	522	38.3	158
7	Apple	11.0	246	16.1	157
8	Date, dry	60.0	1,344	88.5	141
9	Carrot	7.5	168	11.0	136
10	Raisin	62.0	1,389	91.2	114
11	Yam	18.7	419	30.6	105
12	Grape (all varieties) ..	11.5	258	16.9	101
13	Corn	57.8	1,295	94.1	100
14	Peach	8.7	195	12.9	94
15	Prune, dry	55.0	1,232	80.6	93
16	Pineapple	11.9	267	17.5	87
17	Rice, rough	54.6	1,223	89.0	74
18	Pear	8.9	199	12.9	55
19	Barley	54.3	1,216	88.7	54
20	Molasses, blackstrap ..	51.0	1,142	78.8	50
21	Apricot	10.4	233	15.2	46
22	Grain Sorghum	54.5	1,221	88.9	40
23	Oats	43.6	977	71.2	40
24	Buckwheat	57.2	1,281	93.3	38
25	Wheat	58.6	1,313	95.2	37
26	Fig, fresh	16.0	358	24.6	36
27	Fig, dry	45.0	1,008	66.1	34
28	Rye	54.0	1,210	88.3	27
29	Plum	8.3	186	12.2	25

* = 2,240 lb.

From Table VII. it is seen that the highest yield of 99.5 per cent. alcohol per acre is obtained from cassava, being 487 gallons. Sugar beet gives the next highest yield and sugar cane the third highest. The yield from potatoes is less than half that from cassava.

In compiling Table VII., it has been assumed that in each case alcohol recovery will be 85 per cent. of the theoretical yield, calculated on the part of the material naturally fermentable by yeast. In commercial practice, this would be exceeded in most cases. In general, yield figures, which are calculated on the basis of the carbohydrates (less pentosans) present, are conservative values.

Alcohol Production.—The method of obtaining alcohol from cassava tubers does not differ appreciably from that used in the case of other similar materials, such as potatoes. There are three principal steps:—(1) Preparation of mash or wort; (2) Fermentation by means of yeast of the mash drawn off from the mash tun; (3) Distillation of the dilute alcohol formed in the beer or wash from the fermentation tanks.

Mashing.—The cassava is first softened by steaming and then gradually broken up and mixed with water to reduce the starch in the raw material to a thin paste in order that the malt ferment, subsequently added, may act upon it readily and convert it into sugar.

The conversion of starch into a fermentable sugar may also be accomplished without the intervention of malt. This is done by heating the raw material with dilute acid under pressure when it is largely converted into glucose, which can be fermented directly by yeast.

Fermentation.—The mash, after the starch has all been converted into sugar, is passed into fermenting tanks and the yeast added. These tanks often have a stirring apparatus with which the contents are thoroughly mixed with the yeast and kept in motion. This is not necessary after the fermentation is well established, but it is advisable, especially in the early stages, to keep the yeast well distributed throughout the mass. In these tanks the temperature is varied according to the nature of the product to be made. In making power alcohol, the sole object is to secure the largest possible percentage of alcohol at the lowest possible cost without reference to its potable properties or odour.

Distillation.—The object of this process is to separate the alcohol contained in the fermented liquor from the non-volatile products and water with which it is mixed. The stills in use for this purpose are of numerous types and their structure and method of action are too complicated to be discussed here, but, in general, it may be said that they are so arranged as to permit of a current of steam being driven through a falling column of the fermented liquor, which is thus gradually deprived of its alcohol, the latter being carried off by the current of steam which gradually becomes richer and richer in alcohol until finally, on condensation, it yields alcohol of the required strength.

Alcohol that is to be mixed with petrol for use as a motor fuel should not contain more than a few tenths of 1 per cent. water. When ordinary 95 per cent. alcohol is mixed with a much larger proportion of petrol at low temperatures, the mixture is likely to separate into two layers unless certain blending agents, or mutual solvents, such as butyl alcohol, benzol, or acetone, are added. Anhydrous alcohol mixes with petrol in all proportions and at practically all temperatures.

Commercial processes and equipment have been developed for obtaining alcohol in a nearly anhydrous condition from ordinary high proof alcohol, or directly from the fermented mash. Many of these processes and the essential equipment are patented, and during the life of the patents can be used only under licence. They include—

(1) Azeotropic distillation methods, which are dependent on the fact that when suitable organic liquids, such as benzol, trichloroethylene, or volatile mineral spirits are mixed with high strength alcohol during distillation, the water present, with a small proportion of the alcohol, is distilled over; the excess of the azeotropic agent then distills out, leaving the rest of the alcohol in an anhydrous state.

