COMPARATIVE STUDY OF OIL RECOVERY IMPROVEMENT BY STERILIZATION PROCESS USING FIREWOOD AND ELECTRICITY

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ABSTRACT

This study presents a palm fruits sterilization unit that was designed for firewood and electricity independently as sources of energy and its performance was evaluated. 2kg of palm fruit at 100 °C for 30, 45, 60, 75, 90, 105 and 120 minutes using steam generated from electricity was evaluated. The yield of the palm fruits was also evaluated at 100 °C for 30, 45, 60, 75, 90, 105 and 120 minutes using firewood to cook palm fruits directly in water. Further laboratory experiment was conducted to investigate the quality of oil obtained from fresh palm fruits cooked with steam and fresh palm fruits cooked in water. The maximum oil fluid recovery percentage at 100 °C for 120 minutes sterilization time using electricity energy source and firewood energy source were 27.1 and 26.0 % respectively. The experimental result shows that at 100 °C and 90 minutes of sterilization using firewood and electricity, oil released from the digested fibre accounted for 46 % (111.33 g) and 54 % (130.5 g) of the total oil content respectively. The free fatty acid ,content peroxide value and moisture content of the oil sample cooked with steam and in water at 100 °C for 90 minutes were 3.9 %, 8.5 (O_2/kg), 0.11 % and 4.4 %, 10.3 (O_2/kg), 5.5 % respectively. The boiler efficiency of 99.5% was achieved for the unit.

Keywords: *Palm fruit, sterilization, oil recovery, boiler, firewood, electricity.*

1. INTRODUCTION

The oil palm is a common crop that has economic value in West Africa. It has a major position in the agriculture and economy of the nations where it is discovered, and is describable as the prince of the plant kingdom. Humans used oil palm up to 5000 years. Back in the early 1800s, archeologists found a substance that was initially thought to be palm oil in a Abydos tomb dating back to 3000 BCE [1]. Traders are thought to have brought the oil palm to Egypt [2]. Palm oil and palm kernel oil have a wide range of applications in which nearly 80% of the palm oil produced finds its way into food products, while the rest are feed stock for a number of non-food applications [3].

Although palm oil production technology has progressed in latest years with fresh technological innovation to yield superior quality palm oil and palm kernel oil, study results showed that 80 percent of Nigeria's oil palm sector still survives with very few

large estate plantations, costly and unaffordable by most farmers, thus making the traditional technique predominant.

Traditionally, the harvested bunches of palm fruit are heaped and fermented to enhance fast fruit stripping. The picked fruits are collected and digested into a mash, mixed with water and agitated in a pit to separate the oil from the mixture. Once the oil has been properly mixed, floats are picked off for clarification. In addition to the waste of drudgery time and high labor requirements in this technique, it gives poor quality oil as the fermentation period increases the free fatty acid (FFA) content of the oil [1]. According to [4], fruit processing without delay or fermentation yielded the maximum oil extraction of 87 % and best quality oil with free fatty acid (FFA) of 2.31 %. It is therefore essential to process fresh fruit bunches as quickly as possible in order to avoid a fast increase in free fatty acid that usually affects palm oil quality. Sterilization (cooking) of fresh fruit bunches

(FFB) is the first heat treatment in processing of palm oil. Heat permeates the fruits through the pericarp to the mesocarp, softening the oil-bearing pigments and loosening the kernels with their shells. This makes sterilization one of the most important operations in which the success of other processes depends on.

In small-scale processing mills, sterilization is done by cooking loose fruits in water which requires labour and much water wastage. Studies have shown that sterilization method of using steam to cook the palm oil fruits leads to higher oil quality and yield than when cooked in water [5]. Oil palm produces two types of oil namely; palm oil and palm kernel oil. Palm oil is obtained from the fruit's fleshy mesocarp, which contains 45-55% oil and differs in color from light yellow to orange-red and melts at 25 ^{0}C. The palm kernel oil is extracted from the endocarp-enclosed kernels. Oil palm derived its generic name from the Greek word elaia, (meaning olive, due to its oil rich fruits) and its place of origins, Guinea's rain forest (West Africa) and the name of the man who first illustrated it in 1763, Nicholas Jacquin hence its name, Elaeis guineensis jacquin. It is a tropical crop that originated from the costal swamp plains and freshwater riverine of Central and West Africa and is grown maximally in West and Equatorial Africa, southeast Asia, and Latin American countries. The African oil palm (*Elaeis guineensis Jacquin*), is placed in the plant family caceaea alongside all other palms, as coconut, carnauba, gebang, palmetto, raffia, palmyra, corozo, coco der mer, bêtel and date palms, etc. There are three naturally occurring breeds of the palm fruit, termed dura, tenera, and pisifera. Most cultivars are the tenera which produces fruit with higher oil content [6].

