COMPARISON OF ETHANOL PRODUCTION FROM SUGAR AND STARCH CROPS: SUSTAINABLE BIOETHANOL ENERGY RESOURCES CHALLENGER TO HYDROCARBONS.

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Abstract

As a non-oil-producing country, Madagascar is currently confronted with an energy problem that is focused on over-dependence on wood energy and fossil fuels, and low exploitation of other energy sources, despite numerous options and research activities that are either localized or still at the experimental stage. However, the country has natural resources that can be exploited through the various varieties of sugar and starch plants that can be transformed and used as a renewable energy source, notably bioethanol. This is the case for pineapple, a sweet plant, and manioc, a starchy plant, the subjects of this research work.
Studies and research carried out in the laboratory of the National Center for Industrial and Technological Research (CNRIT) have helped to optimize the bioethanol production process from these two plants.
The results of these studies have provided technical parameters for optimizing bioethanol production, including fermentation time, yeast content, sugar reduction and maximum alcoholic strength after rectification. Apart from yeast content, which was around 5% for both plants, the other parameters studied were dominated by the value obtained by cassava, including fermentation time: 3 days for cassava compared with 5 days for pineapple; sugar attenuation: 62,5% for cassava compared with 60,72% for pineapple. Finally, after rectification, cassava recorded an alcoholic degree of 90°GL, compared with 87°GL for pineapple.

Keywords: *cassava, pineapple, fermentation, distillation, rectification, ethanol, optimization, optimum parameters*

1. INTRODUCTION

Since Neolithic times, human development has been based on the possession of energy. Energy is necessary for all sectors of life, as well as for industry to produce the goods and services required to meet the needs of the population. Access to energy means the possibility of housing, heating, transport, food, healthcare, farming... Yet this access is far from being a given throughout the world. Most of the world's energy is based on coal, oil and gas, and therefore emits greenhouse gases. However, global warming makes the energy transition imperative, which involves replacing carbon-based energies with low-carbon energies, and consuming less and better energy through energy efficiency, building insulation and the development of public transport and rail freight, to enable the necessary transfers of use and meet the needs of the population.

Fossil fuel resources are unevenly distributed around the world, and have always been at the heart of tensions, and even wars, over their appropriation. The global economy's heavy dependence on these unevenly distributed resources creates tensions. It is against this backdrop that this research project, focusing on agrofuels, was initiated.
Faced with these situations, and with a view to offering the population not only an ecological, sustainable and low-cost source of energy, but also to alleviating tensions around the world due to the unequal distribution of fossil resources, this research project entitled "Comparison of ethanol production from sugar and starch plants: sustainable bioethanol energy resources as a challenger to hydrocarbons" was initiated. Questions such as
- Is biofuel one of the ideal solutions to the country's current energy problems?
- Among the available and potential resources for producing ethanol and, of course, bioethanol, are cassava and pineapple in the best position?
- Which of these two resources is more interesting: pineapple or cassava, in terms of production technology and yield?

The aim of the present research is to undertake a comparative study of ethanol production from pineapple, a sweet plant, and cassava, a starchy plant. It highlights the importance of these two types of resource in solving part of the country's energy problem.

2. METHODOLOGIES

This research work concerns two different plants: cassava and pineapple. Both plants are located along the national road N°1. Cassava is found in Analavory in the Miarinarivo district and pineapple in the urban commune of Imerintsiatosika, Arivonimamo district.

2.1. Location of cassava study area: Analavory rural commune

The rural commune of Analavory is one of the communes making up the Miarinarivodistrict in the Itasy region. It lies 22km west of Miarinarivo, the capital of the Itasy region. If you follow the road to Route Nationale N°1 (RN1), which links the city of Antananarivo and Tsiroanomandidy, it is 111km away. It is bordered to the north, east, south and west by a number of rural communes:

- To the north: AnosibeIfanja, SarobaratraIfanja, and Ambatomanjaka.
- To the east: Miarinarivo II, and Manazary.
- South: Ampefy, and Ankaranana.
- West: Alatsinainikely, AnkadinondrySakay.
- According to Ampandrianomby data, the rural commune of Analavoryse is located at latitude: 18°58'42.01"S and longitude: 46°42'45.35"E.
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Figure 1: Location map of the rural commune of Analavory
(Source: Analavory commune monograph)

2.1.1. Climate

Like the soil, the climate in Analavory resembles that of the Malagasy highlands, i.e. a tropical climate at altitude, whose main characteristics are the alternation of two contrasting seasons (hot and rainy, and dry and cold). This climate dries out the further west you go, and its variation for Analavory is as follows:
- November - March: hot, rainy season
-April-July: cold, dry season
-August-October: hot, dry season

This type of climate makes it possible to vary the types of crops and livestock raised in the commune.

2.1.2. Temperature

The following table shows average monthly temperatures in the Hauts Plateaux region over the last five years, including the commune of Analavory.

Table 1: Average monthly temperatures in °C over the last five years (2005-2010)

Mois / T°	J	F	M	A	M	J	J	O	S	O	N	D
T° max (°C)	26,38	26,4	26,76	25,52	23,65	21,7	20,42	32,45	31,43	25,66	35,7	26,86
T° min (°C)	17,74	17,52	17,18	16,02	14,1	11,67	11,02	11,03	12,47	13,73	16,32	17,06
T° M (°C)	22,6	21,96	21,97	20,77	18,87	16,68	15,72	21,74	21,95	19,7	26,01	21,96

(Source: meteorological data)
T° max: Maximum temperature in degrees Celsius
T° min: Minimum temperature in degrees Celsius
T° M: Average monthly temperature in degrees Celsius
Temperature of 26°C, while the coldest month is July, with an average temperature of 15°C. Accordingly, there are two seasons in any given year: hot and rainy, and dry and cold.

2.1.3. Economic situation

As a rural commune, agricultural activities dominate Analavory's economy. Other common activities include livestock breeding and eucalyptus forestry, as well as trade and handicrafts.

