DEVELOPMENT OF SMALL SCALE PALM FRUIT BIOMASS-FIRED BOILER

BY

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This is to certify that Yusuf Adeshina SALAKO executed this research work in partial fulfillment of the requirements for the award of Master of Science Degree in Agricultural Engineering, Faculty of Technology, Obafemi Awolowo University, Ile Ife.

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DEDICATION

To the best of men ever created: Prophet Muhammad (SAW), his household, his companions and to those that follow his guidance till the day of reckoning.

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ABSTRACT

This study characterised palm fruit biomass for proper selection as fuel. It designed a boiler to utilize the fuel and evaluated the boiler for its performance. This was with a view to providing appropriate technology for small scale palm fruit processing.

Fresh fruit bunches (FFB) were processed to obtain the required waste products and the wastes collected were sun-dried to constant weight. Fuel properties such as the moisture content, bulk density, ash content, volatile matter, fixed carbon content and the calorific value were determined at interval of 3 days. Boiler parts like the furnace, boiler drum, water and fire tubes were designed based on the quantity of steam required to process 0.25 ton ffb/hr (i.e. 150 kg/hr). The volume of the furnace was determined based on the quantity of fuel required to deliver 70% efficiency of the boiler. The furnace was double walled with the inner wall made of kaolin (pure white clay) brick while the outer wall was made of clay laterite. The boiler was evaluated for its fuel consumption, steam production rate and efficiency using 100 kg of different fuel samples (shell, palm fibre, empty fruit bunch (efb) and wood) with known calorific value and their combinations for a period of 60 minutes firing time.

Result showed that moisture content of the wastes exhibited direct relation with the bulk density and the volatile matter, as they decreased with decrease in the moisture content. On the other hand the calorific value, fixed carbon content and the ash content exhibited an indirect relation with the moisture content. These parameters increased as their moisture contents decreased. The moisture contents of the shell, fiber and efb decreased from 31.16 to 6.58, 49.46 to 3.32 and 57.37 to 7.71%, respectively, while the bulk densities reduced from 0.31 to 0.28, 0.15 to 0.08 and 0.31 to 0.08 g/cm^3, respectively, in that order. Also the ash contents of the shell, fibre and efb increased from 6.55 to 12.67, 3.46 to 8.27 and 5.18 to 16.46%, respectively, while the

volatile matter decreased from 81.39 to 73.59, 87.17 to 77.15 and 84.60 to 62.80%, respectively. The fixed carbon contents increased from 12.065 to 13.747, 9.363 to 14.58 and 10.22 to 20.74%, respectively, and the calorific values increased from 10.87 to 14.94, 7.57 to 16.45 and 5.57 to 13.99, respectively. The effect of drying was observed to significantly ($p<0.05$) affect the fuel properties of the palm fruit waste. The rate of fuel consumption by the furnace differed with the type of fuel materials as 100 kg of shell and 100 kg of wood burnt within 55 minutes firing time while the combination of shell and wood burnt within 60 minutes of its firing time under the same condition. Combination of shell and efb lasted for 50 minutes during firing while efb alone burnt completely within 35 minutes. The highest quantity of steam (17.99 kg/min) and maximum boiler efficiency (79.6%) were recorded when fired with efb only while 10.96 kg/min steam production rate and 76.4% efficiency were recorded when fired with shell and efb combination. Combination of shell and wood produced 10.31 kg/min of steam and 76.6% boiler efficiency while 11.31 kg/min of steam and 76.9 % boiler efficiency was obtained using wood only. Combination of shell, efb and fibre gave 15.28 kg/min of steam and 73.1 % boiler efficiency while 10.32 kg/min of steam and 76% boiler efficiency was obtained using shell only. The effect of fuel material was found to significantly ($p<0.05$) affect the steam temperature, vapour pressure and enthalpy.

The study concluded that the boiler developed using adequately-prepared locally-available materials has the potential to be incorporated into the small scale palm fruit processing technology profile and at the same time there is opportunity for improving its performance.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

1.1 Origin and Economic Importance of the Oil Palm

Oil Palm *(Elaeis guineensis)* originated in the tropical rain forest region of West Africa. It belongs to the family of *Palmae,* a sub family of *Cocordae* and is distributed in the region between latitude 13 ^{0}N and 12 ^{0}S. The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo. During the 14th to 17th centuries, some palm fruits were taken to the Americas from where it went to the Far East. The plant appears to have thrived better in the Far East, thus providing the largest commercial production of an economic crop far removed from its centre of origin (FAO, 2002).