The objectives of this work include to design a palm fruit processing unit that will improve oil recovery from palm oil by sterilization process using firewood and electricity and also to evaluate the performance of the unit.

2 MATERIALS AND METHODS

The conception design of this system was the combination of steam boiler principles and the traditional method of cooking palm fruits into a compact unit. Steam boilers are units in which the steam is generated from boiling water, which the source of energy could be biomass, oil, gas, wood or electricity. The traditional method of cooking palm oil is by pouring the palm fruit into a drum or pot containing water and then boil. The system combines these two principles in its operation. The steam generated by boiling water either in the electric boiling chamber or wood boiling chamber is moved by its pressure into the steam passage tank and through a galvanized steam pipe to the steam cooking chamber where the palm fruits are cooked. The Volume, V (m³) of the wood and electric boiling chamber is given as;

$$V = D \times h \qquad (1)$$

where, D - diameter of the chamber and h - height of the water chamber.

The cross-sectional area, A (m²) of the wood and electric boiling chamber is given as;

$$A = h + W = h \times \pi D \qquad (2)$$

where, h - Height of the water chamber (m), D - Diameter of the water chamber (m), π = Constant. Volume, V (m³) of the steam cooking chamber is given as;

$$V = A \times L \qquad (3)$$

where, A - Area (m²) and L - Length (m).

The heat transfer by conduction is expressed as:

$$Q = -K \left(\frac{T_2 - T_1}{dx} \right) \qquad (4)$$

where, Q - Heat transfer, K = thermal conductivity of the mild steel (w/m.k).

where T_1 - initial temperature (ºC), T_2 - final temperature (ºC) and dx − change in thickness of material (m).

The convective heat transfer using Nusselt number (N$_u$) is expressed as:

$$N_u = \frac{hcL}{k_l} \qquad (5)$$

where L − length of solid surface (m), h_C - convective heat transfer coefficient (J/s), K_l − thermal conductivity of liquid (constant)

The quantity of heat needed to heat the water is given as:

$$Q_1 = mc\, DT \qquad (6)$$

where, Q_1 - amount of heat required to raise the water to 100 ºC (kJ/kg/ ºC), m - mass of water (kg), c - specific heat capacity of water (kJ/kg), DT - temperature differences,

Mass of water m (kg) is expressed as:

$$m = V \times D \qquad (7)$$

where V - volume of water (m³) and D - density of water (kg/m³).

The latent heat of evaporation for a unit mass of water is expressed as:

$$Q_2 = mL_h \qquad (8)$$

where Q_2 - heat required for vaporization of water (kJ/kg), L_h − latent heat of vaporization of water (2,257 kJ/kg), and m - mass of water (kg).

Hence, the total heat needed to raise the temperature of water from 28 °C to 100 °C

$$Q_T = Q_1 + Q_2 \qquad (9)$$

where Q_T - total heat required by the system (kJ/kg), Q_1 - amount of heat required to raise the water to 100 °C (kJ/kg/ °C), Q_2 - heat required for vapourization of water (kJ/kg).

Thermal resistance R_{wall} (°C.m/w) of the wall against heat conduction is given as:

$$R_{wall} = \frac{L}{KA} \qquad (10)$$

$$Area\ (A) = \frac{\pi D^2}{4} \qquad (11)$$

where, L - length of water chamber (m), A - cross-sectional area of the water chamber (m²), and K - thermal conductivity of the mild steel (w/m.°C).

Heat loss Q_c (kJ/kg) through a composite cylindrical surface is given by:

$$Q_c = \frac{T_i - T_0}{R_T} \qquad (12)$$

where, T_i - inside unit temperature (°C), T_0 - outside unit temperature (°C), $and\ R_T$ - total heat resistance.

$$R_T = \left(\frac{1}{a_w A_i} + \frac{1}{a_s A_i} + \frac{x_{is}}{\lambda_s A_i} + \frac{x_{in}}{\lambda_f A_1} + \frac{x_{os}}{\lambda_s A_o} + \frac{1}{a_o A_0} \right) \qquad (13)$$

For the wood boiling chamber

$$1 \Big/ a_w A_i = \frac{1}{a_w\ 2\pi r l} \qquad (14)$$

where, A_i - inner cylinder surface area (m²), A_o - outer cylinder surface area (m²), a_w - heat transfer coefficient from water to mild steel (11.3 w/m²k), a_o - heat transfer coefficient from mild steel to air (7.9 w/m²k), a_s - heat transfer coefficient from steam to mild steel (14.2 w/m²k), λ_f - thermal conductivity of fibreglass (0.04 w/mk), λ_s - thermal conductivity of mild steel (48.5 w/mk), x_{is} - inner steal thickness (mm), x_{os} - outer steal thickness (mm), and x_{in} - insulation thickness (mm).

For the insulated steam pipe, R$_T$ is given by:

$$R_T = \frac{ln\ (r_2/r_1)}{2\pi AL} \qquad (15)$$

where, r_1 - the inner radius of the layer in consideration (mm), and r_2 - outer radius of the layer in consideration (mm).