2.1.3.1. Agriculture

As far as agriculture is concerned, rice, market gardening and fruit growing dominate in Analavory, as they do in the neighbouring communes of Ampefy, Anosibe-Ifanja and Andolofotsy. Off-season crops are dominated by cassava, maize and sorghum. The most widely used fruit crops are papaya and banana. In general, the factors that burden the agricultural sector with low productivity are as follows:
-Lack of mastery of farming techniques: old techniques using archaic equipment still predominate. This phenomenon is caused by the lack of agricultural technicians in the commune and the lack of effective follow-up to training already provided.
-Lack, obsolescence and progressive destruction of infrastructure

Table 2: Agricultural production in the Analavory commune

Types	**crops**	**useful agricultural area (ha)**	**utilized agricultural area (ha)**	**Productivity (T/ha)**	**Production (T/an)**
céréals	River rice	3436	2804	3	8258
	Rainfed rice	2232	1011	2,5	2150
	Corn	2805	1904	3	4985,5
Vegetables	Beans	1678	739	2	1702,5
	Tomatoes	705,5	292,5	10	4116
	Melons	600	230	6,5	536,1
	Potato	131	8,1	8	290
	Bambara weight	530	29	2	57
	watercress	10	10	2	20
	Other	186	37,85	2	127,63

	cassava	6034	4524	4	24028
	Sweet potato	1570	515,3	3,5	3070,3
Tuberous roots	Tarot			3	250
	sugar cane	200	12	10	250
	Pistachio	510	126	1,5	123
Industrial crops	Tobacco	604	10	2	18
	Papaya	601,8	50,4	20	312,25
	Melons	10	5	5	50
	Bananas	304	10	5	70
Fruits	Other	300	50	5	80

(Source: Analavory commune monograph)

Average rice-growing productivity is still around 3t/ha. Among cereals, this result is the same for maize. However, maize production in t/year exceeds rainfed rice production in t/year by half.
Farmers are also diversifying their agricultural activities to boost their incomes. Papaya cultivation is a concrete example of this initiative. The Fokontany involved in this practice are Analavory, Ankotrabe, Amparaky, Tsarazaza and Ambatomitsangana.
A family in these Fokontany earns an average of between 1,000,000 Ar and 5,000,000 Ar/year, depending on the size of the farm.
Market gardening also deserves particular attention, with bambara peas and beans.
Industrial crops are of lesser importance, and sugar cane cultivation is not yet large enough to meet the needs of any industry.

2.1.3.2. Breeding

Among the primary sector activities, livestock farming plays a significant role in the commune. Cattle farming is highly regarded in the commune, followed by pig farming and poultry farming. Meat is primarily sold to local butchers. Pigs are sold outside the commune, and even outside the region. Livestock farming is also encountering a number of problems within the commune, namely:
-lack of mastery of new techniques.
-lack of investment due to lack of access to the micro-finance system.
-non-compliance with health standards.
-the frequency of disease.
-banditry in the form of zebu rustling...
These problems are largely due to the lack of supervision and personnel at commune level, despite the presence of private veterinarians who support those employed by the commune.

2.2. Location of pineapple study area: Imerintsiatosika urban commune

Part of the Itasy region, the Commune Urbaine d'Imerintsiatosika is located in the central highlands of Madagascar. Located 27km south-west of the city of Antananarivo on Route Nationale number 1, it lies at latitude -19°01'and longitude 47°15'.
The Imerintsiatosika commune covers an area of 173km2.

2.2.1. Administrative delimitation

As one of the 24 Communes that make up the District of Arivonimamo, the commune is made up of 36 Fokontany that are organized for its development. Crossed by the Katsaoka river, it borders the Morarano - Ambohitrambo communes to the north, Ambohimandry to the south, Arivonimamo I and II to the west and Ambatomirahavavy to the east. The commune lies between the three regions of Itasy, Vakinakaratra and Analamanga.

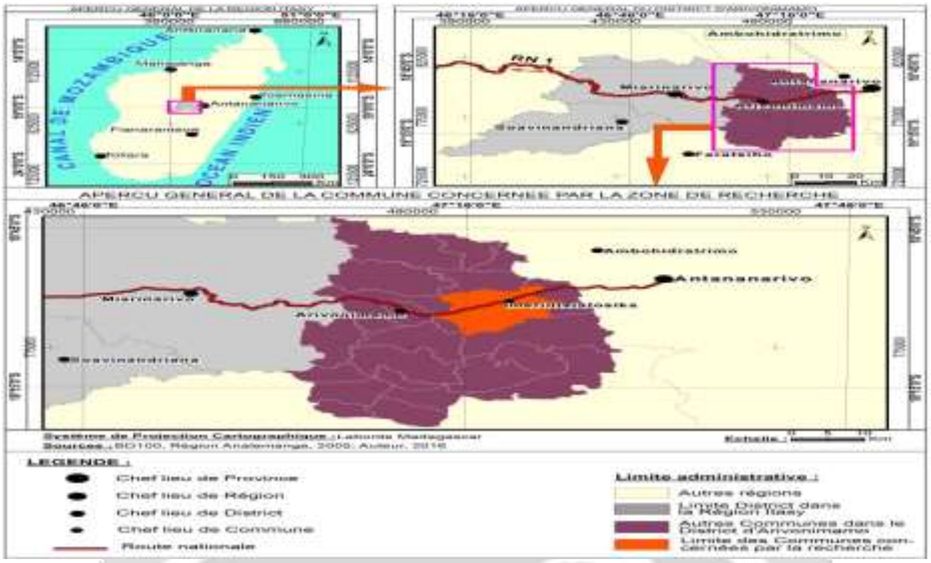

Figure 2: Location map of study area (source: PCD Imerintsiatosika)

2.2.2. Climat

The region has a high-altitude tropical climate characterized by an average annual temperature of 20°C and a dry season lasting 6 to 7 months. Average rainfall is quite high, averaging 10500 m.

The distribution of the year, particularly in recent times, includes long dry months, which makes it difficult to get the agricultural season off to a good start.

As in the central highlands, the Commune enjoys a tropical climate with two distinct seasons: a cool, dry season from May to October, and a hot, rainy season from November to April.**2.2.3. Agriculture**

La population de la commune rurale d’Alakamisy Fenoarivo est à majorité rurale qui vit de l’agriculture et de l’élevage. Le tableau 3 récapitule les cultures les plus pratiquées.

Table 3: Farming production by farmer

Crops grown	Number of farmers	Cultivated area in Hectare (Ha)	Annual production in tonnes
Rice	2 609	1 547	4 230
Cassava	540	320	3 210
Potato	185	110	597
Potatoes	127	75	1 080
Tomato	590	350	4 250
Corn	708	420	850
Bean	371	220	162
Other	329	195	165

2.2.4.1. Breeding

In addition to agricultural activities, the commune also raises cattle, pigs, laying hens and broilers.

