PRODUCTION OF ETHANOL FROM TROPICAL FRUIT JUICE PASTEURIZATION WASTE. CASE OF THE COMPANY MADAGASCAR PREMIUM EXOTICA (MPE).

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ABSTRACT

The east coast of Madagascar is an area rich in tropical fruits that are highly prized on the European market. Among these fruits, we can mention: passion fruit, soursop, guava, lychee and pineapple. Several companies are involved in the processing of these tropical fruits, including the company MPE or "Madagascar Premium Exotica" which produces tropical fruit juice and puree through pasteurization. The production of fruit juice and purée generates a lot of waste representing on average 6% to 10% of the raw fruit. The problem of BEP is the rational management of this waste.

The present research work focused on lychee and pineapple waste. Its purpose is: first, the production of bioethanol through the energy recovery of the waste from pasteurization of these fruits; second, the contribution to the solution of the BEP waste rational management problem. Bioethanol is a renewable, ecological and alternative energy source to wood energy.

The methodology adopted for the realization of this research work is both qualitative and quantitative. and requires a priori the passage through the following activities: collecting bibliographic and webographic data, going down to the BEP company level to see first-hand the reality of the waste to be treated, experimentation work in the laboratory, data analysis and processing and writing this research work.

The results of this work showed that fruit waste has a huge potential in sugars. To manage this waste rationally, the solution is the application of fermentation technology followed by distillation and then rectification in order to transform it into bioethanol. The economic feasibility study for the establishment of a waste processing distillery unit within the company is interesting with a profitability index of 1.33, i.e. the investment of 1 MGA will lead to a net profit of 0.33 MGA. In addition, the Internal Rate of Return is 28.45% which is much higher than the bank rate.

Keyword: *waste, tropical fruits, pasteurization, bioethanol, distillation.*

1. INTRODUCTION

Industrial activities generate large quantities of waste which are both a nuisance to the environment and a loss of recyclable materials.

Waste rich in organic material is a valuable product and is a new material for many industries, and is therefore referred to as secondary raw material. Their recovery by biotechnological processes represents a solution of choice insofar as it not only contributes to the elimination of environmental pollution, but also makes it possible to produce substances with high added value and bioenergy.

Madagascar Premium Exotica (MPE), a tropical fruit juice pasteurization plant, is facing a waste management problem. Indeed, the waste generated by this plant is neither systematically collected nor treated before discharge. The company does not have a specific place of deposit but the waste is deposited outside the pasteurization plant. This certainly leads to serious pollution which could tarnish the image of the company. Faced with this situation, a memorandum of understanding has been drawn up between MPE and the National Centre for Industrial Research and Technology (CNRIT) to help solve this problem.

Technological (CNRIT). It is with this in mind that we initiated this project of:

"Production of ethanol from waste from the pasteurization of tropical fruit juices".

Thus, several questions arise:

- how can we manage this waste?
- Are there appropriate methods for the ecological recovery of this waste?
- Are these methods feasible and cost-effective?

This research work attempts to answer these questions through this document.

2. METHODOLOGIES

2.1. Study area: company MADAGASCAR PREMIUM EXOTICA (MPE) Toamasina

2.1.1. Geographical location

The study area is located in the Fokontany of Analamalotra, on the road of Ivoloina RN5, 5 km from the urban municipality of Tamatave:

- district of TAMATAVE II (South Latitude: 18°5" and 11°65" South and East longitude: 49°23" and 28°81" East)
- Antsinanana region