The heat conduction through the boiler wall is given by:

$$Q_T = \frac{T_1 - T_2}{R_{wall}} \qquad (16)$$

where, T_1 - initial temperature (°C), T_2 - final temperature (°C) and R_{wall} - thermal resistance of the mild steel (°C.m/w)

The electrical energy required for the boiler by taking care of heat losses and attaining the required temperature is given as:

$$E_g = Ivt = (Q_T + Q_c xt) \qquad (17)$$

where, E_g - the electrical energy (J), I - electrical current (A), v - voltage (V), t the time (s), Q_T - total heat required by the system (kJ/kg), and Q_c - heat losses from the system (kJ/kg).

The power required is given as:

$$P_e = \frac{E_g}{t} = Iv = \frac{Q_T}{t} + Q_c \qquad (18)$$

where, P_e − electrical power (W), I - electrical current (A), v - voltage (V), $and\ t$ - time (s).

With the national grid voltage of 220 V.

$$V = IR \qquad (19)$$

where, v - electrical voltage (V), I - electric current (A), and R - electrical resistance (Ω).

$$R = \frac{\rho L}{A} \qquad (20)$$

where, ρ − electrical resistivity (Ωm) (1.724×10^{-8}) for copper wire A − cross-sectional area of a unit length of wire (m²), L - length (m).

From the corollary of first law of thermodynamics, the quantity of heat added to a closed system minus the work done by the system is equal to the change in internal energy of the working fluid.

$$Q_T - W = \Delta u \qquad (21)$$

where, Q_T - total heat required by the system (kJ/kg), W - work done by the system (J), Δu - change in internal energy of the system (kJ/kg).

Since there is no moving part, W = 0
Therefore;

$$Q_T = \Delta u \qquad (22)$$

The quantity of heat required to increase the temperature of a unit mass of the steam from 100 °C to an elevated temperature, 120 °C and the specific heat capacity of water vapour (Cpv) = 1.996 (J/g°C).

$$U = U_f + x \left(U_g - U_f \right) \qquad (23)$$

where, U - internal energy of the system (kJ/kg), U_f - internal energy of water (kJ/kg), x - dryness fraction (dimensionless) and U_g - internal energy of the steam (kJ/kg).

$$h = h_f + x h_{fg} \qquad (24)$$

where, h - enthalpy of the system (kJ/kg), h_f - enthalpy of wet steam (kJ/kg), x − dryness fraction (dimensionless), h_{fg} - pressure (N/m²).

The general gas law for a constant volume process is given as:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad (25)$$

where, P_1 - initial pressure (N/m^2), P_2 - final pressure (N/m^2), T_1 - initial temperature (°C), T_2 - final temperature (°C).

Ballaney [7] expressed evaporation rate from a water surface as:

$$E_e = E_a \times F_e \qquad (26)$$

where,

$$F_e = \frac{h_1 - h_{feed}}{h_{fg}(atm)} \qquad (27)$$

where E_e − equivalent evaporation (dimensionless), E_a − actual evaporation (dimensionless), F_e − factor of evaporation (dimensionless), h_{feed} − enthalpy of feed water (kJ/kg).

The time required for heating element $(5400\,W)$ power to evaporate 20 litres of water was evaluated using:

$$t = \frac{E_e}{Iv} \qquad (28)$$

where, t − time required for water to evaporate (s), E_e − equivalent evaporation, I - electric current (A), and v - voltage (V)

2.1 Wood energy requirement

To provide the power needed for the heating, the amount of wood needed for a batch heating of 3 hrs 4 mins was determined using the relation:

$$Weigth\ of\ wood = \frac{energy\ required\ for\ heating}{LCV\ of\ wood} \qquad (29)$$

where, LCV - average lower calorific value of wood (kJ/kg).

The average lower calorific values (LCV) of wood as given by different authorities as: 9088 kJ/kg, [7]. Domestic wood; 10 mJ/kg. Oil palm fibres 7-8 MJ/kg, [8]

Hence, using the lower of the LCV of oil palm fibres, which is the raw material generated by the processing mills:

Energy required for heating (E$_h$) is given as:

$$E_h = IvT\ (J) \qquad (30)$$

where, I - electric current (A), v - voltage (V), and T - temperature (°C).

2.2 Thermal efficiency of the boiler

The thermal efficiency of the boiler was calculated using equation given by [7]:

$$\eta_b = \frac{steam\ mass\ x\ (steam\ heat - feed\ water\ heat)}{feed\ mass\ x\ heating\ value\ of\ fuel} \times 100 \qquad (31)$$

The moisture content was calculated as:

$$MC = \frac{w_2 - w_3}{w_2 - w_1} \times 100 \qquad (32)$$

where, w_1 - initial weight of empty crucible (g), w_2 - weight of crucible plus oil before drying (g) and w_3 - the final weight of crucible plus oil after drying (g).