(2) Use of anhydrous materials, such as potassium or sodium alcoholate, potassium or sodium acetate, aluminium or calcium oxides, or calcium sulphate, to absorb water from a vapour mixture of alcohol and water.

(3) Distillation of the alcohol under a partial vacuum.

Present methods of power alcohol production generally produce the alcohol in a comparatively pure form first and then it is intentionally contaminated or denatured before being marketed. Although power alcohol should contain only small amounts of water, it may contain considerable amounts of other impurities without its value being considerably impaired and, since such alcohol must also be produced very cheaply, initial purification with subsequent denaturation appears to be an unnecessary expense. Thus the manufacturing process could be undoubtedly simplified if power alcohol were the only product manufactured.

The conventional alcohol process is schematically depicted in Figure I., which shows the different steps as well as the daily requirements of each.

Quite recently, moulds have been discovered which are able both to saccharify starch and ferment the resulting sugars. They thus eliminate one step in the above process. This new process has been employed with considerable success in some countries and could possibly be used to advantage in New Guinea.

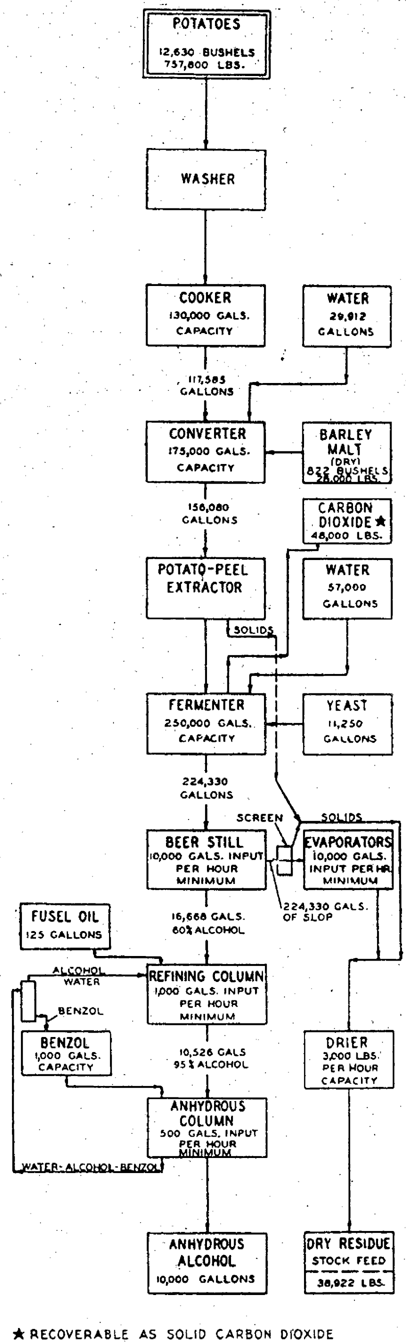
The Sago Palm (*Metroxylon sagus* and *M. rumphii*).

The two important species of *Metroxylon* are *M. sagus,* the smooth-sheathed sago palm, and *M. rumphii,* the spiny-sheathed sago palm. Both are found in New Guinea. The latter is a slightly smaller palm than the former, but both are so alike that they will be treated together. The spiny species has a somewhat shorter trunk and a lower yield of starch.

Description.—The sago palm is a pinnate-leafed palm, the leaves being 20 or more feet in length. It reaches a height of 30 to 40 feet and has a short cylindrical trunk having a girth of 50 to 60 inches from which is obtained the sago of commerce. The palm reaches maturity in about twelve years and, after fruiting, dies.

Habitat and Available Areas.—The sago palm thrives in New Guinea and Papua where it may be found growing in all coastal districts. It is most abundant in low-lying land at the mouths of rivers and grows best in swamps where it would be almost impossible to grow any other crop. The most extensive areas in New Guinea are in the vicinities of the Sepik and Ramu Rivers and in the Aitape

FIGURE I.



From "Motor Fuels from Farm Products."

District. Starch obtained from the trunk of the sago palm is used in many Districts as a native food although often only when the taro crop fails. In some areas, the starch content of the palms is so low that the natives do not consider them worth working. Such areas, however, could be eventually planted up with selected material from high yielding palms.

The sago palm may be propagated either from seed or suckers. Unless suckers are most carefully removed from the parent palm, they will not survive after being planted out. On the other hand, there is a considerable advantage to be gained by planting seeds in nurseries and transplanting the seedlings when about twelve to eighteen months old. Not only is this method less expensive, but the results generally prove to be far more satisfactory.

Care should be taken in the selection of the seed to avoid the "spiny" types. This leads to a difficulty when growing from seed, as they do not always breed true and hybrid spiny types may be produced. The difficulty may be overcome by selecting the seedlings before planting out.