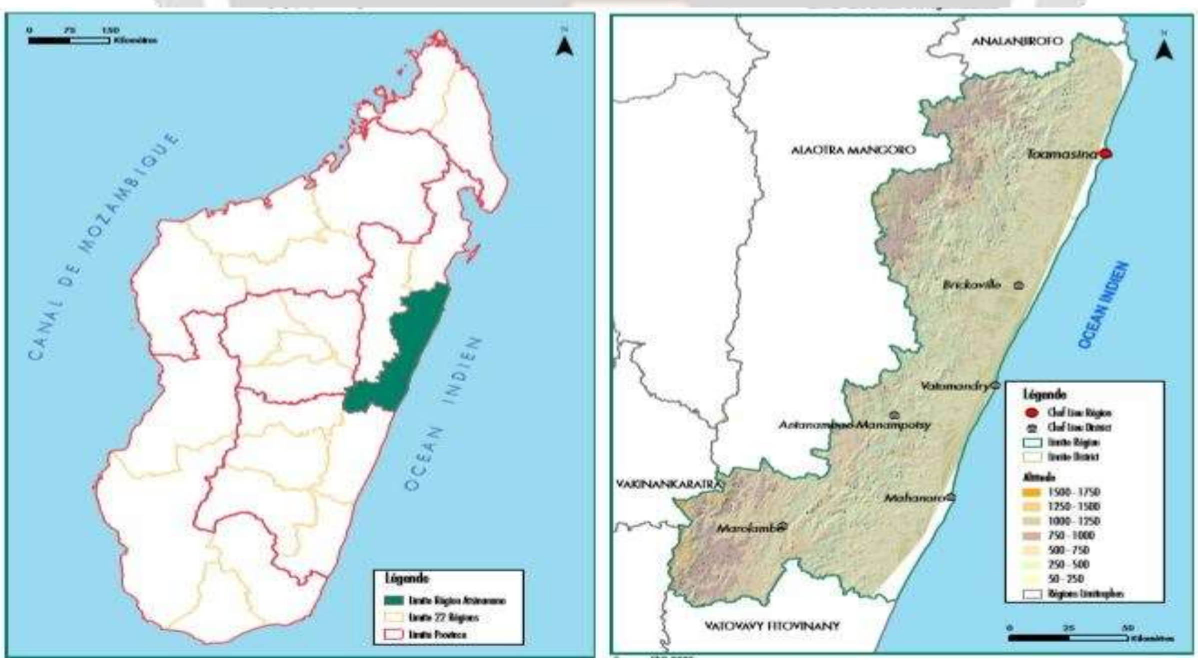

Figure 1: Localisation géographique et le relief de la région Antsinanana

2.1.2. Madagascar Premium Exotica (MPE. SA)

The company MPE or "Madagascar Premium Exotica" is an industrial company of the SCRIMAD group working for the development of the agro-food industry. The creation of the MPE allows SCRIMAD to have an activity that is now spread throughout the year through the processing and export of seasonal tropical fruit variants.

Photo 1: Présentation de la "MPE" SA

2.2. Activity and issues of BEP SA

MPE SA, is a food company that produces tropical fruit juice and purée by pasteurization. The production started in December 2015.

The production unit is currently experiencing a strong growth in demand for pasteurized juices and/or purées despite the problems with the product smelling and tasting burnt, after analysis of samples taken during production. In addition, the

MPE also suffers from a huge waste management problem.

In order to satisfy the needs of the customer, who demands a better product in quality and large quantity, the factory decided to have a study and research work carried out that allows it to have optimal parameters. It is within this framework that MPE SA requested the CNRIT through its dry researchers to intervene.

2.3. Plant production line

The manufacturing process comprises respectively:

- Washing: to remove dirt and a large part of the surface microorganisms. The water must be clean and sanitized, otherwise the result will be the opposite of what is expected.
- Sorting: to separate products in good condition from those that are defective, not ripe or showing signs of rot.
- peeling: to remove the peel or shell of the fruit
- pitting: to separate the cores from the pulp
- refining: passing through an apparatus for separating the juice to be pasteurized
- Pasteurization: passing through two series of tubular heat exchangers to pasteurize the juice.

2.4. Laboratory work

In parallel with the treatment of waste from the Tamatave plant, simulation research with local waste was carried out at the CNRIT laboratory.

Bioethanol production

The transformation into ethanol is the method considered adequate to valorize the fruit waste from the MPE SA pasteurization plant.

This process can be achieved by fermentation in an anaerobic environment to convert sugar into ethanol, followed by distillation and rectification.

