

# Development of a Distilling Machine

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## ABSTRACT

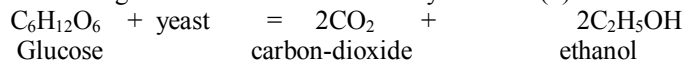
The study focus on the design and development of a distilling machine for producing alcoholic beverages. The materials required were locally sources for and selected appropriately. Design analysis and calculation to determine the volume of the boiling chamber, strength of the boiler, volume of the refrigeration or cooling compartment, pipe strength, volume of the heating compartment, and total Dimension of the Machines were all carried out. The machine was tested using gas and electricity as a means of heating the fermented palm wine. Results shows that when gas was used, it takes about 60minutes to completely distill the fermented palm wine while it takes a longer period of 152 minutes to boil 4liters of the fermented palm wine when electricity was used. Also, the capacity when gas was used to boil the fermented palm wine was 0.067 l/min compared to that of electricity which was 0.026 l/min/. This shows that the distilling capacity of the machine when gas was used was greater than that when electricity was used, thus making the gas a more reliable choice for distillation to electricity.

**Keywords:** *Distil, Machine, Ferment, Alcoholic, Beverages*

## INTRODUCTION

The invention of a distilling machine is directed towards the art of converting fermented palm wine, orange juice, pineapple juice into gin or wine, whiskey, beer, brandy, e.t.c. Distillation is a unit operation or a physical separation process and not a chemical reaction process. Fermented pineapple, oranges, grapes, palm wine are distilled to alcohol, that is, either whiskey, rum, brandy, gin, e.t.c. Gin is liquor which derives its predominant flavour from juniper berries (*juniperus communis*).

Dues to evolution, gin can be broadly differentiated into three basic styles, that is, pot distilled gin, column distilled gin and compound gin. The word alcoholic beverages covers an extremely wide range of products from wines and beer to whiskies, rum, brandy, gin, liqueurs, e.t.c. and a very wide starting materials, from grapes to potatoes to milk. The common denominator which ties all of them together is the alcohol itself, a pure chemical with the empirical formula  $C_2H_5OH$ . All alcoholic beverages are made by fermenting a sugar solution with yeast, a process which converts the sugar to carbon dioxide and ethyl alcohol (2).



The aim is of this study is to develop a distilling machine for producing alcoholic beverages with the following objectives

- ❖ Design and fabricate a low cost distilling machine for alcohol using a locally sourced materials
- ❖ Conversion of likely waste products/materials to useful ones.
- ❖ Evaluate the machine using gas and electricity as a means of heating the fermented palm wine
- ❖ Test the machine functionality and efficiency.

## LITERATURE REVIEW

The two ingredients necessary for alcoholic fermentation are widely spread and always appear together, civilizations in almost every part of the world developed some form of alcoholic beverage very early in their history. The Chinese were distilling a beverage from rice beer by 800BCE. The Arabs developed a distillation method that was used to produce a distilled beverage from wine. Greek philosophers reported a crude distillation method. The Romans apparently produced distilled beverages, although no references concerning them are found in writings before 100BCE. The Roman, Spain, France as well as the Western Europe produced distilled spirit at an earlier date.

Some government control dates from the 17th century. As production methods improved and volume increased, the distilled spirits industry became an important source of revenue. Rigid controls were often imposed on both production and sale of the liquor.

The earliest stills were composed simply of a heated closed container, a condenser, and a receptacle to receive the condensate. These evolved into the pot still, which is still in use, particularly for making malt whiskeys and some gins. The next refinement was heating the alcohol-containing liquid in a column made up of a series of vaporization chambers stacked on top of one another. In 1831 the Irishman Aeneas Coffey designed such a still, which consisted of two columns in series.

Since distillation requires that the liquid portion of a fermentation mixture be vaporized, considerable heat must be applied to the process. The fuel used in distilling spirits has always been that which has been most readily available at the particular time and place. Peat, coal, and wood were the fuels used historically, while the fuels of choice today are coal, natural gas, and oil. The high steam requirement for continuous-still operation inhibited the development of rectifying columns for production of spirits until after the Industrial Revolution.