The peroxide value (PV) was determined using the equation:

$$PV = \frac{T \times M \times 100}{Weight\ of\ sample\ used} \qquad (33)$$

where, T - titre, and M - molarity of Na$_2$S$_2$O$_3$.

The free fatty acid (FFA) of the palm oil was determined using the equation:

$$FFA = \frac{5.61 \times B}{W} \qquad (34)$$

where, B - volume in millilitres of 0.1N alkali (mm^3), and W the weight in grammes of sample taken.

Dimension of wood boiling chamber
360 mm (diameter) $by\ 470\ mm\ (height)$
The Cross-Sectional area (A) of the wood boiling chamber was calculated using Equation (2)
A = $0.1018\ m^2$
The wood boiling chamber was lagged with fibre glass to prevent heat loss to the environment. The diameter of the outer surface of the cylinder is $410\ mm$ and $470\ mm$, height. The area of the outer surface of the wood boiling chamber was calculated using Equation (14).
$A_0 = 0.1320\ m^2$
Hence the cross-sectional area of the lagged $(insulation)$ region was:
$A_i = 0.1320 - 0.1018\ m^2 = 0.0302\ m^2$
The volume (v) of the wood boiling chamber was calculated using Equation (3)
Volume $(v) = 0.0478\ m^3$
Dimension of Electric boiling chamber
356 mm $(diamter)\ x\ 471\ mm\ (height)$
The cross-sectional Area (A) of the electric boiling chamber was calculated using Equation (11)
$A = 0.0995\ m^2$
The electric boiling chamber was also lagged with fibre glass to prevent heat loss to the environment. The diameter of the outer surface of the electric boiling cylinder is $410\ mm$ and $471\ mm\ (height)$. The area of the outer surface of the electric boiling chamber was calculated using Equation (11)
$A = 0.1320\ m^2$
Hence the cross-sectional area of the lagged $(insulation)$ region was,
$A_i = (0.1320 - 0.0995)\ m^2 = 0.0325\ m^2$
The volume (v) of the electric boiling chamber was calculated using Equation (3)
Volume $(v) = 0.0468\ m^3$

Dimension of the inner cylinder of the steam storage tank
$400\ mm\ (height)\ x\ 200\ mm\ (diameter)$
The cross-sectional area of the inner cylinder of the steam storage tank was calculated using Equation (12)
$A = 0.03142\ m^2$
The steam storage tank was lagged with fibre glass to prevent heat loss to the environment, the diameter of the outer surface of the steam storage chamber is 225 mm $(diameter)\ and\ 420\ mm\ (height)$.
The area of the outer cylinder of the steam storage tank was calculated using Equation (12)
$A_0 = 0.03976\ m^2$
Hence, the cross-sectional area of the lagged $(insulation)$ region was
$A_i = 0.03976 - 0.03142 = 0.00834\ m^2$
The volume of the steam storage tank was calculated using Equation (3)
$V = 0.01256\ m^3$
Dimension of the steam cooking chamber
$310\ mm\ (dimater)\ by\ 470\ mm\ (height)$
The Cross-sectional area of the steam cooking chamber was calculated using Equation (12)
$A_0 = 0.07548\ m^2$
The steam cooking chamber was also lagged with fibre glass to prevent heat loss to the environment.
The steam cooking chamber was lagged with fibre glass to prevent heat loss to the environment. The diameter of the outer cylinder is $410\ mm$ and $470\ mm$ $(height)$ the area of the outer cylinder was calculated using Equation (12)
$A_0 = 0.320\ m^2$
Hence the cross-sectional area of the lagged region $(insulation)$ of the steam cooking chamber is:
$A = 0.1320 - 0.07548 \quad A = 0.0565\ m^2$
The quantity of heat needed to heat the water was calculated using Equation (6)
The mass (m) was calculated using Equation (7)
$m = 47.8\ kg$
Assuming an average ambient temperature of 28 ºC to heat the $47.8\ litres$ of water from 28 ºC to 100 º C
$Q_1 = 14,454\ kJ$
The latent heat of evaporation for a unit mass was calculated using Equation (8)
$Q_1 = latent$ heat of vaporization of water $(2257\ kJ/kg)$
$Q_1 = 2257\ kJ$
Hence, the total heat needed to raise the water from 28 ºC to 100 º C was calculated using Equation (9)
$$Q_T = 16,711\ kJ$$