Table 4: Livestock numbers

Animals	Workforce
Bovidae	2260
Pig	2680
Poultry	7250

broiler chicken	3 000
Laying hens	10 000

2.3 Experimental work

Experimental work was carried out in two different ways on cassava and pineapple.

2.3.1. Cassava experimentation

2.3.1.1. Protocol for ethanol production from cassava

The protocol for making ethanol from cassava follows the chronological order of the following activities:

a) Pre-treatments

Pre-treatments include

- Sorting: eliminating products in poor condition;
- Washing: to remove dirt and stains (mud, etc.);
- Peeling: removing outer bark;
- Cutting into pieces and grinding: to obtain a fine, homogeneous mixture

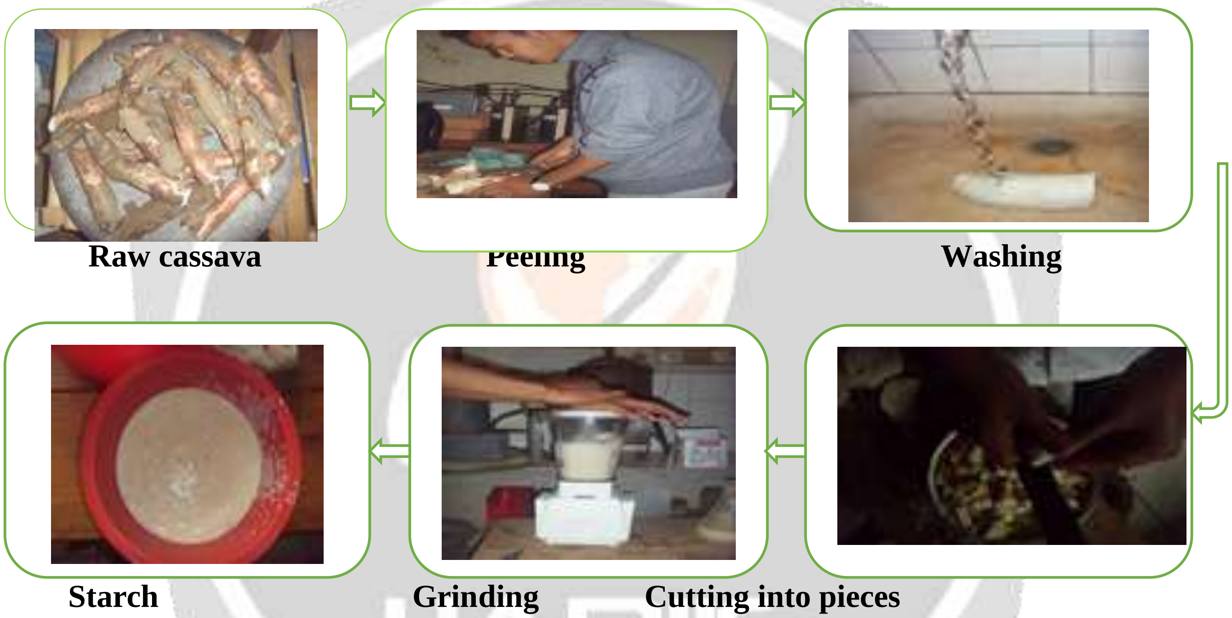

Photo 1: Pre-treatment

b) Hydrolysis

Enzymatic hydrolysis based on paddy grain comprises the following steps:

Amylase preparation

- Soaking: paddy grains are moistened and conditioned in a warm, humid place to facilitate and accelerate germination.
- Germination: a period lasting four to six days, during which the barley begins to germinate, giving rise to what is known as 'green malt'.

Photo 2: Paddy grain sprout

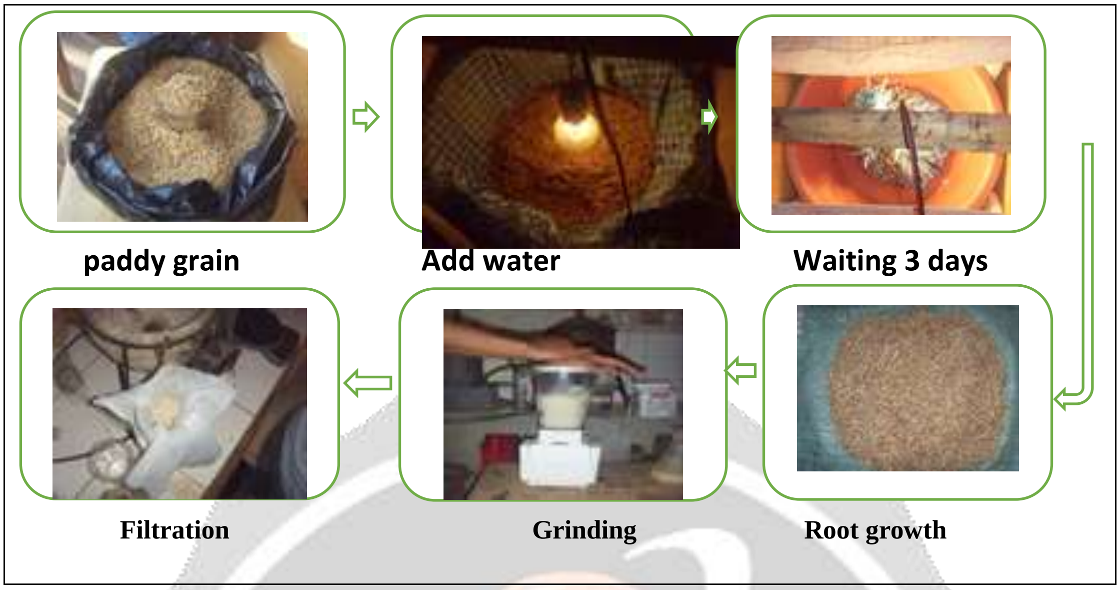

Photo 3: Enzyme preparation

Hydrolysis
Hydrolysis is the transformation of starch into fermentable sugar under the action of enzymes at a given temperature and with constant agitation. Hydrolysis itself comprises two stages:

o Gelation
The aim is to modify the structure of the starch by the action of heat and water. The gelling of cassava starch facilitates the action of the enzymes present in the malt.

o Liquefaction
Liquefaction improves and accelerates enzyme activation in gelled cassava juice.