The seeds in the husk are planted about one foot apart in slightly raised nursery beds and shaded until they bear three leaves. They should be ready for planting in the field after twelve to eighteen months. The area to be planted should be cleared, and holes dug for the seedlings about 15 feet by 15 feet apart, giving 193 palms to the acre. For one or two years the plants should be circle-weeded and any undergrowth cleared sufficiently to prevent interference with the growth of the palms; after this period, little attention will be required. After nine or ten years, when the palms begin to flower their starch content is at a maximum and they may be cut down. About 50 trees per acre will mature about the ninth year, after which an annual crop of 50 trees per acre may be expected, as those cut down will be replaced by suckers produced from the roots of the original palms.

In a dense area of wild sago palms, the number of trees per acre have been estimated at 2,000–1,500 of which at least 100 may be expected to reach maturity each year. Because of the density of growth, the size and starch content of these palms is low but could probably be increased by thinning out. The starch content of an average "smooth-sheathed" palm growing under fair conditions is about 300 lb. although a particularly large palm may yield 1,200 lb. of starch. A conservative estimate for a wild palm would probably be 250 lb. per palm or an annual production of 11 tons to the acre. On a plantation where the palms were grown from selected seed, the yield would be much higher than this amount. A yield of 11 tons will be used during later computations.

In order to work the areas of wild sago palms in this Territory, it would be first necessary to thin them out so that all palms are accessible. This would mean a considerable loss of palms but, as already pointed out, this loss would probably be more than compensated for by the increase in size, and thus yield, of the remaining palms.

When the palms reach the flowering stage they contain a maximum amount of starch and are ready for felling. The native method of extracting the starch (*see* illustrations) would be too slow and expensive for the large scale production of alcohol, and special machinery would be required for the disintegration of the trunk. After the palm is felled, the trunk could be cut into convenient lengths of about 3 feet for transportation to the factory. A considerable reduction in weight could be introduced by removing the outer layer of bark before transhipment, although the slight loss of starch and the extra time involved in removing the bark by hand may not favour the step.

From analyses carried out in this laboratory on a typical sago palm, the interior of the trunk was found to have the following composition:—

Water	52 per cent.
Protein	2 ,, ,,
Fat	0.5 ,, ,,
Sugar and starch	26.8 ,, ,,
Fibre	18.0 ,, ,,
Ash	0.7 ,, ,,

These figures indicate that at least 25 per cent. of the interior of the trunk consists of fermentable material, or 560 lb. per ton. This would yield approximately 40 gallons of 99.5 per cent. alcohol per ton, that is, 440 gallons of 99.5 per cent. alcohol per acre. Comparing these figures with those given in Table VII, it is seen that the sago palm is a better source of power alcohol than any of the materials listed, with the exception of cassava.

After the material has arrived at the factory and has been suitably disintegrated, the steps for the manufacture of alcohol would be exactly as outlined for cassava.

The Nipa Palm (Nipa Fruticans).

The nipa palm is found growing wild throughout parts of the Malayan Archipeligo, Borneo, the Philippine Islands, New Guinea and Papua.

Description.—The nipa palm is an erect, stemless palm, the leaves and inflorescences arising from a branched rootstock, the leaves being pinnate, 20 feet and more in length. The inflorescence is erect, bears numerous sheathing spathes and both male and female flowers, the former lateral, catkin like, the latter terminal in a globose head. The fruit is globose, as large or larger than a man's head and consists of many abovoid, six-angled, one-celled, one-seeded carpels.

Habitat and Available Areas.—This palm grows only along the mouths of tidal rivers in low, wet land subject to overflows of brackish water as the tide rises each day. It will not thrive in localities where either fresh or sea water alone is available. Extensive areas of nipa palm are to be found at the mouth of the Fly River and in the Delta Division of Papua and smaller areas exist on New Britain and parts of the mainland of New Guinea, particularly at the mouth of the Ramu River. Apart from these areas of nipa, there are other areas of swamp on the mainland of New Guinea which are considered suitable for the cultivation of the palm.

The nipa palm reproduces from seed and also by the branching of its roots. In an artificially made nipa plantation, the seedlings, after removal from the nursery, are planted in drains, 3 feet wide by 1 foot deep. The seedlings are actually placed in recesses cut in the side of the drain so that, when the plant grows, it will not interfere with the flow of water along these planting drains from the main stream.

The usual planting practice is about 200 seedlings to the acre. The plants begin to bear in about four years. It has been estimated by Dennett (1927) that the maximum total cost of bringing nipa into bearing at three years is about $60 per acre (£7).