Palm oil is an edible plant oil derived from the fruit of the *Arecaceae Elaeis* oil palm. It is also an important component of soaps, washing powders and personal care products, it is also used to treat wounds. Palm oil itself is reddish in colour because it contains a high amount of beta-carotene. It is used in cooking, making margarine and as component of many processed foods. Palm oil, like other vegetable oils, can be used in making biodiesel employed in internal combustion engines (www.wikkipedia.com, 2009). Biodiesel has been promoted as a form of renewable energy source to reduce net emissions of carbon dioxide into the atmosphere. Therefore, biodiesel is seen as a way to decrease the impact of the greenhouse effect and as a way of diversifying energy supplies to assist national energy security plans. For each tonne of crude palm oil (CPO) produced from fresh fruit bunches, the following residues, which can all be used for the manufacture of biofuels, bioenergy and bioproducts, become available: around 6 tonnes of waste palm fronds, 1 tonne of palm trunks, 5 tonnes of empty fruit bunches (EFB), 1 tonne of press fiber (from the mesocarp of the fruit), half a tonne of palm kernel endocarp, 250 kg of palm kernel press cake, and 100 tonnes of palm oil mill effluent (POME). In short, a palm plantation has the potential to yield a very large amount of biomass that can be used for the production of renewable products (www.wikipedia.com, 2009).

International trade in palm oil began at the turn of the nineteenth century, while that of palm kernels developed only after 1832. Palm oil became the principal cargo for slave ships after abolition of the slave trade. The establishment of trade in palm oil from West Africa was mainly the result of the Industrial Revolution in Europe. Tinplating required technical oil for which palm oil was found suitable. In the early 1870s exports of palm oil from the Niger Delta were 25,000 to 30,000 tonnes per annum and by 1911 the British West African territories exported 87,000 tonnes (FAO, 2002).

The export of palm kernels that began in 1832 from British West Africa hit 157,000 tonnes of which about 75 percent came from Nigeria. Africa led the world in the production and export of palm oil throughout the first half of the 20th century. This was spear-headed by Nigeria and Zaire. By 1966, however, Malaysia and Indonesia had surpassed Africa's total palm oil production (FAO, 2002)

1.2 World Palm Oil Producers

Around the world, it must be noted that about 110 million tons of vegetable oil are produced per year, and that about 70% of that production are accounted for four vegetal species which are soya oil, palm oil, sun flower oil and rape oil. They constitute 26%, 18%, 13% and 12%, respectively *(www.cyberlipid.org*, 2009*)*. Palm oil is the world's most important lauric oil, and for the past six decades, world production of palm oil has shown an astonishing growth having risen tenfold. It was reported to have the highest oil yield per unit area and it was being rated second next to soya bean oil in the world ranking of the most important vegetable oil. Soya bean oil and palm oil presently constitute 29% and 23% of the world's vegetable oil production, respectively (Tropical Agriculturalist, 1998). It was also reported further that the key to this growth is the tremendous contribution of more than 80% of the world total palm oil production by Asia.

Nigeria was the world's highest producer and exporter of palm oil between 1920 and 1960 (Hartley, 1988). Two decades ago, the product was almost missing on the nation's export lists. In 1991, no shipment was recorded, a trend that continued until 1995 when about 30 tonnes of the product was shipped by a private exporter (CBN, 1998). Presently, efforts are being made to revive palm oil production in Nigeria, but there has been little or no impact up till now. Malaysia followed by Indonesia now leads the production of palm oil in the whole world. It had been reported that the two countries have some years ago, been engaging in the downstream processing of excess palm oil into fuels and chemicals (Owolarafe, 2007).

Some of the major factors contributing to Nigeria's decline in rank of World producer and exporter of palm oil were highlighted as follows (Owolarafe, 2007):

i. Declining productivity of oil palm plantations due to old age;
ii. Lack of appropriate technologies for palm fruit processors (notably small and medium scales);
iii. Unfavourable government policies as regards agriculture in general; and
iv. Non-availability of effective extension communication profile.

Lack of appropriate technology for the small and medium scale palm fruit processors had been observed to be the major problem facing the palm oil industry and it needs to be addressed (Owolarafe, 2007).