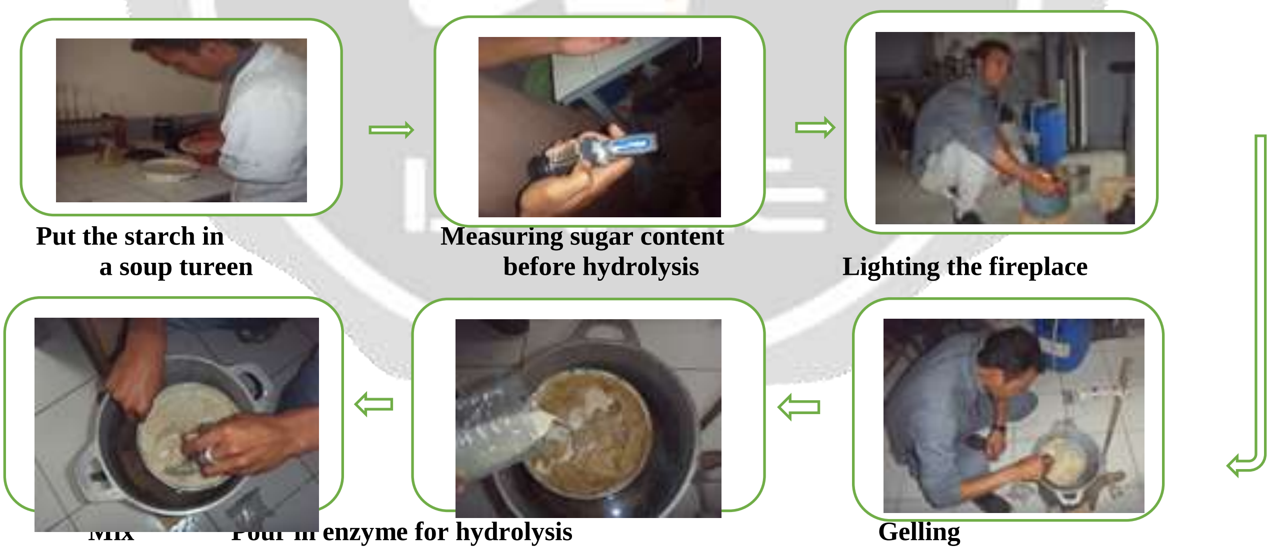

Photo 4: Gelation and hydrolysis

2.3.1.2. Yeast quantity and fermentation
Fermentation transforms glucose into ethanol. To achieve this, yeast must be added to the mixture. Fermentation lasts about a week. Alcoholic fermentation takes place anaerobically, at a temperature of between 15°C and 35°C. The anaerobic environment enables the yeast to convert glucose into ethanol. Photo 5 shows the preparation for fermentation

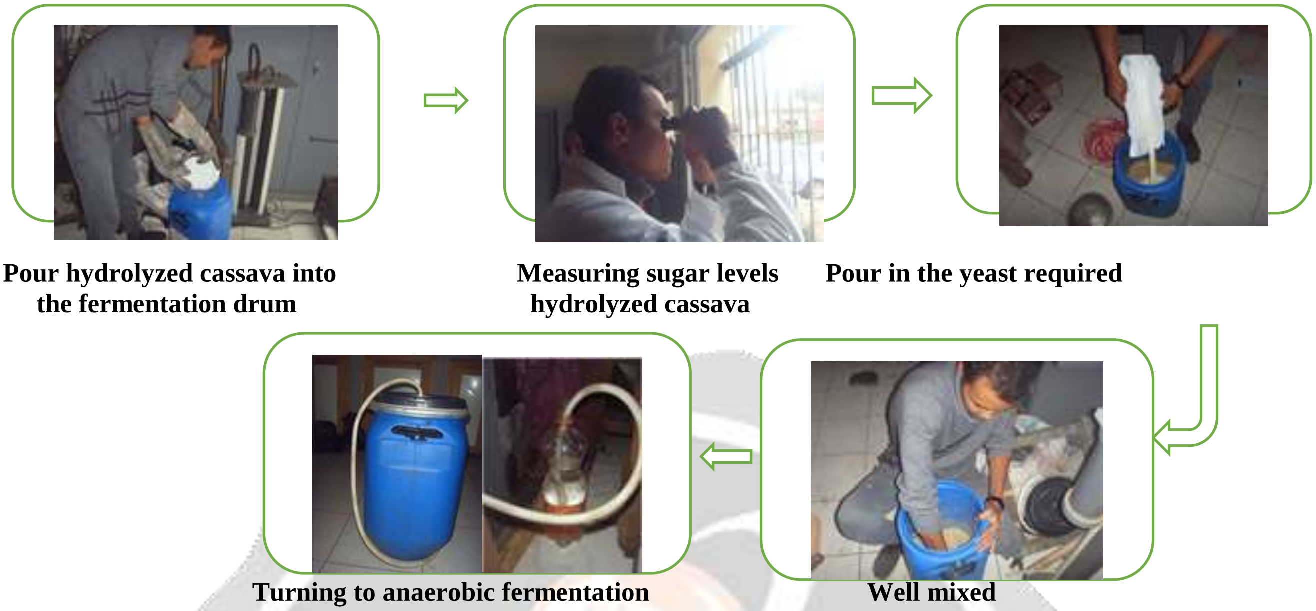

Photo 5: Preparing for fermentation

a)Boiler and column head setpoint temperature limits.

- Distillation

Immediately after fermentation, a so-called wort is obtained. The distiller is then prepared and the wort is loaded into the boiler. Check that the distiller's pipes are hermetically sealed to prevent any steam leaks, and start distillation.

The distillation steps are summarized in photo 6.