The diagram below shows the different steps of ethanol production.

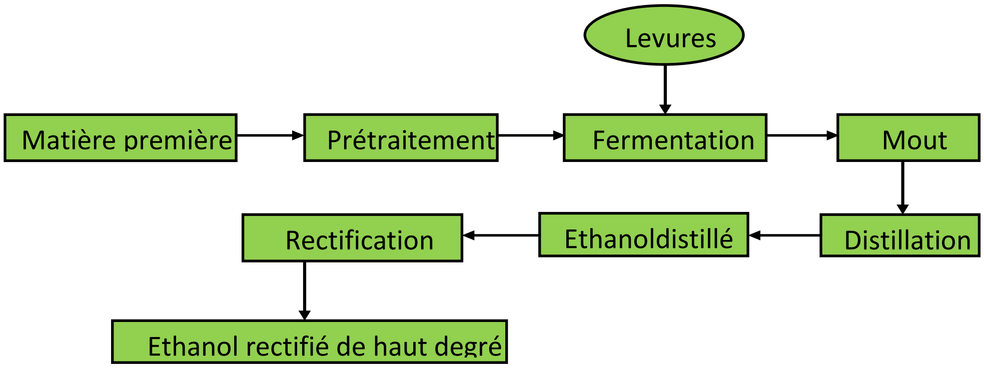

Figure 2: Ethanol Manufacturing Flow Chart

2.4.1. Fermentation

Principle

Fermentation is the transformation of glucose into ethanol. To do this, the addition of yeast to the mixture is necessary. The duration of fermentation is about one week [19]. The alcoholic fermentation must be in an anaerobic environment, a temperature between 15°C and 35°C. The anaerobic environment allows the yeast to change the glucose into ethanol.

Procedure

a) Litchi

Before the fermentation process, the lychee fruit waste must go through pre-treatments such as washing, stoning and grinding. And after measuring the brix degree, the amount of yeast required for fermentation will be poured into the mixture.

b) Pineapple

After weighing, the collected waste was rinsed and then cut and crushed in a blender to obtain an almost homogeneous mixture whose brix degree is measured. The mixture thus formed will be introduced into the fermentation vat after the addition of previously dosed yeast.

Fermentation was carried out according to the procedure described in the following photos.

Parameters to be controlled

The main parameters whose evolution has to be followed and controlled are:

The brix degree before and after the fermentation. This parameter is measured with a refractometer.

The attenuation of the sugar level after fermentation, given by the following formula

$$Attenuation = \frac{E - E_a}{E} * 100$$

Where: E = Sugar content of the solution before fermentation;

Ea=Sugar rate in solution after fermentation.

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

2.4.2. Distillation

Distillation is an operation to separate ethanol from water by the difference in their boiling temperatures.

Procedure for distillation

- Prepare the distiller;
- Filter the must;
- Load the filtered wort into the boiler;
- Close the distiller and plug in the socket (assembly); Collect the distillate.

Preparing for distillation

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

- Filter the fermented wort to get rid of solid debris and thus obtain a more fluid solution.
- Start the distillation, monitor the temperature, recover the distillate.

2.4.3. Rectification

Rectification or fractional distillation is a process of purification of a solution of low alcoholic degree, making it possible to obtain an alcohol of high degree.

The operation must be carried out at a well-controlled temperature because the boiling temperature of water is 100°C and that of ethanol is 78°C.

Principle of operation

The alcohol obtained from the first distillation will be introduced into the rectifier's boiler and heated by the electrical resistance. The vapor thus formed passes through the column lined with structured material (tray). The temperature drops as it rises in the column. The vapor consisting of the least volatile component (water) cools and condenses on the trays of the column and falls back into the boiler. The vapor rich in the most volatile component (alcohol) continues to rise in the distillation column, then passes through the piping (vapor circuit) and passes through the condenser to give distilled liquid alcohol.

Procedure for distillation

Collect the alcohols from the distillation and measure the alcoholic strength of the resulting mixture.

Load the mixture into the boiler of the rectifier.