Many of the minor components of distilled spirits, which are present only in parts per million, are detectable by the senses of taste and smell, but efforts to identify and quantify these compounds chemically have often been hampered by the lower limits of detection by analytical methods. Classes of compounds such as aldehydes, organic acids, esters, and alcohols were easily identified by conventional methods, but many of them could not be determined until after the development of chromatography. The Russian botanist Mikhail Tsvet was an early pioneer of this measurement technique, reporting his first work in 1903. Refinements in both technique and equipment, made during the first half of the 20th century, allowed numerous flavour components in distilled spirits to be identified by gas chromatography (3)

Usually one does not start with a pure sugar but with fruit juices for wine, the starch in grains for beer and whiskey, the starch in grain or potatoes for vodka, molasses for rum e.t.c .(4).

In addition to the variations imposed by the source of sugar, the particular strain of yeast and the conditions under which it is used(temperature), nutrients e.t.c also make their contribution to the character of the final production. This is because yeast produce other substances in addition to the main product – ethyl alcohol.

Yeast is a vegetative microorganism that lives and multiplies in media containing carbohydrates—particularly simple sugars.

The principle of alcoholic distillation is based upon the different boiling points of alcohol (78.5 °C, or 173.3 °F) and water (100 °C, or 212 °F). If a liquid containing ethyl alcohol is heated to a temperature above 78.5 °C but below 100 °C and the vapour coming off the liquid is condensed, the condensate will have a higher alcohol concentration, or strength (5).

The raw materials used for making a distilled spirit are of two basic types: (1) those containing a high concentration of natural sugars or (2) those containing other carbohydrates that can easily be converted to sugars by enzymes. Enzymes are proteins that act as catalysts to promote chemical reactions. Very small amounts of enzyme can cause a fundamental change in a large amount of material. Most enzymes are specific in their action, so that a system of several enzymes is necessary, for example to convert starch into sugar and ultimately into ethyl alcohol.

### **Fermentation**

As mentioned above, yeasts are found throughout the world; more than 8,000 strains of this vegetative microorganism have been classified. Approximately nine or 10 pure strains, with their sub-classifications, are used for fermentation of grain mashes; these all belong to the type *Saccharomyces cerevisiae* (6).

In grain-based products, yeast cells are grown in grain mixtures. The preparation of a cooked mash of rye and barley malt is most common. The mash is sterilized, then inoculated with lactic-acid bacteria to increase acidity. (Yeast is

more tolerant of higher acidity than many commonly occurring bacteria.) When the desired acidity is reached, the mixture is again sterilized and a pure yeast culture is added. In liquid fermentation, as from fruits and sugarcane, the yeast is generally grown in a mixture similar to the one it will be used to ferment; for example, a yeast culture to be used for molasses fermentation is usually grown in molasses.

### Fermenting Methods

In the fermentation process, simple sugars, including dextrose and maltose, are converted to ethyl alcohol by the action of yeast enzymes. Several intermediate compounds are formed during this complex chemical process before the final ethyl alcohol is obtained.

Yeast functions best in a slightly acid medium, and the prepared grain mash, fruit juice, molasses, or other mixture must be checked for adequate acidity (pH value). If acidity is insufficient, acid or acid-bearing material is added to achieve the necessary adjustment. The previously prepared yeast is then added, and final dilution of the mixture is made.

Commercial fermentation is carried on in large vats. Most plants now use closed stainless steel vats for easier cleaning, and many are equipped with jackets or cooling coils for better temperature control. The time required for completion of fermentation is mainly dependent upon the temperature of the fermenting mash. Normal yeast is most effective in breaking down all of the fermentable sugars at temperatures ranging from 24 to 29 °C (75 to 85 °F), and, in this range, completion of fermentation requires from 48 to 96 hours. Fermentation at lower temperatures requires longer periods. When the fermentation is concluded, then the mash is ready for distillation. If fermentation is allowed to continue past this period, it will be adversely affected by bacterial action. The ethyl alcohol content will be reduced, and the flavour and aroma of the finished product will be tainted (7).

## DESIGN ANALYSIS AND CALCULATIONS

### Determination of the Volume of the boiling chamber

The boiling chamber is where the fermented materials to be distilled is. It is cylindrical in shape.

The volume of the cylinder

$$\text{Volume} = \pi r^2 h \quad (1)$$

$$\text{Diameter}(D) = \frac{r}{2} \quad (2)$$

From equation 1

$$\pi = 3.142$$

$$\text{Diameter}(D) = 254\text{mm} = 0.254\text{m}$$

$$\text{Radius}(r) = 127\text{mm} = 0.127\text{m}$$

$$\text{Height}(H) = 482\text{mm} = 0.482\text{m}$$

$$\text{Volume} = 3.142 \times 0.127^2 \times 0.482$$

$$\text{Therefore Volume} = 0.0244\text{m}^3$$

From minimum plate thickness for boiler table, we have that for boiler diameter over 1.8m its thickness is 12mm, that is 0.012m.