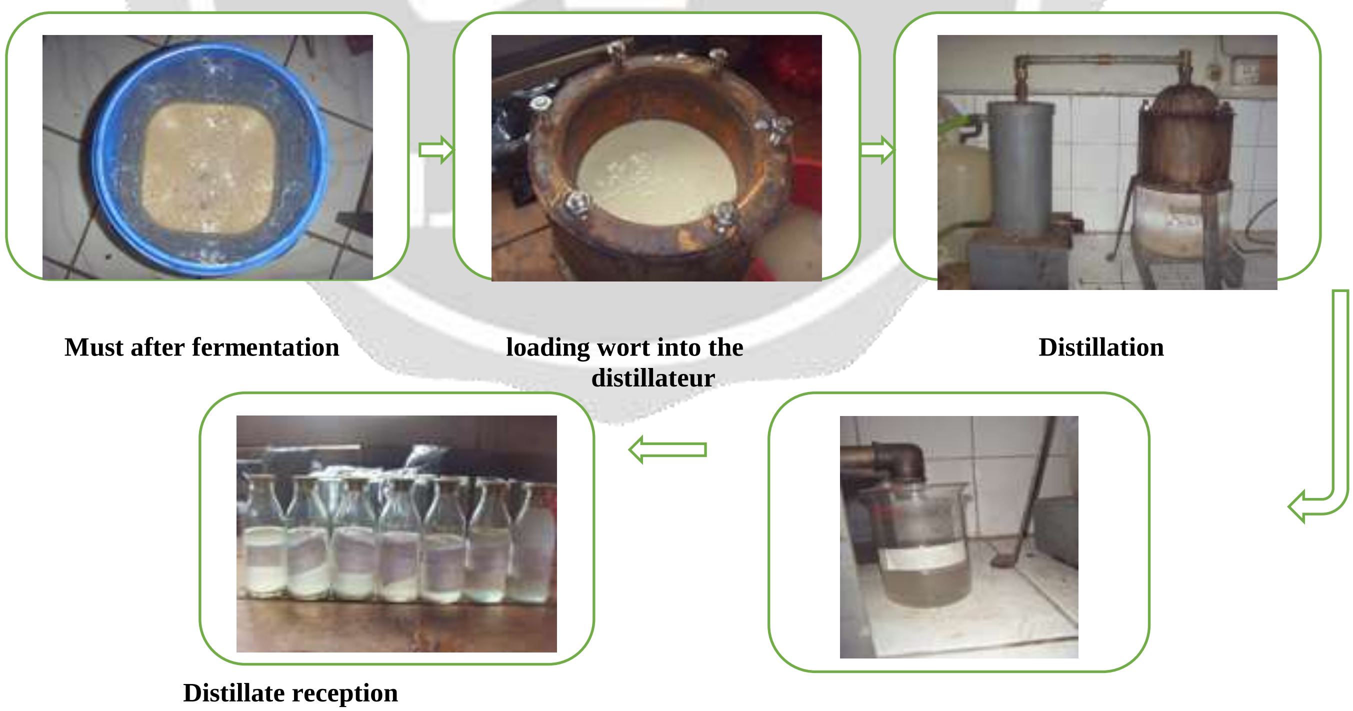

Photo 6: Distillation

- **Rectification**

Rectification, also known as fractional distillation, is a separation process based on fractionation. Its aim is to separate the various constituents of a mixture of miscible liquids with different boiling points. It uses the same principle as conventional distillation, but is distinguished by the use of a separation column, which enables better discrimination of the mixture's constituents.

The operation must be carried out at a controlled temperature, as the boiling point of water is 100°C and that of ethanol 78°C.

a) Rectification procedure

The alcohol obtained from distillation is introduced into the rectifier's boiler and heated by the electric resistance. The steam thus formed passes through the column packed with structured material (tray). The temperature drops as the column is raised. The vapour made up of the least volatile components (water) cools and condenses at the level of the column trays, before falling back into the boiler. The vapour rich in the most volatile component (alcohol) continues to rise in the distillation column, then passes through the piping (vapour circuit) and passes through the condenser to give distilled liquid alcohol.

b) Operating mode

- Collect the alcohols from the distillation process and measure the alcoholic strength of the resulting mixture.
- Prepare the alcohol, then pour it into the boiler through the loading funnel. The minimum quantity of alcohol to be rectified is 1L, and the maximum is 4.5L;
- After loading, close the tap to prevent leakage;
- Open the cooling water circuit, then check that all unit taps are closed;
- Start grinding;
- During rectification, gradually collect the distillate with a graduated container, then measure and record each corresponding alcoholic degree;
- At the end of rectification, wait for the unit to cool down, then open the discharge tap and collect the residue.

2.3.2. Pineapple experiments

2.3.2.1. Fermentation

a)Principle

Fermentation consists in transforming glucose into ethanol. To achieve this, yeast must be added to the mixture. Fermentation lasts about a week. Alcoholic fermentation takes place in an anaerobic environment, at temperatures between 15°C and 35°C. The anaerobic environment enables the yeast to convert glucose into ethanol.

b) Procedure

After weighing, the collected waste was rinsed, then cut up and ground in a blender, to obtain a virtually homogeneous mixture whose Brix degree was measured. The resulting mixture was then introduced into the fermentation tank, after addition of yeast.

Fermentation was carried out according to the procedure described in photo 7.

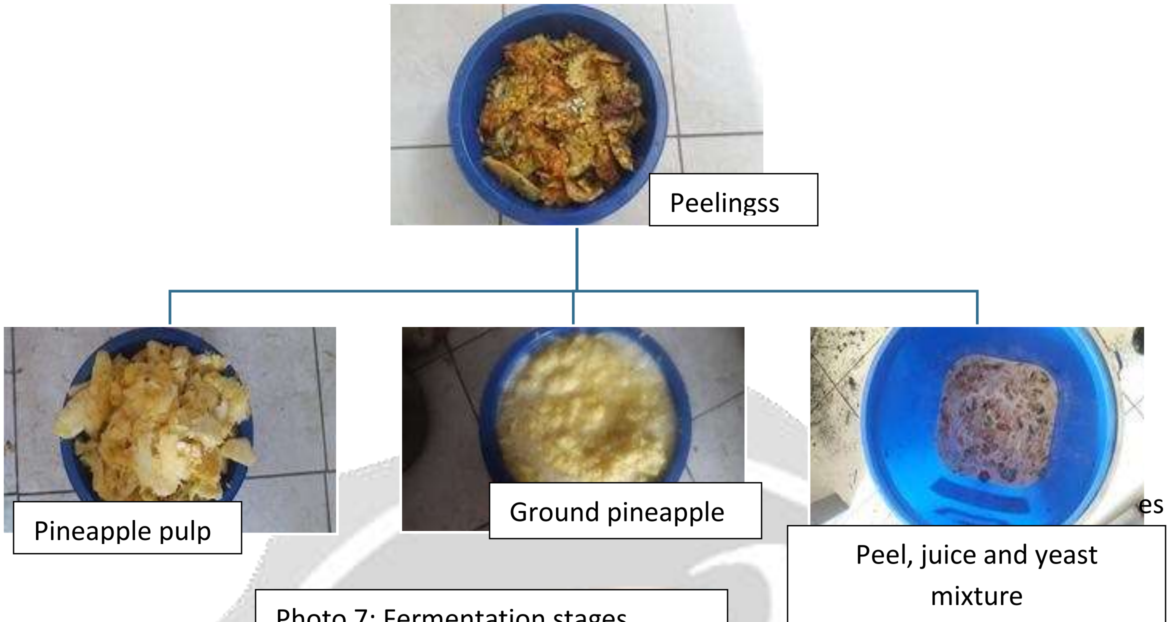

Photo 7: Fermentation stages

c) Parameters to be monitored

The main parameters whose evolution must be monitored and controlled are :

- Brix degree before and after fermentation. This parameter is measured using a refractometer.
- The attenuation of the sugar level after fermentation is given by the following formula
- $$Attenuation = \frac{E - E_a}{E} * 100$$

Where: E =Sugar level in solution before fermentation;

Ea=Sugar level in solution after fermentation.

