Development of a dryer with a reduced industrial emission to the environment using sawdust briquettte

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ABSTRACT

A locally made dryer was developed to curb industrial emission that pollutes the environment by using sawdust briquette. Other sources of fuel like electricity and gas are relatively expensive while other form of biomass especially charcoal which is gotten from falling of trees emits high carbon dioxide and visible smoke unlike sawdust which is readily gotten as a by-product of woodworking operation. The sawdust was carbonized and compressed to give briquette which is very efficient in combustion and does not emit smoke. The materials were carefully selected and includes mild steel and stainless steel. Stainless steel was used for the drying trays for health reasons because of its high resistance to corrosion which if not properly checked can lead to food contamination. The dryer has a capacity of 5 kg per batch. The efficiency in generating heat from briquette is 61.4%. The dryer efficiency based on heat input and output is 70%.

Keywords: *Sawdust briquette, cabinet dryer, stainless steel, emission*

1.0 Introduction

A dryer using briquette is being used in our food industry for drying fruits, vegetables, fish, and biological active products in many countries. The main advantages of using a briquette dryer are the energy saving potential and the ability to reduce emission to the environment for a wide range of drying conditions. The increased demand for ready to eat products and convenient foods requires well controlled drying conditions to obtain sufficiently high-quality food products. The industrial emission encountered in the cause of drying this product has also been a major concern especially since most of this dryer make use of charcoal, wood and other biomass which emits smoke that contains gaseous air pollutants such as CO, NOx and VOCs linked with a range of potential health outcomes such as respiratory and cardiovascular mortality and morbidity (Zoë et al 2015). At least 28 pollutants present in smoke from biomas use have been shown to be toxic in animal studies, including 14 carcinogenic compounds and four cancer-promoting agents (Smith et al 2014). When exposed Short-term to particles from wood combustion appears to be as harmful to health as exposure to particles from the combustion of fossil fuels which has a relatively high level of gaseous substance released into the atmosphere which can pose threat to the environment. One of the important roles affecting the global carbon cycle involves exposed waste dung, biomass burning, charcoal production and uses. Research approximates that biomass burning accounts not only for 25-40% of the annual global emissions of CO_2 but also for 15-50% of CO and 3-10% of CH_4 (Levine, 1990). Few studies have been done on the effects of long-term or prenatal exposure to residential wood smoke in developed countries. Exposure to wood smoke during pregnancy (number of days), however, was associated with small size for gestational age (Gehring et al., 2014); exposure to wildfire smoke during pregnancy slightly reduced average birth weight in infants (Holstius et al., 2012). The dryer can also be independent of the ambient weather conditions, and the use of low temperature is of great importance. Energy consumption is reduced due to high coefficient of performance of the dryer and high thermal efficiency of the dryer when properly designed. Energy savings of about 40% were reported using briquette dryers as compared to electrical resistance dryers and charcoal. The briquette dryer is suitable for high value products and its ability to produce controlled transient drying conditions in terms of temperature, humidity, and air velocity has been investigated in order to improve product quality and reduce drying cost (Eduardo *et al.*, 2014). The moisture is being suck out through the chimney via an impeller fan. For specialty crops the optimum drying temperature at which no structural damage and nutrient losses occurs lies between 30 to 45˚C. The briquette dryer can be used to dry heat sensitive food products requiring low-temperature drying and in tropical countries where the level of air humidity is high. Research has acknowledged the importance of briquette dryer in producing a range of precise drying conditions to dry a wide range of heat-sensitive products. Briquetting can be done with or without binder. Doing it without the binder is more convenient but it requires sophisticated and costly presses and drying equipment which makes such processes unsuitable in a developing country like Nigeria. As observed by Wamukonya and Jenkins (1995), for briquetting industry to be successful in the less industrialized countries, the equipment should consist of locally designed simple, low-cost machines. Briquette fuel is obtained by the compression of loose biomass materials into product of higher densities than those of the parent materials usually with the application of high-pressure heat. It is pollution free and co-friendly has low emission of sulphur and greenhouse gases responsible for acid rain and global warming and also lead to the reduction of deforestation and management of forest resources. It can be easily ignited and for a long time and has high burning efficiency as a result of low moisture content and higher density. However, the material mostly commonly used is a typical waste from the timber industry: sawdust. Compared to agricultural raw material, sawdust has a lower ash content, lower risks of corrosion and dirtying, requires high temperatures of ash deformation (>1200ºC) and also requires no additives or thickeners to increase production costs since humidity and the actual wood lignin work as natural adhesive(Eduardo et al 2014). For industrial production of compacted biomass from sawdust, adequate process controls focused on risk management are required as this material is a forestry residue with one of the largest environmental impact, being a contaminant agent of soil and water. In addition, when in the open, it is harmful to human health and a safety risk with regard to fire and spontaneous combustion (Fonseca & Tierra 2011).