Start rectification after connecting the cooling system.

Collect samples of distillates during the rectification operation and measure and record each corresponding alcoholic strength.

3. RESULTS

This chapter presents all the experimental results obtained.

3.1 Fermentation results

Fermentation takes place in a non-renewed environment. MAATALLAH (1970) suggests 7 days for total fermentation, while BOUGHNOU (1988) suggests 3 to 4 days. In our case, we opted for a fermentation period of 5 days.

Several tests were carried out in the laboratory. The following tables summarize the results of these experiments.

Table 1: Fermentation of lychee trials

Trial No.	Waste pulp + juice (g)	Yeast (g)	Time (days)	Sugar level bifore fermentation (°Brix)	Sugar level after fermentation (°Brix)	Attenuation (%)
1	250	12,5	5	17	5	70,59
2	500	25,0	5	17	6	64,71
3	750	37,5	5	18	7	61,11
4	1000	50,0	5	19	5	73,68

Table 2: Pineapple Trial Fermentation

Trial No.	Waste pulp+bark (g)	Yeast (g)	Time (days)	Sugar level before fermentation (°Brix)	Sugar level after fermentation (°Brix)	Attenuation (%)
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

Taking into account the formula on mitigation, the results shown in the tables above show that on different initial masses of waste used in fermentation, the following was recorded:

- For lychee, a variation in attenuation from 61.11% to 73.68% with an average of 67.52%.
- For pineapple, a variation in attenuation from 52% to 76% with an average of 60.72%.

3.2. Results of distillation

Several distillation trials were developed with the must from the fermentation of the two types of waste studied.
At the end of fermentation, we will be in the presence of a pineapple or lychee juice, which must be distilled in order to extract the ethanol. The aim is therefore to have a distillate rich in ethanol and of high purity. At the top of the column, we collected the distillate. The distillation temperature is around 78°C.
The beginning of the operation until the withdrawal of the first drop lasts between 30mn to 120min.

a) LITCHI

The tables below show the quantities of ethanol obtained from each distillate stream and their distillation time, which made it possible to determine the alcoholic strength.

Table 3: Results obtained after distillation of the first lychee test

Jet No.	Distillation time (min)	The volume of ethanol obtained (ml)	The alcoholic degree (°GL)
1	32	125	72
2	38	125	60
3	66	125	53
4	124	125	40

For this first test, the quantity of ethanol obtained is 500ml whose alcoholic degree varies from 40° to 72°.

Table 4: Results obtained after distillation of the 2nd lychee test

Jet No.	Distillation time (min)	volume of ethanol obtained (ml)	Alcoholic degree (°GL)
1	45	125	75
2	72	125	63
3	82	125	54
4	128	125	45

For this second test, the quantity of ethanol obtained is 500ml with an alcohol content ranging from 45° to 75°.

Table 5: Results obtained after distillation of the third lychee test

Jet No.	Distillation time (min)	volume of ethanol obtained (ml)	Alcoholic degree (°GL)
1	55	125	53
2	87	125	25
3	116	125	10
4	174	125	4

For this third test, the quantity of ethanol obtained is 500ml with an alcohol content ranging from 4 to 53°.

Table 6: Results obtained after distillation of the fourth lychee test

Jet No.	Distillation time (min)	volume of ethanol obtained (ml)	Alcoholic degree (°GL)
1	29	125	69
2	48	125	51
3	75	125	31
4	124	125	16

For this fourth test, the quantity of ethanol obtained is 500ml with an alcohol content ranging from 16 to 69°.

b) PINEAPPLE

The beginning of the operation until the first drop of pineapple alcohol is drawn off takes about 100 minutes. After racking, we were able to group the distillates obtained in the tables below.

Table 7: Results obtained after distillation of the first pineapple test

Jet No.	Distillation time (min)	volume of ethanol obtained (ml)	Alcoholic degree (°GL)
1	39	125	73
2	87	125	51
3	131	125	32
4	161	125	10

For this first test, the quantity of ethanol obtained is 500ml with an alcohol content ranging from 10 to 73°.