In fact, the total amount of sugar present in the must is not completely transformed into ethanol. Attenuation therefore reflects the yield of fermentation

2.3.2.2. Distillation

a) Procedure

- Prepare the distiller;
- Filter must;
- Load filtered wort into distiller;

Close the distillation unit tightly and seal the plug; Collect the distillate.

b) Distillate preparation

-First prepare the distiller and pour the wort into the boiler. Then check the distiller's piping for leaks and start distillation.

- Filter the fermented wort to remove solid debris and obtain a more fluid solution.

Photo 8: Must after 5 days of fermentation

-Loading filtered must into the boiler

Photo 9: Loading must into the distiller

-Start distillation, monitor temperature, recover distillate

2.3.2.3. Rectification

Rectification or fractional distillation is a process for purifying a low-alcohol solution to obtain a high-alcohol product.

The operation must be carried out at a controlled temperature, as the boiling point of water is 100°C and that of ethanol 78°C [9].

a) Operating principle

The alcohol obtained from the first distillation will be introduced into the rectifier's boiler and heated by the electric resistance. The steam thus formed passes through the column packed with structured material (tray). The temperature drops as the column is raised. The vapour made up of the least volatile components (water) cools and condenses at the level of the column trays, before falling back into the boiler. The vapour rich in the most volatile component (alcohol) continues to rise in the distillation column, then passes through the piping (vapour circuit) and passes through the condenser to give distilled liquid alcohol.

b) Operating mode

-Combine the alcohols obtained from distillation, then measure the alcoholic strength of the resulting mixture.

-Load the mixture into the rectifier's boiler.

-Start rectification after connecting the cooling system.

-Collect distillate samples during rectification, then measure and record each corresponding alcoholic degree.**3. 3.**

3.RESULTS

The results include, respectively, those obtained from laboratory work with cassava and those with pineapple.

3.1 Results with cassava

Fermentation took place in a non-renewed medium, varying the percentage of yeast and the duration of fermentation for the same mass of hydrolyzed cassava. Fermentation results are summarized in Table 5:

Table 5: Fermentation results

Test no.	Hydrolyzed cassava(g)	Yeast (%)	Yeast (g)	Fermentation time (days)	Sugar before fermentation (°Brix)	Sugar after fermentation (°Brix)	Atténuation (%)
1	8000	5	400	3	16	6	62,50
2	8000	7	560	4	14,5	8	44,83
3	8000	8	640	5	14	8	42,86
4	8000	9	720	6	13	8	38,46
5	8000	10	800	7	11	**7**	36,36

The table shows that trial 1, carried out with a yeast content of 5%, for a fermentation time of 3 days, resulted in the highest fermentation yield of 62.50%. This represents a higher fermentation yield. We can therefore assume that the optimum fermentation parameters are as follows
- 5% yeast content,
- 3-day fermentation time

3.1.1. Results of distillation with cassava

It should be noted that the volume of the distiller in the CNRIT laboratory was too small, so distillation of the mash from a fermentation operation was carried out in two waves.
In addition, the distillation runs took place under the same conditions. The temperature at the distiller's head was controlled using a mercury thermometer.
Distillation from the 5 fermentations was thus carried out in 5 series:

3.1.1.1. First series of distillation tests with cassava

Table 6: First series of distillation tests

Jet number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Alcohol volume (ml)	89	90	90	90	92	90	91
Degré (°GL)	64	72	72	70	61	61	54
Jet number	**8**	**9**	**10**	**10**	**11**	**13**	**14**
Alcohol Volume (ml)	90	89	90	92	90	95	90
Degré (°GL)	45	41	35	28	19	18	13

The total volume of ethanol obtained is 1268ml, with alcoholic strength ranging from 13° to 72°.
From the second to the fifth distillation series, the results are as follows:
-Second series of tests: the total volume of ethanol obtained is 1403ml, with alcoholic strength ranging from 10 to 71°.
-Third series: the total volume of ethanol obtained is 1385ml, with alcoholic strength ranging from 15 to 70°.
-Fourth series: the total volume of ethanol obtained is 1145ml, with alcohol content ranging from 11 to 59°;
-Fifth series: the total volume of ethanol obtained is 1027ml, with alcoholic strength ranging from 10 to 56°.
Figure 3 shows the evolution of the alcoholic strength of the distillate as a function of the spray rank, for the five test series.

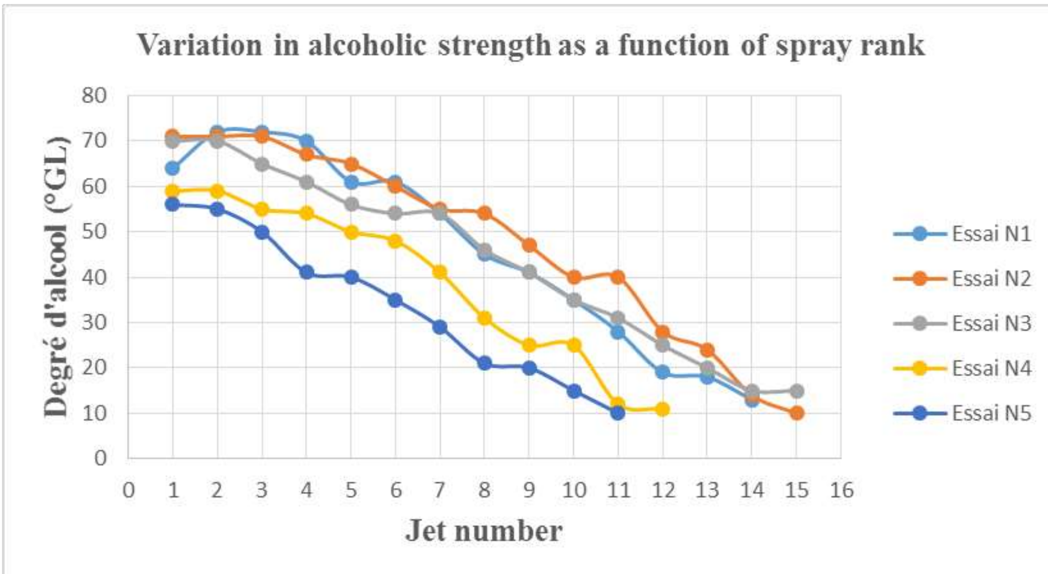

Figure 3: Variation in alcoholic strength of distillate as a function of jet rank

3.1.2. Results of rectification with cassava

Before rectification, we grouped the alcohol obtained from the first distillation into 4 groups of alcoholic strength: 66°; 51°; 33°, 19°.