Therefore the boiler thickness  $t = 0.012\text{m}$

### Determination of the Strength of the Boiler

For thin cylindrical shell

$$\sigma = \frac{pd}{2t} \quad (3)$$

From equation (3)

$$\text{stress}(\sigma) = \frac{pd}{2t}$$

Diameter (d) = 254mm = 0.254m

Thickness (t) = 50mm = 0.05m

$$\text{Pressure (p)} = \rho gh \quad (4)$$

Where

Density of the liquid ( $\rho$ ) =  $98 \times 10^5 \text{ Kg/m}^3$

Acceleration due to gravity (g) =  $9.81 \text{ m/s}^2$

Height of the boiler (H) = 482mm = 0.482m

From equation (4)

$$\text{Pressure} = 98 \times 10^5 \text{ Kg/m}^3 \times 9.81 \text{ m/s}^2 \times 0.482 \text{ m}$$

Therefore, pressure =  $463.385 \times 10^5 \text{ N/m}^2$

$$\begin{aligned} \text{Stress}(\sigma) &= \frac{46338500 \times 0.254}{2 \times 0.05} \\ &= 117.700 \text{ KN/m}^2 \end{aligned}$$

#### Determination of the Volume of the Refrigeration or Cooling Compartment

The refrigerator/cooling compartment is of the shape of a cuboids

$$\text{External volume of the cuboids} = \text{Length} \times \text{Breath} \times \text{Height} \quad (5)$$

Where

External length  $L_e = 40 \text{ m}$

External breath  $B_e = 42 \text{ m}$

External height  $H_e = 44 \text{ m}$

Therefore External volume  $V = 40 \times 42 \times 44$

Volume =  $73.920 \text{ km}^3$

The thickness of the refrigerator (t) = 4m

For internal dimension of the refrigerator

Note that

Internal height  $H_i = \text{External height } H_e$

But

Internal Length  $L_i = \text{External Length} - 2 \times \text{thickness}$

That is.  $L_i = L_e - 2(4)$

$$L_i = 40 - 8 = 32 \text{ m}$$

Internal Breath  $B_i = \text{External breath} - 2 \times \text{thickness}$

That is.  $B_i = B_e - 2(4)$

$$= 42 - 8 = 34 \text{ m}$$

Now, the internal volume of the refrigerator is

$$V_i = L_i \times B_i \times H_i$$

$$= 32 \times 34 \times 44$$

Therefore Volume =  $47.872 \text{ km}^3$

#### Determination of Pipe Strength

The thickness of pipe can be determined using maximum internal pressure for the design calculated, using Barlow's formula.

$$\sigma = \frac{pd}{2t} \quad (6)$$

Where

t = thickness of the pipe

p = internal pressure in the pipe in Kpa

$\sigma$  = allowable design stress in N/m<sup>2</sup>

d = diameter of the pipe in mm.

Given

$$P = 463.385 \times 10^5 \text{ N/m}^2$$

$$d = 25 \text{ mm} = 0.025 \text{ m}$$

$$t = 2 \text{ mm} = 0.002 \text{ m}$$

$$\text{Therefore, } \sigma = \frac{463.385 \times 0.025}{2 \times 0.002} \\ = 2896.152 \text{ N/m}^2$$

#### Determination of the Volume of the Heating Compartment

The heating compartment of a cuboids in shape.

Volume = Length x Breath x Height

Where

Length L=50m

Breath B=45m

Height H =44m

Therefore,

$$\text{Volume} = 50 \times 45 \times 44 = 99 \text{ Km}^3$$

#### Determination of the Total Dimension of the Machines

Total breath ( $B_T$ ) =  $B_h + B_c$

Total Height ( $H_T$ ) =  $H_h + H_c$

Total Length ( $L_T$ ) =  $L_h + L_c$

Where

$B_T$  = Total breath of machine

$B_h$  = Breath of the heating compartment

$B_c$  = Breath of the cooling compartment

$H_T$  = Total height of the machine

$H_h$  = Height of the heating compartment

$H_c$  = Height of the cooling compartment

$L_T$  = Total length of the machine

$L_h$  = Length of the heating compartment

$L_c$  = Length of the cooling compartment

Therefore

$$B_T = 45 + 42 = 87 \text{ m}$$

$$H_T = 44 + 44 = 88 \text{ m}$$

$$L_T = 50 + 40 = 90 \text{ m}$$

#### The Electric Heater

The electric heater used in this system is rated 1000Watt, the 50/60 Hz and 220 – 240V, the decision was to buy an electric heater rather than fabricating one. It has all the properties of a standard heater.