Table 8: Results obtained after distillation of the second pineapple test

Jet No.	Distillation time (min)	volume of ethanol obtained (ml)	Alcoholic degree (°GL)
1	113	125	65
2	153	125	44
3	299	125	27
4	320	125	10

For this second test, the quantity of ethanol obtained is 500ml with an alcohol content ranging from 10 to 65°.

Table 9: Results obtained after distillation of the third test on pineapple

Jet No.	Distillation time (min)	volume of ethanol obtained (ml)	Alcoholic degree (°GL)
1	76	125	25
2	116	125	22
3	140	125	19
4	166	125	5

For this third test, the quantity of ethanol obtained is 500ml with an alcohol content ranging from 5 to 25°.

Table 10: Results obtained after distillation of the fourth test of pineapple

Jet No.	Distillation time (min)	volume of ethanol obtained (ml)	Alcoholic degree (°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 an alcohol content ranging from 35 to 55°.

3.3. Results of the rectification

In order to achieve a better result, the rectification of the alcohols obtained by distillation was carried out in two stages and by grouping alcohols of similar degree.

a) LITCHI

3.3.1. First rectification

a) First test group

Operating conditions

- Alcoholic degree 50°.
- Initial volume of alcohol 1000ml
- Setpoint temperature of the boiler controller 150°C
- Set-point temperature of the column head controller 78°C

Table 11: Results obtained after rectification of the first test group of lychee alcohol

Jet No.	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)	Time (min)
1	100	84	40
2	100	84	75
3	100	84	100
4	100	82	137
5	50	79	190

- For this rectification, a volume of ethanol of 450ml was obtained with an alcohol content ranging from 79 to 84°.

b) Second test group
Operating conditions:
- Alcoholic degree 15°.
- Initial volume of alcohol 1000ml
- Set point temperature of the boiler controller 150°C
- Set-point temperature of the column head controller 78°C

Table 12: Results obtained after rectification of the first test group of lychee alcohol

Jet No.	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)	Time (min)
1	100	77	56
2	25	50	194

The volume of ethanol obtained is 125ml with an alcohol content ranging from 50 to 77°.

3.3.2. Second rectification
Operating conditions:
- Alcoholic degree 80°.
- Initial volume of alcohol 575ml
- Set point temperature of the boiler controller 150°C
- Set-point temperature of the column head controller 78°C

Table 13: Results obtained after the 2nd lychee grinding

Jet No.	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)
1	100	89
2	100	88
3	100	84
4	100	83

The second rectification resulted in 575ml of high ethanol from 83 to 89°.

b) PINEAPPLE

Before the rectification, we gathered the alcohol obtained by the first distillation in four groups of which:
Three groups of alcoholic degree: 35°;
One group of alcoholic degree: 15°.

3.3.3. First rectification
a) First test group
Operating conditions
- Mixture of alcohol of alcoholic strength 35°.
- Initial volume of alcohol 600ml
- Set point temperature of the boiler controller 150°C
- Set-point temperature of the column head controller 78°C

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

Table 14: Results obtained after rectification of the first test group of pineapple alcohol.

Jet No.	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)	Time (min)
1	100	74	38
2	50	69	116

3	25	45	216

The volume of ethanol obtained is 175ml of which the first distillate (after 38mn) had an ethanol degree of 45° while the last one was at 74°.

b) Second test group

Operating conditions:

- Mixture of alcohol of alcoholic degree 35°.
- Initial volume of alcohol 650ml
- Set point temperature of the boiler controller 150°C
- Set-point temperature of the column head controller 78°C

Table 15: Results obtained after rectification of the 2nd pineapple alcohol test group

Jet No.	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)	Time (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 an alcohol content ranging from 61 to 80°.

c) Third test group

Operating conditions:

- Mixture of alcoholic degree 35°.
- Initial volume of alcohol 750ml
- Set point temperature of the boiler controller 150°C
- Set-point temperature of the column head controller 78°C