Alcohol is manufactured from the sap of the palm. The sap as it flows from the stalk is clear and transparent, almost colourless, and very sweet to the taste. In the Philippines (Gibbs, 1911) samples from six different palms were analysed. The results showed that sap of the best quality, as it flows from the flow stalk, has approximately the following composition, stated in grams per 100 cubic centimetres.

Density $\frac{15^\circ}{15^\circ}$	1.0720
Total solids	18.00
Sucrose	17.00
Ash	.48
Reducing sugars	trace

In the Philippines, the best managed nipa groves, or "nipales", are divided into sections about 1 hectare (2.47 acres) in area. Each area contains about 2,000 plants, 700 or 800 of which are producing plants. Estimations of the yield of sap vary within very wide limits. Gibbs (*loc. cit.*), who has made an exhaustive study of the subject, writes—

"As a result of the experimental work performed by myself and others associated with me in this work, I believe that the average conditions in a 'nipale' cared for according to present methods will result in a yield of 43 litres for each plant during the season, an average daily yield during the period of production of .58 litre and a total yield of 87,000 litres per hectare per year"—that is, 9,300 gallons per acre per year.

According to Gibbs (*loc. cit.*), the production of alcohol from nipa palm sap should be above 6 per cent. of the sap and under favorable conditions it would be 7 per cent. Taking 7 per cent. as the alcohol content of the sap, it is seen that 9,300 gallons of sap would produce about 650 gallons of alcohol, which would be the annual yield per acre.

In Malaya, Dennett (*loc. cit.*) gives the maximum true yield per spathe as .1025 gallons. On a basis of two spathes in tapping per palm, 200 palms per acre and 340 tapping days per annum, this gives a yield of 13,940 gallons of sap per acre per annum. He gives the mean alcohol content as 10 per cent. by volume, so that the mean yield per acre per annum would be 1,394 gallons. He also gives the minimum true mean yield as 1,270 gallons. In *"An Outline of Malayan Agriculture", Grist* (1936) gives the theoretical yield of absolute alcohol as over 1,100 gallons per acre per annum, which indicates an actual yield of nearly 900 gallons per acre per annum. Grist's figures are the more recent and probably the more reliable for present-day conditions in Malaya.

The difference between the yields in the Philippines and in Malaya is probably due to the fact that in one country the tapping is seasonal whilst in the other it is continuous. Apparently the farther nipa palms are grown from the equator, the more seasonal is their fruiting period. No observations appear to have been made on the length of the tapping season in New Guinea, but as the territory lies approximately 0° to 8° south of the equator, it is probably continuous. Nevertheless, the lower of the three above estimates, namely, 650 gallons, will be taken as a conservative figure for the yield of alcohol per acre per annum.

An area of wild nipa would contain many more than 2,000 palms per hectare, probably 5,000 or more, but the number of producing palms would be low. By thinning out and dividing the palms into convenient areas by means of waterways, the total number of palms would be decreased to perhaps less than half, but there wound be an enormous increase in the yield per unit area.

Alcohol Production.—The method of producing alcohol from the nipa palm is much simpler than that for the production of alcohol from either cassava or the sago palm. There are only two principal steps in the process: (1) Fermentation of the sap; (2) distillation of the dilute alcohol thus formed. The procedure is briefly as set out below.

Tapping the Palm.—Since the nipa palm sends its inflorescence up from the base, the flower stalk is near the ground and conveniently situated for the gathering of sap. Four years after planting the seed, the nipa bears small fruits, but it is not generally tapped until the fifth year. Some time after the fruit has formed, the stalk should undergo a preliminary treatment known in Malaya as "gonchanging". This process is started when the fruit-head is fairly well grown, but before any darkening of the seed takes place. It consists of gently oscillating the fruit once a day. As the fruit-head grows, the violence of the operation is increased until it becomes a good hard kick or violent shaking by hand. Experience has shown three weeks to be a suitable length of time for this operation, any increase in the period tending to increase labour costs uneconomically. The stalk is then cut across near its top, usually just below the fruit, and each day a thin slice is removed to keep the wound fresh and to facilitate exudation. When a plant bears two flower stalks, the usual practice is to draw sap from only one, the other being removed and the stem allowed to dry up.

The sap is collected in bamboo joints, about 18 inches high and 3 inches in diameter, having a capacity of about half a gallon.