Heat loss through a composite cylindrical surface was calculated using Equations (12), (13) and (14)
For the wood boiling chamber
$\dfrac{1}{a_w\ 2\pi r l} = 0.1664\ k/w$
For the Electric boiling chamber, the steam passage tank and steam cooking chamber, the heat losses were:
$\dfrac{1}{a_w\ 2\pi r l} = 0.1679\ k/w$
$\dfrac{1}{a_w\ 2\pi r l} = 0.2801\ k/w$
$\dfrac{1}{a_w\ 2\pi r l} = 0.3076\ k/w$
Hence, for the wood boiling chamber, electric boiling steam passage chamber, and the steam cooking chamber, the sum equals $0.922\ k/w$
For the insulated steam pipes, it was calculated using Equation (15)
The wood boiling steam pipe
$= 1.6472x10^{-4}\ k/w$
The Electric Boiling steam pipe
$= 1.6472x10^{-4}\ k/w$
The storage tank pipe
$= 1.4645 \times 10^{-4}\ k/w$
The Pipe insulation
$= 2.9412\ k/w$
Hence, the total heat resistance coefficient was calculated using Equation (13)
$R_T = 3.8636\ k/w$
Therefore, heat loss from the system was calculated using Equation (12)
$Q_c = 31.6\ W$
From Equation (18), the electrical power required by the system was calculated.
The system was designed to attain a temperature of 120 ºC in $45\ minutes$
$P_e = 6,221\ W$
Three heating elements of 2,200 W each were used hence,
$Iv = 6,600\ W$
With the National grid voltage of $220\ V$
$I = 30\ A$
From Equation (19)
$R = 7.3\ \Omega$
Using Equation (20)
$\rho = 2.3616\ x\ 10^{-3}\Omega\ mm^2$
The quantity of heat required to increase the temperature of a unit mass of the steam from 100 ºC to an elevated temperature of 120 ºC
$Q = 2,297\ kJ/kg$
Hence, $\Delta \cup = 2,297\ kJ/kg$

From the steam table [9] at 120 °C , $U_f = 503.6$ kJ/kg and

$U_g = 2,528.9$ kJ/kg

From Equation (24)

$x = 0.885$

The Enthalpy of the system was calculated using Equation (24)

$h = 2,452.6$ kJ/kg

The Internal Pressure of the system was calculated using Equation (25)

$P_2 = 1.2N/m^2.$ From Equation (29), $F_e = 1.0345$

It takes $2,257$ kJ/kg to evapourate Ikg of water; therefore, for $47.8kg$ of water,

$E_e = 107,885$ kJ

The time required for the $6,600$ W power to evaporate the 47.8 $litres$ of water was calculated using Equation (30)

$t = 4$ hrs 32 $mins$

$E_e = 10.5$ kg/h

Adding the 30 minutes for heating the water to the point of evaporation; $47litres$ of water is recommended to be poured into water chamber every 5 hours.

However, a working system should be fed continuously.

To generate the $6,600$ W of power needed for the heating; the amount of wood needed for a batch heating was calculated using Equation (26).

Energy required for heating $= 118,800,00$ J

Weight of biomass $= 16.9$ kg

Thermal efficiency of the boiler was calculated using Equation (31)

$$\eta_b = 99.5\%$$

The moisture content, MC, Peroxide value, PV and free fatty acid were calculated using equations 32, 33 and 34.

The sectional view of electric boiling chamber is shown in Figure 1. Figure 2 shows the sectional view of the steam cooking chamber. Figure 3 shows the palm fruit oil sterilization unit.

3. RESULTS AND DISCUSSION

The sterilization time at 100 °C using firewood and electricity are presented in Tables 1 and 2, respectively.

The oil recovered from palm fruits sterilized in water and steam at100 °C for 90 minutes are presented in Table 3 while the parameters of the oil quality are given in Table 4.
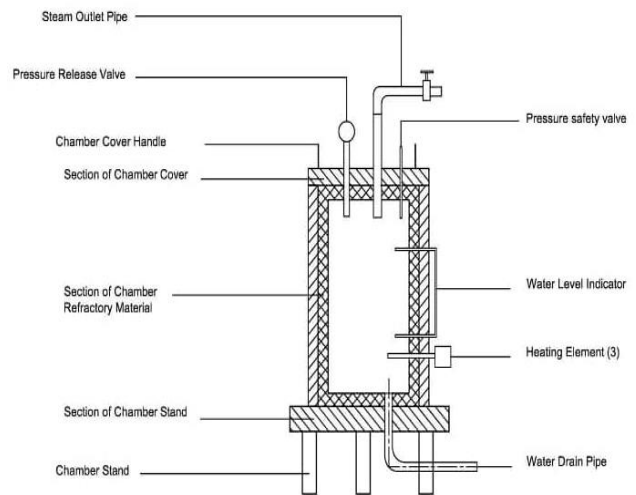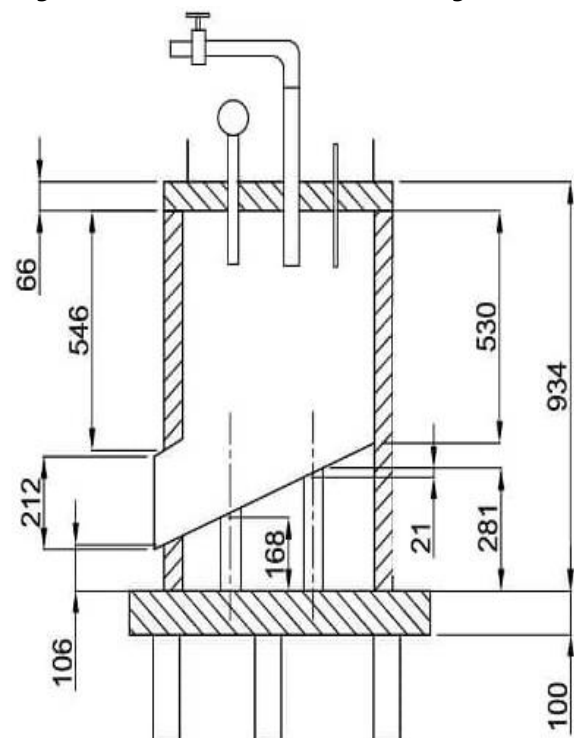