#### The Gas Heater

The gas heater was also bought rather than fabricated. A 3Kg gas cylinder was bought for this purpose.

**RESULTS AND DISCUSSION**

**Performance Evaluation**

The result obtained when machine was run manually, that is using gas to heat fermented materials (palm wine) are shown in the table below

Note: When palm wine is used, two stages of distillation will be carried out.

Table 1 Test result for the first distillation obtained when gas was used to heat fermented palm wine;

Test	Quantity of fermented Raw materials (liters)	Time taken for distilling (min)	Quantity of distilled alcohol (ml)
	1	15	18.75
	2	28	37.50
	3	43	56.25
	4	60	75

From table 1

The average time taken for distilling fermented palm wine is given as  
 $= \frac{15+28+43+60}{4} = 36.5\text{min}$ . The average quantity of distilled alcohol is

alcohol is given as  $= \frac{18.75+37.50+56.25+75}{4} = 46.875\text{ml}$

The distilling capacity of the machine = Total quantity of fermented material divided by the time taken to distill the material. The total fermented palm wine distilled is 5Kg. The total time taken to distill the material 50min.

The distilling capacity of the machine =  $4/60 = 0.067 \text{ l/min}$

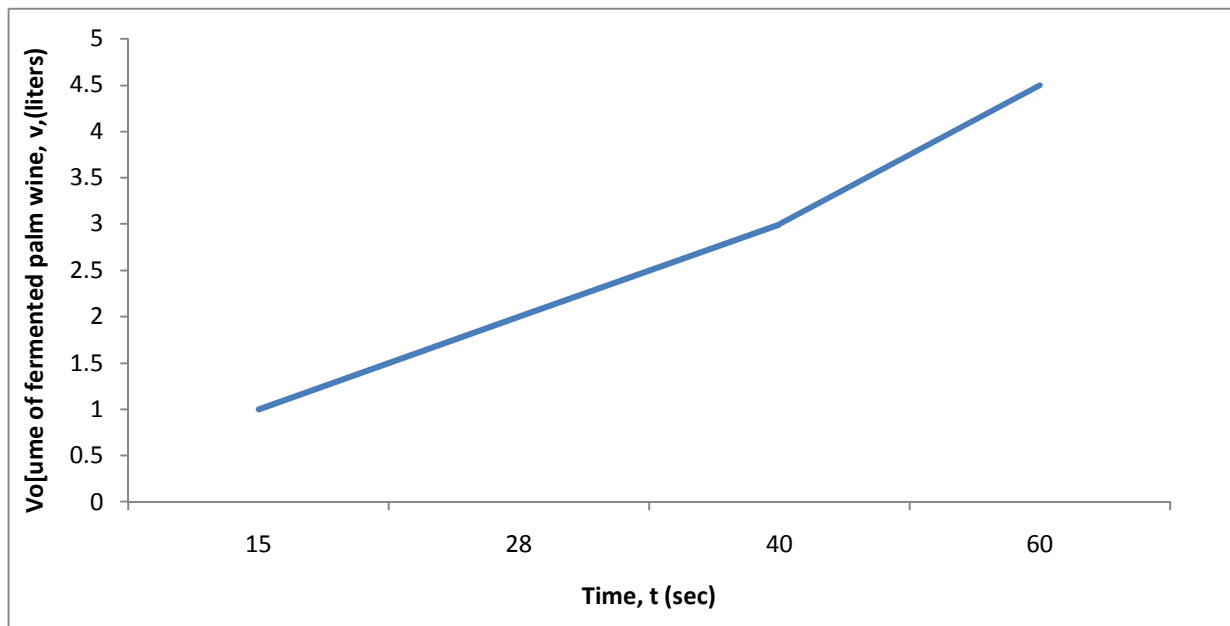


Fig 1 volume of fermented palm wine against time

The result obtained when the machine was run electrically, that is , using electricity to heat the fermented material (palm wine) is shown on the table below:

Table 2: Result for the first distillation test when electricity was used to heat fermented palm wine

Test	Quantity of fermented palm wine (liters)	Time taken for redistilling (min)	Quantity of distilled alcohol (ml)
	1	37.5	18.75
	2	72.0	37.50
	3	112.5	56.25
	4	152.0	75

From table 2

The average time taken for the first distillation of fermented palm wine is gotten as =  $\frac{37.5+72.0+112.5+152.0}{4} = \frac{374}{4}$   
 =93.5min

The average quantity of distilled alcohol is given as  $= \frac{18.75+37.50+56.25+75}{4} = \frac{187.5}{4}$   
 =46.875ml

The distilling capacity of the machine = Total quantity of fermented material distilled divided by the total time taken to distill the materials. The total fermented palm wine distilled 4 litres and the total time taken to distill the material 152 minutes.