One stalk normally flows for about three months, but it is not uncommon for it to be entirely cut away, at least so close to the ground that it can no longer be utilized by the daily paring of small slices to keep the wound fresh, long before the flow has ceased. In some plantations, the flower is cut before the fruit is formed and under such circumstances the daily yield of sap is said to be increased, but the period of flow reduced from three to one and one-half months, the total yield being practically the same in both cases. The plant seemingly is not affected by this treatment. Where the tapping is seasonal, only a portion of the palms is cut at the beginning of the season in order to supply the distilleries with sap throughout the year and thus avoid shutting down the plant. As these palms are exhausted, the others are brought into production by cutting, and thus the season becomes continuous. No accurate estimates of the length of the time during which the nipa palm will continue to fructify and give sap are available, but all observers unite in saying that this process will continue for many years, perhaps for 50 or more.

Fermentation.—The inversion of the sucrose and the alcoholic, acetic and other fermentations begin almost immediately the sap drops from the stem into the bamboo joints ordinarily employed for collecting the sap, although, when the sap is collected in clean vessels, it undergoes little change for four or five hours. Often the inversion is complete and the alcoholic fermentation well under way, sometimes completed, when the sap arrives at the distillery. On arrival, it is milky in appearance and covered by a thick layer of foam. First, the sap is transferred to large fermenting tanks, some of which hold as much as 3,000 gallons. The fermentation is usually allowed to proceed for 24 hours and sometimes longer. When it has proceeded sufficiently, it is arrested by the addition of lime or some such substance. The liquid is then ready to be pumped into the stills. The simplicity of this procedure gives to nipa sap a considerable advantage over other raw materials which generally have to be prepared for fermentation at the distillery.

Distillation.—This part of the process is practically the same as for cassava and the sago palm.

Raw Material Required for the Production of Power Alcohol.

In Table VIII. are given the quantities of raw materials and the acreage required for the operation of alcohol plants of various sizes for a year of 300 days—

TABLE VIII.—RAW MATERIAL REQUIRED FOR UNITS OF VARIOUS SIZES.

Material.	Unit.	Requirements for the Daily Alcohol Production of— 1,000 gallons.			2,500 gallons.		
		Daily.	Annually.	Annual Acreage.	Daily.	Annually.	Annual Acreage.
Cassava tubers ..	Ton	21	6,300	630	53	15,750	1,575
Sago palm ..	Ton	25	7,500	690	63	18,750	1,725
Nipa palm sap ..	Gallon	14,300	4,290,000	460	35,750	10,725,000	1,150

Material.	Unit.	Requirements for the Daily Alcohol Production of— 5,000 gallons.			20,000 gallons.		
		Daily.	Annually.	Annual Acreage.	Daily.	Annually.	Annual Acreage.
Cassava tubers ..	Ton	105	31,500	3,150	420	126,000	12,600
Sago palm ..	Ton	125	37,500	3,450	500	150,000	13,800
Nipa palm sap ..	Gallon	71,500	21,450,000	2,300	286,000	85,800,000	9,200

Alcohol production should not be started unless raw materials are available to provide for a plant of the minimum size capable of producing alcohol profitably. Such a plant should probably contemplate a production of at least 2,000 gallons daily to be able to maintain the essential technical supervision for efficient operation without increasing unit costs unduly. Minimum amounts of raw materials required annually to operate an alcohol plant of this size for a year of 300 days are shown in Table IX.—

TABLE IX.—RAW MATERIALS REQUIRED TO PRODUCE 2,000 GALLONS OF ALCOHOL DAILY.

Material.	Unit.	Required for Distillery Annually.
Cassava roots	Ton	12,320
Sago palms	Ton	15,000
Nipa palm sap	Gallons	8,570,000

Table X. shows the crop tonnage and crop acreage required to produce a quantity of alcohol equivalent to 20 per cent. of the petrol consumed in Australia and New Guinea.

TABLE X.—REQUIREMENTS TO REPLACE 20 PER CENT. OF AUSTRALIA'S AND NEW GUINEA'S PETROL CONSUMPTION.

Material.	Unit.	Amount of raw material required to make 1,000 gallons of alcohol.	Amount of raw material required to make alcohol equal to 20 per cent. of Australia's and New Guinea's annual consumption.	Acreage required to produce material for 1,000 gallons of alcohol.	Acreage required to produce alcohol equal to 20 per cent. of Australia's and New Guinea's annual consumption.
Cassava roots ..	Ton	21	1,260,000	2.1	126,000
Sago palms	Ton	25	1,500,000	2.3	138,000
Nipa palm sap ..	Gallon	14,300	858,000,000	1.5	90,000

The Plant.

Because of the desirability of producing a very cheap and perhaps an impure product, use of the methods and equipment normally employed for producing pure spirits is advisable only when it entails no extra cost, or is justified for reasons other than the character of the product. The general procedure will probably have to be modelled on the conventional process, while costs are reduced by use of short cuts, revision of plant design, or other appropriate deviations. Since the production cost of alcohol depends on raw material, labour, fuel, capital, and overhead costs, each of these items must be held rigidly to a minimum.