Fig.1: Sectional view of electric boiling chamber
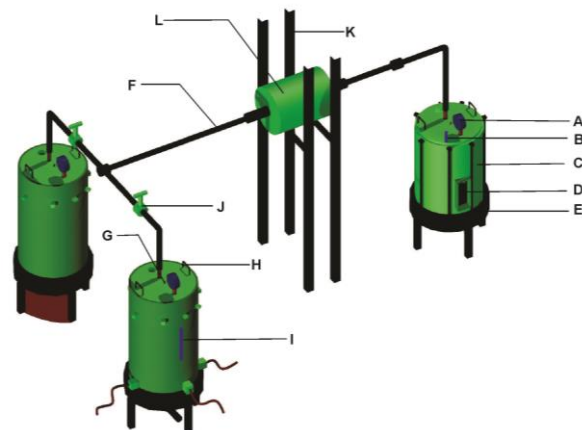

Fig. 2: Sectional view of steam cooking chamber

Fig. 3: Pictorial drawing of palm fruit oil sterilization unit

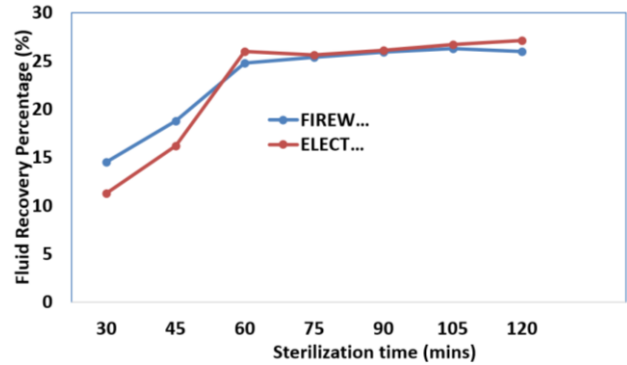|	PART LIST
A	PRESSURE GAUGE
B	SAFETY VALVE
C	STEAM CHAMBER
D	OUTLET DOOR
E	BOILER STAND
F	7mm ROUND PIPE
G	TEMPERATURE GAUGE
H	TOP HANDLE
I	WATER INDICATOR
J	REGULATOR VALVE
K	STEAM TRANSITION TANK STAND
L	STEAM TRANSITION TANK

Fig. 4: A plot of oil fluid recovery at 100 °C steaming with firewood and electricity.

From Figure 4, it is observed that the oil fluid recovery in both electricity and firewood source increases as sterilization time increases up to 60 minutes. Beyond 60 minutes, the oil yield was almost constant till it reaches 120 minutes sterilization.

Table 1: Sterilization at 100 °C using firewood

Sterilization time (minutes)	Weight of palm fruit before cooking (g)	Weight of palm kernel and fibre after washing (g)	Fluid recovery (g)	Fluid recovery percentage (%)
30	300	256.5	43.5	14.5
45	300	243.7	56.3	18.8
60	300	225.5	74.5	24.8
75	300	223.7	76.3	25.4
90	300	222.3	77.7	25.9
105	300	221.1	78.9	26.3
120	300	221.9	78.1	26.0

Table 2: Sterilization at 100 °C using electricity

Sterilization time (minutes)	Weight of palm fruit before cooking (g)	Weight of palm kernel and fibre after washing (g)	Fluid recovery (g)	Fluid recovery percentage (%)
30	300	265.9	34.1	11.3
45	300	251.3	48.7	16.2
60	300	222.0	78.0	26.0
75	300	223.0	77.0	25.6
90	300	221.5	78.5	26.1
105	300	219.8	80.2	26.7
120	300	218.7	81.3	27.1

Table 3: Oil extraction from palm fruits sterilized in water and in steam at 100 °c for 90 minutes