Stainless steel is a generic term covering a family of chromium (Cr) containing alloys. The chromium content is usually between 11% and 30% and the primary property of stainless steel is corrosion resistance. Stainless steels, because of their resistance to corrosion, are often used in highly aggressive conditions, which will cause most alternative materials to fail rapidly. It is relatively the standard steel used in food industries cause of its high resistance to corrosion which helps mitigate contamination of food most especially in dryers while at the same time serves as a good conductor of heat. For this research, it was used for the dryer trays where the product was spread on and in the combustion chamber to readily withstand high temperature and conduct heat. The combination of sawdust briquette as power source and stainless steel for drying tray greatly help in waste management, reduction in industrial emission as well as increase in health and safety while drying agricultural products through the dryer.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used for the body fabrication includes fibre glass, mild steel sheet, stainless steel sheet, square pipe, angle iron, rivet pins, screws, hinges and other used for the design are; d.c fan, thermostat, relay, battery, solar panel and fuel.

2.2 Method

The method used is subdivided into three categories; the design of the dryer, fabrication of the dryer and evaluation performance of the dryer

2.2.1 Amount of moisture to be removed

$M_R = M(\frac{M1-M2}{1-M2})$ Ichsani and Dyah (2002) 2.1

Where,

M_R is the amount of moisture to be removed (kg)

M is the dryer capacity per batch (kg)

M_1 is the initial moisture content of relative humidity

M_2 is the maximum dried final moisture content

$Q_a = \frac{M_R}{H_{R2}-H_{R1}}$ Ichsani and Dyah (2002) 2.2

Where,

Q_a is quantity of air required to effect drying

T_1 is the initial temperature

T_2 is the final temperature in the dryer

R_h is the relative humidity

H_{r1} is the initial humidity ratio of air

H_{r2} is the final humidity ratio of air

2.2.2 Volume of Air (m^3) to effect drying

$V_a = \frac{Q_a}{\rho_a}$ 2.3

Where, Qa is the quantity of air in kg

ρ_a is the average density of air

2.2.3 Heat transfer rate (Q_{ht})

The heat transfer rate for a cylinder is given by the expression

$Q_{ht} = \frac{(KA(T_1-T_2))}{D}$ 2.4

Where,

Q_{ht} is the heat transfer rate

K is the thermal conductivity of stainless steel

2.2.4 Thermal Efficiency of dryer

Efficiency based on latent heat of vapourisation = $\frac{Heat\ to\ evapourate\ moisture\ only}{\text{heat in hot air being supplied}}$ 2.5

2.2.5 Briquette production

The briquettes were made from sawdust. The sawdust was carbonized in a heating device for hours. After carbonizing the carbonized sawdust was mixed with starch, and was mould by a pressing device into a circular hollow shape shown in Figure 2.1.

Figure 2.1: Briquette moulds

2.2.6 Emission measurement

The hood method was used for taking a sample of the emitted gas during burning of the briquettes. The chimney was placed under an extraction hood through which the gas escaped. The emitted gas likes CO, CO_2, Unburnt hydrocarbons, NO and NO_2 were measured from the escaping gas. To determine the CO and CO_2 content, the gas samples were collected in 220 ml syringe and analysed using a gas chromatograph. The gas samples were led through suction pump having an inlet pipe diameter of 2 mm without affecting combustion. The readings were taken at an interval of 20 min. The emitted gas samples were calculated following the method of Bhattacharya *et al* (2002).