Establishing an alcohol plant would be justified only on an expectancy of at least 20 years' operation in order that amortization may be possible without using too high a yearly depreciation percentage, which would raise the unit cost of the production. Extensive repairs or rebuilding or equipment additions would naturally lengthen the required amortization period. Alcohol plants cannot be constructed for efficient operation on a temporary basis and adequate and continual operation should be assured for a long time.

Plants should be located on solid ground as close as possible to: (1) Adequate supplies of raw materials; (2) Constant and relatively cheap sources of pure water, fuel, power, labour, building materials and process chemicals; (3) Facilities for the disposal of waste; (4) A seaport, navigable stream or other means of transport.

Because of the relatively low price that can be obtained for power alcohol any alcohol-producing plant design should provide for: (1) Units of adequate yet economical size; (2) flexibility of raw materials; (3) economy in handling and processing, and the use of automatic devices where economical; (4) possibility of using other fermentations, perhaps simultaneously; (5) quantity rather than quality of product.

PLANT DESIGN.

Selection of a specific plan, construction materials, and detailed building specifications would have to be governed partly by the geographic location. Frame studding and ordinary galvanized walls, with roofing of galvanized metal carried on open rafters, may be sufficient in many cases. Walls and roofs which may be washed down by steam or water are recommended. All wood interiors should be painted, and ledges where dust may accumulate should be avoided. In general all buildings should have substantial floors of concrete, preferably dustproof and non-absorbent. They should be well sloped to convenient sewer outlets and bordered by a curb or rim, on which the wall plates should be placed. This method makes it easy to keep all floor corners clean and free from sources of contamination. Fermenter houses using open-top fermenters should have ventilation down to floor level.

Wooden fermenting tubs are cheaper than steel tubs, but they are more difficult to sterilize and more liable to leak, and there is some loss of the product by evaporation from the top. Wooden tubs should be located indoors to control contamination or other factors, and they should be covered.

Steel fermenting tanks may be located outdoors if of the closed top design. Beer wells are a convenience when the number of fermenters is limited. They should be of metal or non-absorbent concrete, well sloped, and easily accessible for washing and sterilization.

The installation of convenient hoist-supporting beams over certain portions of apparatus (such as columns) is recommended to facilitate erection and dismantling. Walls and floors for any structure should be ample to sustain all the weight likely to bear thereon. Buildings should preferably be fire-proof and well-ventilated, and boilers or open flames must be kept at a safe distance from, and to windward of, refinery buildings so that alcohol vapours cannot reach the boiler room.

Ample track siding and ground storage space for fuel and raw materials are essential. Double sidings are preferable to a single track. Boiler and plant water supplies and adequate sewer facilities are of the utmost importance.

All pipe lines must be carried in the open for complete inspection, and they must be painted in designated colours. All valves, unions, or other openings must be locked or sealed.

The cost of a plant is dependent on both size and design. The kinds of raw material to be used, the amount and type of feed recovery, the recovery of carbon dioxide gas, &c., have a great influence on the design and total cost. Geographic location is also a factor in cost. No general cost estimates can be made, but certain rough computations are possible, as indicated later.

Cost of the fermenting, refining and miscellaneous equipment used in conventional alcohol processes can be established only indirectly. Each manufacturer of such equipment has his own ideas regarding size, design, weights of metal, types and efficiency of distilling columns and plates, &c. Therefore, refineries are frequently built throughout by one manufacturer although specific items made or controlled by other manufacturers may be included. The general designs are about the same. Since plants are usually designed to fit local conditions or raw material, many of the large suppliers of such equipment maintain complete engineering staffs and sell the complete plants (including foundations, equipment, erection, and complete piping) on a guarantee which includes a specific operating cost. The cost of maintaining such service is, of course, included in the gross cost of the equipment. Smaller concerns are more likely to make units to order, rather than to erect complete plants. The responsibility for successful operation of such then rests largely with the purchaser, who formulates the general specifications. Costs, therefore, vary not only with the required labour and the weights of copper or other metal used, but with the degree of advisory engineering detail furnished.

Costs.

Initial Costs.

As indicated in the preceding section, only approximate figures can be given for initial and production costs. Plant costs are continually changing and the cost of erecting a plant in one locality may be quite different to that in another.