Sterilization method	Weight of palm fruit before cooking (g)	Weight of palm fruit after cooking (g)	Weight of palm kernel and fibre after washing (g) (g)	Weight of extracted fluid (g)	Weight of oil extracted 4(g)
In Water	1000	1246	724	276	111.3
By Steam	1000	1127	671	329	130.5

Table 4: Parameters of the palm oil quality

Sample	FFA Content (%)	Peroxide Value (O_2/kg)	Moisture Content (%)
S	3.9	8.5	0.11
W	4.4	10.3	5.5

W - Oil from sample cooked in water at 100 °C for 90 minutes;   S - Oil from sample cooked with steam at 100 °C for 90 minutes

The oil fluid recovery at 100ºC sterilization temperature using electricity and firewood as energy source for 60 minutes was 26.0% and 24.8% respectively with the maximum oil fluid recovery of 27.1 % and 26.0 % at 120 minutes sterilization time respectively. Interestingly, it was found that the palm fruits sample sterilized at 100 ºC using electricity as energy source yielded more liberated quality oil from their mesocarp than palm fruits sterilized with firewood energy source and this was observed at all duration of the sterilization time. It was also found out that sterilization time of 60 minutes was adequate when using electricity in a small-scale operation to conserve energy. The result is in agreement with [8] which reported that there is no appreciable difference from 60 and 120 minutes sterilization. In [9], it was reported that melting oil globule commenced at sterilization time as low as 30 minutes and then suggested the adoption of 60 minutes sterilization for small scale sterilization operation to conserve energy and preserve the quality of product. Interestingly, it was also observed that palm fruit fibre sterilized at the temperature of 120 ºC for 120 minutes using firewood energy source had a darker colour of fibre. This was as a result of prolonged sterilization time and temperature. Figure 5 shows oil yield (g) when cooking 2 kg of palm fruits in water and with steam at 100 ºC for 90 minutes.

Figure 5 presents a pie chart of oil yield from 2 kg of fresh palm fruits sterilized at 100 ºC for 90 minutes using steam from electricity energy source and cooking in water using firewood as energy source. The result obtained proved that, at 90 minutes of sterilization at 100 ºC using firewood and electricity as source of energy, oil released from the digested fruit fibre accounted for 46 % (111.33 g) and 54 % (130.5 g) of the total oil content respectively. It was clearly seen that optimum oil yield was obtained from fruits sterilized using steam from electricity as source of energy. This was due to the fact that more cells were ruptured fast in electricity energy source than firewood source within the stipulated sterilization time (90 minutes). This finding is in agreement with [10] which reported that apart from the chemical process (hydrolysis) occurring in the sterilization process, further cell rupture will take place during the digestion process through mechanical (cutting and shearing) and physical treatments. Intuitively, oil will have an easier way to flow out of the oil-bearing cells which are ruptured [10]. Apart from easier and fast cell rupture observed when sterilized with electricity

energy source, digestion had better nut fibre separation leading to high oil yield. However, digested palm fruit fibre sterilized at 100 ºC for 90 minutes using firewood as source of energy was darker in colour. This is due to the high sterilization temperature and perhaps absorption of water and smoke particle by the fruits. Figure 6 shows a bar chart of oil quality parameters.

One way to assess palm oil quality is to measure the amount of free fatty acid (FFA), peroxide value and moisture content (W = Oil from sample cooked in water at 100 ºC for 90mins. S = Oil from sample cooked with steam at 100 ºC for 90 mins). It was found that, the FFA of the oil sample sterilized using steam from electricity energy source and oil sample cooked in water using firewood energy source were 3.9 % and 4.4 % respectively. This finding is in agreement with [8] who reported that the FFA of the fresh and boiled oil for cooked fruits were 8.0 and 6.8 % and that for steamed fruits were 3.6 against 3.2 % respectively. Malaysian Palm Oil Association (MPOA), previously known as Malaysian Oil Palm Growers Council (MPOGC) established that the FFA content in crude palm oil (CPO) for trading purpose must not exceeded 5 % [10]. Interestingly, the FFA value measured in this study has not exceed the maximum allowable FFA value and is in line with [11] who reported that palm oil is bought on the basis of an FFA content of 5% by importing countries, with financial penalties for exceeding this percentage [12].
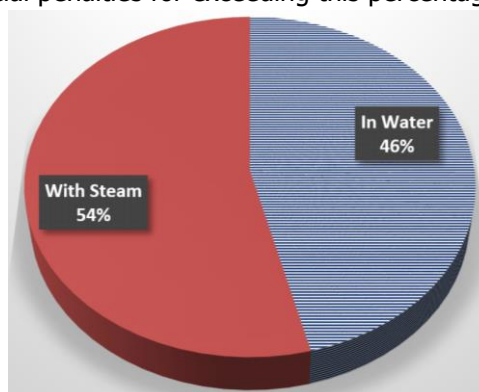