3.1.2.1. First rectification group

Operating conditions :

- Alcoholic strength 66 °GL
- Initial volume of alcohol 1.5L
- Boiler regulator setpoint temperature (ϴb): 125°C then 150°C
- Column head regulator set point (ϴtc): 78°C

Table 7: First rectification

Sections						
Jet number	**1**	**2**	**3**	**4**	**5**	**6**
Duration (mn)	**50**	34	43	**40**	21	25
Degré (°GL)	92	91	90	88	86	85
Θ_b (°C)	127	129	127	157	151	158
Θ_{tc} (°C)	71	70	70	71	71	79
Volume (ml)	150	150	148	150	150	135

The total volume of ethanol obtained is 883ml, of which the first three distillates collected at a boiler temperature of 125°C have alcohol contents ranging from 90 to 92°, while those of the other three distillates collected at 150°C range from 85 to 88°.

In addition, we note that the time taken for the first jet to appear in rectification carried out at the set temperature of 125°C is greater than that at 157°C

(50 mn > 40mn).

Five grinding tests were carried out:

- Deuxième groupe d’essai de rectification:

Opérating conditions : :

- Alcohol content 51 °GL
- Initial volume of alcohol 1.5L

- Boiler regulator setpoint temperature (ϴb): 125°C then 150°C
- Setpoint temperature of column head regulator (ϴtc): 78°C

The total volume of ethanol obtained is 866ml, of which the alcoholic degrees of the first three distillates collected at a boiler set-point temperature of 125°C remain constant at 90°, while those of the other three distillates collected at 150°C vary from 75 to 88°.

- Third grinding test group:

Operating conditions :
- Alcohol content 33 °GL
- Initial volume of alcohol 1.5L
- Boiler controller setpoint temperature (ϴb): 125°C
- Column head regulator setpoint temperature (ϴtc): 78°C
- The volume of alcohol obtained is 400 ml, with an alcoholic strength of 90 for the first jet and 82-89° for the last two jets.

- Fourth rectification test group:

Operating conditions:
- Alcoholic strength 19 °GL
- Initial volume of alcohol 2.345L
- Boiler regulator setpoint temperature (ϴb): 125°C
- Column head regulator setpoint temperature (ϴtc): 78°C

The volume of alcohol obtained is 362 ml, with alcoholic strength ranging from 69 to 88.
It should be noted that for these last two rectifications (3rd and 4th) we set the setpoint temperatures at ϴtc =78°C and ϴb =125°C respectively. Indeed, the application of these parameters during the first two rectifications produced promising results, namely: distillate alcohol content between 90 and 92°..

:**3.2. Résultats avec l'ananas**

3.2.1. Fermentation time and sugar reduction results

Table 8 summarizes the results of the various trials carried out.

Test n°	(pulp+bark) (g)	Yeast (g)	Duration (jrs)	Sugar content before fermentation (°Brix)	Sugar content after fermentation (°Brix)	Atténuation (%)
1	1000	50	5	12,5	3	76,00
2	1300	65	5	13,0	5	61,54
3	1500	75	5	15,0	7	53,33
4	1700	85	5	12,5	6	52,00

Remember that the reduction in sugar content after fermentation is given by the following formula: $Attenuation = \frac{E - E_a}{E} * 100$

Where:
E = sugar level in solution before fermentation;
Ea=Sugar level in solution after fermentation

The results illustrated in Table 8 show that for different initial masses of (pulp, bark) used during fermentation, we recorded a variation in attenuation from 52% to 76%, the average being 60.72%.

3.2.2. Pineapple distillation results

Several distillation trials were carried out with the must obtained from pineapple fermentation.
At the end of fermentation, we are left with pineapple juice, which must be distilled to extract the ethanol. The aim is to obtain a high-purity, ethanol-rich distillate. At the top of the column, we collected the distillate. The distillation temperature is around 78°C.
The distillation process lasts from 30 minutes to 120 minutes, from start to finish.
The time from start to racking of the first drop of pineapple alcohol is around 100 min. After racking, we have grouped the distillates obtained in Tables 9, 10, 11 and 12.
Table 9: Results obtained after distillation of the 1st pineapple test

N° jet	Duration of distillation (min)	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)
1	39	125	73
2	87	125	51
3	131	125	32
4	161	125	10

For this first trial, the quantity of ethanol obtained is 500ml, with alcoholic strength ranging from 10 to 73°.
Table 10: Results obtained after distillation of the 2nd pineapple trial

N° jet	Duration of distillation (min)	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)
1	113	125	65
2	153	125	44
3	299	125	27
4	320	125	10

For this second trial, the quantity of ethanol obtained is 500ml, with alcoholic strength ranging from 10 to 65°.
Table 11: Results obtained after distillation of the 3rd pineapple trial

N° jet	Duration of distillation (min)	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)
1	76	125	25
2	116	125	22
3	140	125	19
4	166	125	5

For this third trial, the quantity of ethanol obtained is 500ml, with alcoholic strength ranging from 5 to 25°.
Table 12: Results obtained after distillation of the 4th pineapple trial

N° jet	Duration of distillation (min)	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)
1	71	125	55
2	147	125	53
3	182	125	45
4	203	125	35

For this fourth test, the quantity of ethanol obtained is 500ml, with alcoholic strength ranging from 35 to 55°.