From information recently received from America, the cost of a modern American Built convential-type, alcohol plant having an output capacity of approximately 10,000 gallons a day is approximately £133,000. This price includes buildings, foundations, boiler plant, fermentation equipment, distillation equipment, storage tanks, dry house equipment and water and power equipment. It is stated that plant capacities can be doubled for about 1.4 times the initial cost or halved at about .7 of the initial cost. If nipa palm sap is the only material to be treated, the above costs could be reduced by perhaps 25 per cent. or more.

Besides plant costs, there would be the cost of obtaining suitable land for the production of raw material. In the case of cassava, this land would probably have to be cleared, and in the case of areas of nipa and sago palms, these palms would have to be thinned out. The cost of clearing land under jungle or rain forest in New Guinea is about £5 per acre, the work being done by natives. If machinery were employed, the cost would be reduced considerably although there would be the initial costs of the tractors, &c., to be considered.

The cost of thinning out areas of sago or nipa palm would probably be less than £5 per acre and, in the case of the former, the material thinned out would have a high value as readily available raw material for the production of alcohol. In Borneo (Wood, 1925) the cost of thinning out nipa was $10 per acre, which was the contract price at Semawang.

Production Costs.

It is estimated that the cost of producing cassava tubers (including the cost of the planting material) in New Guinea does not exceed 15s. per ton and if the yield per acre is greater than 10 tons, the cost of production would be lower than this amount. At present, all cultivation is done by hand, but if the initial preparation of the land and the harvesting were done with machines, the cost could probably be reduced by at least half.

It would be advisable to follow the cassava with a leguminous crop, such as velvet beans or cow peas, before planting the next crop of cassava. The beans or peas could be harvested and used as a native food whilst the plant could be ploughed in as a green manure. Unfortunately, no figures are available for production costs and yields of velvet beans or cow peas per acre under conditions existing in this Territory. However, it is considered that the value of the crop as a native food for feeding the labour line would probably more than pay for its cost of production.

Unless certain by-products are used for this purpose, the cost of fertilization at regular periods will further increase the cost of production.

No figures are available for the cost of harvesting the sago palm in this Territory. At present, the harvesting is done in a very leisurely manner by native women, the final product consisting of approximately 60 per cent. starch and 40 per cent. water. In the production of power alcohol, there would probably be no need to separate the starch from the fibrous material and once the outer bark had been moved the remaining portion of the trunk could be easily disintegrated and mashed for fermentation. Hence the harvesting costs would only consist of felling and trimming the palm and transporting it to the factory.

It is estimated that two natives could harvest at least five palms per day or $5 \times 250 = 1,250$ lb. of starch per day. Native labour costs about 1s. per day per man so that the cost of production of total fermentable matter would be less than 4s. per ton.

As there are no records of the nipa palm having been tapped in this Territory, no figures are available for cost of production. In Borneo, Wood (1925) has estimated that one coolie can tap sufficient palms to yield at least 80 gallons of juice per day. Hence it seems reasonable to conclude that a New Guinea native, once he has learnt the technique and gained a little experience, should be able to collect at least 70 gallons of juice per day—that is 70 gallons may be collected for 1s.

Factory Costs.

Cassava and Sago Palm.—From recent figures published by the United States Department of Agriculture ("Motor Fuels from Farm Products"), the cost of production would be approximately as follows:—

Conversion costs.	Average costs in cents per gallon.
Fuel (production basis of 10,000 gallons/day for 300-day year) ..	1.38
Water and power	.50
Labour	2.50
Interest	.85
Depreciation	.89
Taxes and general overhead	.88
Chemicals and supplies	.50
Raw materials (excluding that from which alcohol is made)—	
Malt	2.40
Anhydrous step	2.00
Denaturing	2.00
Total	13.90
	or 8½ pence.

These costs have been computed for the production of alcohol from grain, but they are a good indication of what the costs would be if cassava tubers or the sago palm were the raw material. It should be remembered, however, that labour is much cheaper in New Guinea than in the United States.

Nipa Palm Sap.—Wood (1925) gives in detail estimated costs of production for plants of three different capacities when running for 24 hours per day. These estimates are summarized in the following table:—

—	2,000-gallon Plant.		4,000-gallon Plant.		8,000-gallon Plant.	
	Per year.	Per gallon.	Per year.	Per gallon.	Per year.	Per gallon.
	$	$	$	$	$	$
Total collecting costs ..	66,000	.18332	132,000	.18332	264,000	.18332
Total distilling costs ..	31,170	.08655	61,620	.08577	103,320	.07175
Total other costs (depreciation, insurance, royalty, cost of running launch, &c.)	31,800	.08830	57,600	.07997	106,800	.07414
Total producing costs ..	128,970	.3582	251,220	.3491	474,120	.3292
Total capital required ..	$272,000		$537,000		$1,044,000	

$1 equals 2s. 4d. (English).