Table 16: Results obtained after rectification of the 3rd pineapple alcohol test group

Jet No	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)	Time (min)
1	100	86	63
2	100	76	106
3	25	63	185

For this third test group, the quantity of ethanol obtained is 225ml with an alcohol content ranging from 63 to 86°.

d) Fourth test group

Operating conditions:

- Mixture of alcohol of alcoholic degree 15°.
- Initial volume of alcohol 1000ml
- Set point temperature of the boiler controller 150°C
- Set-point temperature of the column head controller 78°C

Table 17: Results obtained after rectification of the 4th pineapple alcohol test group

Jet No	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)	Time (min)
1	*100*	*60*	*133*
2	25	56	151

The total volume of ethanol obtained is 125ml with an alcohol content ranging from 56° to 60°.

3.3.4. Second rectification

Operating conditions:

- Alcoholic degree 75°.
- Initial volume of alcohol 700ml
- Set point temperature of the boiler controller 150°C
- Set point temperature of the column head controller 78°C.

Table 18: Results after the 2nd pineapple grinding process

Jet No	Volume of ethanol obtained (ml)	Alcoholic degree (°GL)	Time (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 whose alcoholic degree varies from 83° to 87°.

4. DISCUSSION

The management of industrial waste is a crucial problem in Madagascar. The virtual absence of treatment units and/or landfill sites to recover or dispose of waste leads to problems of insalubrity, vector of various forms of diseases such as plague, diarrhea, cholera. The "MPE" tropical fruit pasteurization plant is facing this problem. The plant generates a quantity of fruit waste of about 6 to 10% of the total incoming flow, a large part of which can be valorized into ethanol. For the present study, the research work focused on two types of waste, namely lychee and pineapple.

The research work carried out in the laboratory following the three stages of ethanol production led to the following results:

Fermentation revealed that in the different experiments developed, the attenuation for lychee (67.52%) is better than for pineapple (60.72%). This suggests that the transformation of lychee waste into ethanol is interesting.

It should be remembered that after an initial distillation, the alcohols obtained from lychee and pineapple are rectified.

After rectification, maximum respective alcoholic degrees of 89°GL for lychee and 87°GL for pineapple were obtained. This confirms that both types of waste are a better source of ethyl alcohol production.

The recovery of these wastes through biotechnological processes such as the manufacture of ethanol is an appropriate solution insofar as it reduces environmental pollution and also contributes to the industrial and agricultural development of the country. Indeed, ethanol is a marketable product with high added value, highly coveted on both the national and international markets. High-grade ethanol is used in several industrial sectors, including pharmaceuticals, cosmetics (deodorant, perfume) and chemicals (solvent).

5. CONCLUSION

At the end of this study, it must be admitted that we were able to contribute to the waste management problem of the "Madagascar Premium Exotica" tropical fruit pasteurization plant.

The study confirms that most of the waste generated by the plant is still recoverable. Indeed, the waste collected at the stoner and more particularly at the refiner consists of fresh juice and pulp with a high sugar content. Thus, the rational management method for this waste is fermentation followed by distillation and then rectification in order to transform it into ethanol.

The application of this recovery technique with lychee and pineapple waste has led to satisfactory results.

Indeed, the economic feasibility study for this project, consisting of the setting up of a waste-processing distillery unit within the company, revealed the following results:

- a Net Present Value (NPV) of MGA 77374797 which is positive;
- an Internal Rate of Return (IRR) of 28.45%, which is significantly higher than the bank loan rate;
- a positive profitability index of 1.33, showing that the investment of MGA 1 million in this project will bring a profit of MGA 0.33 million.

These economic criteria show that this chosen valuation technique is not only profitable but also feasible. It is a flexible technique, easy to implement and does not require huge investment costs.

There are certainly other forms of waste in society that cannot be transformed into ethanol, such as bark, cores, stems, etc. Composting would be one of the appropriate transformation methods for the recovery of this waste.

This offers the company the possibility to supply organic fertilizer to the farmers who supply it and thus to produce organic fruit in large quantities and of good quality in the future..

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