Fig. 5: Oil yield (g) when cooking in water and with steam at 100 ºc for 90 mins
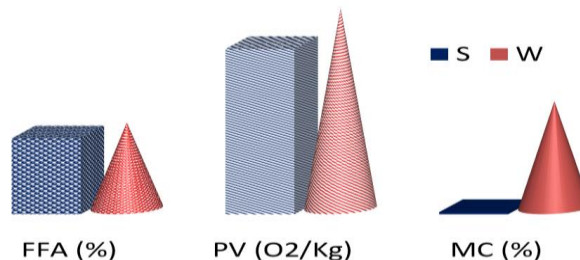

Fig.6 Oil quality parameters

The peroxide value for palm fruits cooked with steam and in water were 8.5 (O_2/kg) and 10.3 (O_2/kg) respectively indicating that PV of fruits cooked with steam is lower than that cooked in water. This might be as a result of the formation of hydro-peroxides of unsaturated fatty acid and the hydrolysis reaction with the presence of sufficient water. This concurred with [13] who concluded that in the existence of moisture under thermal treatment, the hydrolysis reaction heavily depends on the temperature. However, the 8.5 (O_2/kg) peroxide value obtained from this result was within the limit of value of fresh oil to be less than 10 milliequivalent/kg.

The moisture content of the palm oil sample cooked with steam and in water were 0.11 and 5.5 % respectively. Intuitively, the moisture content of the oil cooked with steam was lower than that cooked in water. This result is relatively higher than that reported by [8] and this might be as a result of precisions of the method used and this concurred with [14] who concluded that the moisture and impurity content of palm oil could be greatly influenced by the method of processing [15].

4. CONCLUSION

A steam boiler using either electricity or firewood independently as energy source for sterilization of palm fruit was designed and evaluated. Sixty minutes is adequate when using electricity in a small-scale operation to conserve energy. Optimal yield of palm fruits oil cooked with steam and in water at temperature of 100 °C for 90 mins were 54 % (130.5 g) and 46 % (111.3 g) respectively. Labour requirement is highly reduced when the machine is operated on electricity as source of energy to generate steam. The quality of oil cooked with steam proved to be better than that cooked in water. The machine is simple to operate and could serve as a multi-purpose boiler for the steaming of any agricultural produce.

5. REFERENCES

[1] Kiple, F. K. and Omelas, C. K. eds (2000) *The Cambridge World History of Food.* Cambridge University Press ISBN 052102166.

[2] Obaliagbon F. I. "A Review Aspects of the African Oil Palm (ElasisGuineesisJacq)" (PDF.). *American Journal of Biochemistry and Molecular Biology*. Pp 211 – 223. (2012).

[3] Ramag, G, Mortar G and SAlmiah A, (2006), Non – Food Application of Palm-based products- Market Opportunities and Environmental Benefits, www.researchgate.net/publication/260392940PDF

[4] Badmus G. A. NIFOR Automated small – scale oil palm fruit processing equipment. Its need, development and cost effectiveness, *PORIM International palm oil conference, Chemistry and Technology*, Kuala Lumpur pp 20-31 (1991).

[5] Wacapol, (2009) Oil Palm fresh fruit bunch sterilizer http://www.wacapol.com [Accessed on February 16, 2018].

[6] Malaysian and American palm oil Council report 2007 http://www.mpoc.org [Accessed on February 18, 2018].

[7] Ballaney P. L. (2005) *Thermal Engineering* 24thed Khanna publishers 2-3 Nath market, Naisarak, Delhi-110006, India.

[8] http://www/biofuels.com, (2007) [Accessed on March 12, 2018].

[9] NIST Chemistry Web book www.Ohio.edu [Accessed on January 20, 2008]

[10] Bamgboye, A. I. and Onwe, D. N. "Development of a dual energy steam boiler for small scale sterilization". *International Journal of Engineering and Technology,* Vol. 5(5), pp. 64-69, 2015.

[11] Owolarafe, O.K. and Faborade, M.T. "Macro-structural characterization of palm fruit at stages of Sterilization and digestion in relation to oil Palm Expression "*Journal of Food Engineering* 85 pp 598-605 2008

[12] Nor'aini, S. and Siew, W. L. (1990) Quality control measures in the palm oil industry. https://www.google.com/search?q=Noraini+s [Accessed on March 13, 2018].

[13] Ituen, E. U. U and Modo, I. V. O., (2000). "The effect of the fermentation period on the palm oil production in eastern Nigeria, using traditional methods." *Indigenous knowledge and development monitor*, March 2000

[14] Chong, C. L and Gapor, M. T. Effect of moisture and trace metals on oil quality. Report of the workshop on quality in the palm industry, Bangi Palm Oil Research Institute, Malaysia. Porim, 2-3 August 1983.

[15] Poku, K. (2002) Small-scale palm oil processing in Africa. FAO agricultural services bulletin, 148.