From this table it is seen that the cost of production decreases as the output increases and, for a factory producing 8,000 gallons per day, is about 9d. per gallon.

General.

In indicating production costs, no attempt has been made to compute total production costs per gallon. Before this can be done, certain field experiments would have to be conducted in the district in which it is proposed a factory should be established in order to check up on the foregoing costs.

However, the estimates given indicate that the margin of profit will not be great unless all costs are kept rigidly to a minimum.

By-products.

If sago palms and cassava tubers constituted the raw material, the recovery of stock feeds from distillery wastes could be an important part of the power alcohol industry. It is usual to strain the solids from the spent slop and then dry them when they are fit for marketing.

Another by-product that should yield large profits is carbon-dioxide (CO_2). This could be collected from the fermenting vats instead of being allowed to run to waste, and can be compressed and sold for aerating and refrigeration purposes. The cost of the additional plant would not be great but the successful retailing of the product would call for good business organization.

During an ordinary yeast fermentation, a small quantity of oil having a characteristic odour is formed. This oil, which is normally separated from the alcohol in the refining columns, consists of a mixture of higher alcohols and esters, but its composition varies with different fermentation conditions and different raw materials. It is used principally as a solvent for lacquers.

The sale of these by-products will reduce alcohol production considerably but, with the exception of carbon dioxide and fusel oil it may be more profitable to return the by-products to the soil as a fertilizer. Ethyl alcohol has the following chemical formula—C_2H_6O, that is, it is composed of only carbon, hydrogen and oxygen all of which are contained in the air. Hence, if the stock feeds produced as by-products in the manufacture of power alcohol are returned to the soil from which the raw material came, the soil will yield indefinitely and the supply of alcohol would be *absolutely inexhaustible.*

Summary.

The possibility of producing alcohol from cassava tubers, the sago palm, and the nipa palm are discussed. Figures for the possible yields per ton and per acre are given, and these figures are compared with similar figures for crops grown in temperate climates.

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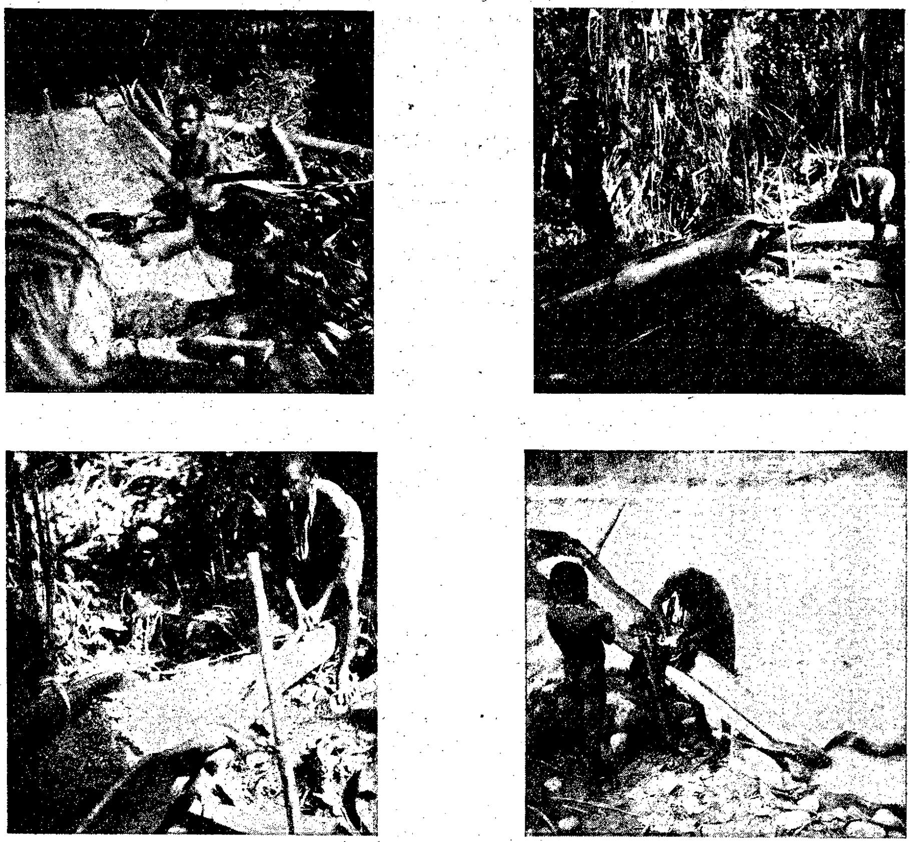

The native method of preparing starch from the sago palm, showing the disintegration of the trunk and the initial and final washings with water.

(Photographs by Wood.)