3.2.3. Rectification results with pineapple

Prior to rectification, we grouped the alcohol obtained from the first distillation into four groups:

- Three alcoholic degree groups: 35°GL;
- One alcoholic degree group: 15°GL

3.2.3.1. First rectification

a) First test group

Operating conditions :

- Mixture of 35° alcohol
- Initial volume of alcohol 600ml
- Boiler controller setpoint temperature 150°C
- Column head regulator setpoint 78°C

At the end of this first group of tests, we obtained the following results:

Table 13: Results obtained after rectification of the 1st group of pineapple alcohol tests

N° jet	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)	Duration (min)
1	100	74	38
2	50	69	116
3	25	45	216

The volume of ethanol obtained was 175ml, of which the first distillate (after 38 min) had an ethanol content of 45°, while the last was 74°.

b) Second test group

Operating conditions:
- Mixing of alcohol with an alcoholic strength of 35°GL
- Initial volume of alcohol 650ml
- Boiler controller setpoint temperature 150°C
- Column head regulator setpoint 78°C

Table 14: Results obtained after rectification of the 2nd group of pineapple alcohol tests

N° jet	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)	Duration (min)
1	100	80	54
2	50	73	116
3	25	61	293

For this second test group, the quantity of ethanol obtained is 175ml, with alcoholic strength ranging from 61 to 80°.

c) Third test group

Operating conditions:
- Mixture with 35° alcohol content
- Initial volume of alcohol 750ml
- Boiler controller setpoint temperature 150°C
- Column head regulator setpoint 78°C

Table 15: Results obtained after rectification of the 3rd pineapple alcohol test group

N° jet	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)	Duration (min)
1	100	86	63
2	100	76	106
3	25	63	185

For this third test group, the quantity of ethanol obtained was 225ml, with alcoholic strength ranging from 63 to 86°.

d) Fourth test group

Operating conditions:
- Mixture of alcohol of alcoholic strength 15°.
- Initial volume of alcohol 1000ml
- Boiler controller setpoint temperature 150°C
- Column head regulator setpoint 78°C

Table 16: Results obtained after rectification of the 4th pineapple alcohol test group

N° jet	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)	Duration (min)
1	100	60	133
2	25	56	151

The total volume of ethanol obtained is 125ml, with alcoholic strength ranging from 56° to 60°.

3.2.3.2. Second rectification

Operating conditions:

- Alcoholic strength 75°.
- Initial volume of alcohol 700ml
- Boiler controller setpoint temperature 150°C.
- Column head regulator temperature 78°C.

Table 17: Results obtained after 2nd pineapple rectification

N° jet	The volume of ethanol obtained (ml)	Alcoholic strength (°GL)	Duration (min)
1	100	83	37
2	100	86	55
3	100	85	76
4	100	87	100
5	50	86	136
6	50	84	175

The total volume of alcohol obtained is 500ml, with alcoholic strength ranging from 83° to 87°.

4. DISCUSSION

As a non-oil-producing country, Madagascar has opted for a policy of diversifying its energy sources. On the other hand, the country has many exploitable resources at its disposal to tackle its energy problems. Several questions arise:

- Which of these exploitable resources is the most interesting and capable of solving our energy problem, while reducing our dependence on hydrocarbons, and at the same time bringing in biomass through agrofuel?
- Is agrofuel one of the ideal solutions to the country's current energy problem?

To shed some light on these questions, we're going to answer them one by one.

4.1. First question: Which of these exploitable resources is the most interesting and capable of solving our energy problem, while reducing our dependence on hydrocarbons, by introducing biomass through agrofuel?

Madagascar has a number of resources that can be exploited for its development, such as solar energy, hydropower and biomass, including wood energy and agrofuel from various sugar and starch crops.

At present, fossil fuels such as petroleum, diesel and gasoline play a major role in the country's energy supply. This solution is not sustainable, given the instability of the price of a barrel of oil on the international market.

La solution pérenne est la valorisation de nos ressources potentielles. Parmi ces ressources, ce sont l'énergie solaire which has the greatest potential, followed by biomass, with lignocellulosic resources in first place, and agrofuels in second place after lignocellulosics. As far as solar energy is concerned, Madagascar benefits from a large solar potential of 2,000 kWh/m2 /year and 2,800 hours of sunshine per year, but the majority of the population is unable to invest in solar energy due to the high cost of the associated equipment. So this is not the solution for Madagascar. As far as lignocellulosics are concerned, this is one of the solutions, given that we have unused land, but faced with deforestation throughout the region on the one hand, and the low level of education of the majority of the population on the other, the development of this sector is among the best and most eagerly awaited, but it will take time to raise awareness among the majority of the population, and that's not going to happen tomorrow. So this is the sustainable solution.

4.2. Second question: Is agrofuel one of the ideal solutions to the energy problem currently facing the country?

In the case of agrofuel, we can say that it is also one of the most eagerly awaited solutions, especially in the case of cassava, where we have so much land available for planting. The question is: how can we develop this ethanol/bioethanol production technology to reduce our dependence on fossil fuels? Will it be developed in the form of artisanal/familial, semi-industrial or industrial operations?

Whether in artisanal or semi-industrial form, the development of ethanol/bioethanol production technology is feasible and could be the most reliable solution in the case of cassava, because given the results obtained through the various production trials, cassava can reduce our dependence on fossil fuels for the following reasons:

- firstly, its short fermentation time of around 3 days compared with other agrofuel resources;
- its sugar attenuation rate is very high compared with that of pineapple;
- From a distillation point of view, four distillation groups were obtained, with 66°GL, 51°GL, 33°GL and 19°GL respectively;
- from the rectification point of view, the alcoholic strength recorded was over 90°GL instead of 87°GL for pineapple;

CONCLUSION

At the end of this study, it is clear that the initial objective has been achieved. The comparison of ethanol production from sugar and starch crops: sustainable energy resources in bioethanol, a challenger to hydrocarbons" has been studied in all its aspects. The experimental part corresponding to the transformation of fermentable sugars present in manioc into alcohol involves enzymatic hydrolysis of the starch, followed by fermentation and ending with distillation and rectification. In the case of pineapple, a sweet plant, this experimental part is carried out in the same way, but without enzymatic hydrolysis.

This made it possible to obtain the optimum parameters for ethanol production from cassava and pineapple:

- the raw materials used are pineapple and freshly ground unpeeled cassava;
- the fermentation takes 3 days for cassava and 5 days for pineapple;
- the sugar attenuation rate for cassava is higher than for pineapple
- the quantity of yeast is the same by 5% for each resource;
- the rectification temperature must not exceed 125°C for the boiler regulator set-point temperature and 78°C for the rectification column head regulator set-point temperature respectively.

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