Therefore, the distilling capacity of the machine =  $\frac{4}{152} = 0.026$  l/min

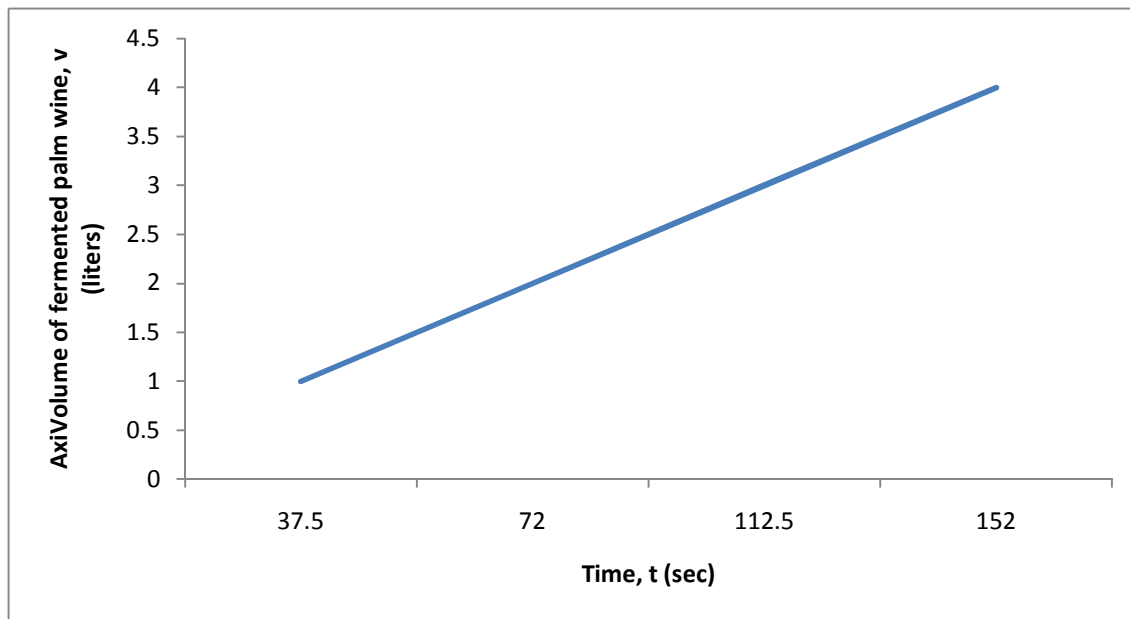


Fig 2 Volume of fermented palm wine against time

Table 3: Comparison of gas and electricity work

	Average time (min)	Distilling capacity(l/min)
Gas work	37.50	0.067
Electricity work	93.75	0.026

**DISCUSSION**

From the result, it can be inferred that it takes about 60minutes to completely distill the fermented palm wine while it takes a longer period of 152 minutes to boil 4liters of the fermented palm wine when electricity was used.

Also, the capacity when gas was used to boil the fermented palm wine was 0.067 l/min compared to that of electricity which was 0.026 l/min/. This shows that the distilling capacity of the machine when gas was used was greater than that when electricity was used, thus making the gas a more reliable choice for distillation to electricity.

**CONCLUSION**

A distilling machine has been designed constructed and tested. The testing of the distilling machine was carried out by feeding 4litres of fermented palm wine into the boiling chamber to determine the capacity of the distilling machine when gas and electricity was separately used to heat the machine.

After testing the distilling machine calculated capacity for gas was 0.067 l/min and that of electricity was 0.026 l/min.

The machine is very unique because it converts wasted material to useful product, so the machine can be term “waste to wealth” study.

**RECOMMENDATION**

The following recommendations are suggested for the improvement of this distilling machine:

1. A timer can be added to machine to automatically stop it after distilling the required contents
2. Solar power can be added to provide constant electricity for reliability.

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