2.2.7 Operation Principle

In operation, the briquette is fired up in the combustion chamber; the heated air then passes through the riser tube which is conserver and where it is filtered with the aid of the suction unit, the heated air is conveyed to the drying chamber. In the drying chamber, as the heated air passes over the products on the drying trays, drying takes place by heat and mass transfer and the moisture is being suck out by the fan to reduce moisture content for effect drying which exits through the chimney. With the suction fan powered by a solar panel with a battery. A thermostat and a relay was incorporated to regular the shutting down of the fan when dry air falls below the required temperature for drying the products and turn on when the temperature increase to circulate the dry air all through the dryer shown in Figure 2.2. The readings of the fresh air inlet and air exit of the drying chamber were recorded, while the atmospheric temperature and relative humidity values were measured and recorded using a digital thermometer/hygrometer. The ambient relative humidity was also measured. The weight of the dried products were weighed and recorded using an electronic weighing scale. Temperatures, relative humidity and the mass of water evaporated were continuously analysed by means of data logging.

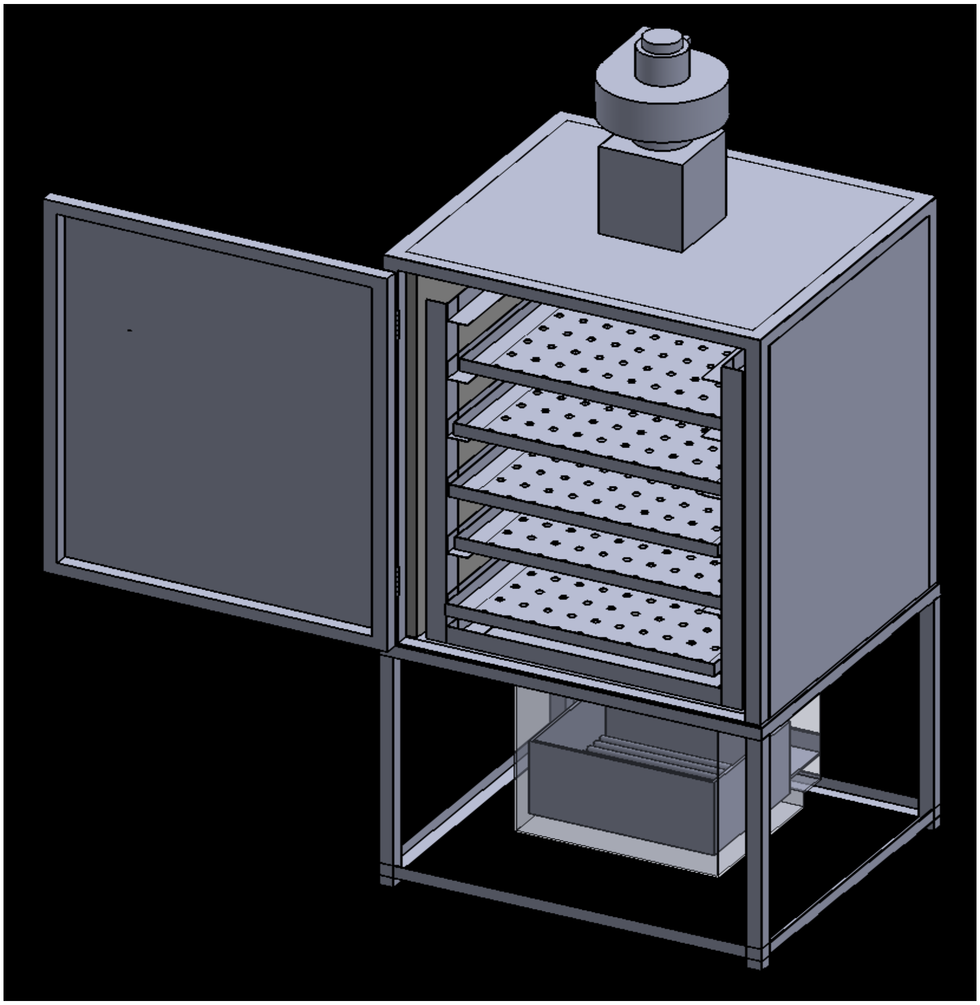

Figure 2.2: Cabinet dryer using sawdust briquette

The products (pepper and okra) was weighed and spread inside the tray before inserting into the dryer. The product in each tray was weighed at every interval of 30 minutes for 4 hours for the setup. This was done by rapidly removing the trays from the trolleys, weighing them in and electronic scale and returned them back into the dryer.

3.0 RESULTS AND DISCUSSION

The dryer was completely fabricated and different tests were performed in order to carry out performance evaluation. Okra and pepper was dried during the test period. The results of different tests performed are presented below.

3.1 Temperature Test for Product loaded

The test for temperature for loaded product was varied for 4 hours at an interval of 30 minutes each which shown in Figure 3.1.

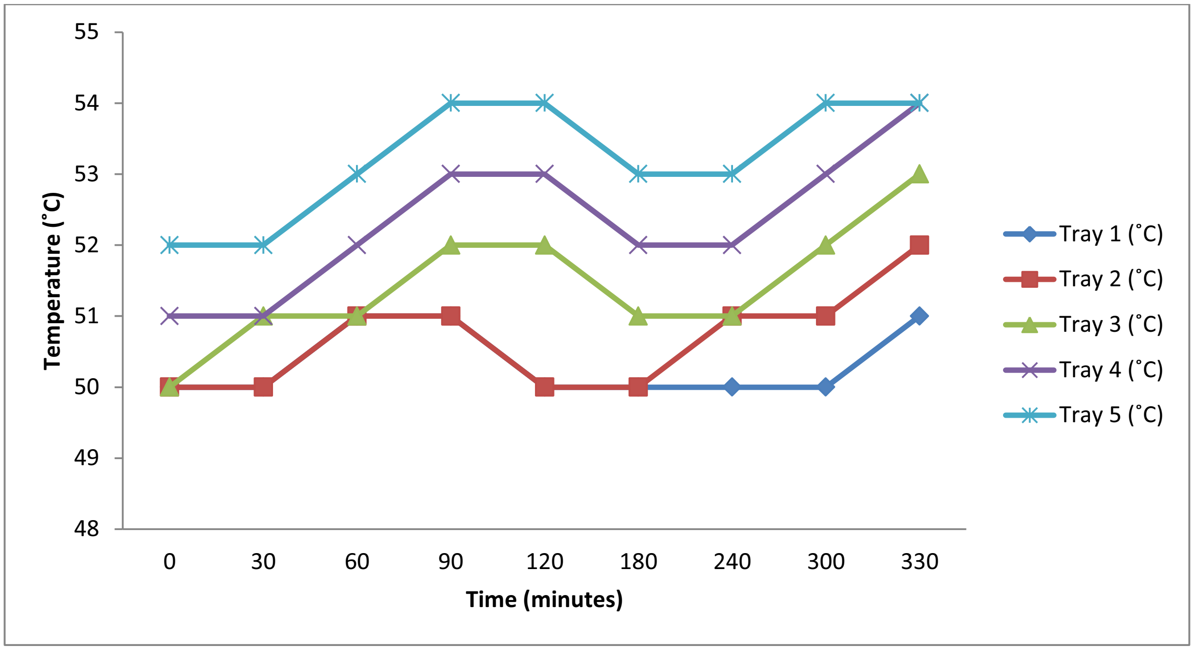

Figure 3.1: Temperature for loaded product

In the morning time the experiment was carried out and the source of heat supply was the sawdust briquette, a maximum temperature of 190˚C was attained by burning briquette after four hours while the average temperature from 10am to 2pm was 54˚C and the ambient temperature was 27˚C. The maximum average temperature rise on the trays was about 51˚C. This indicates that the maximum rise in temperature of the dryer was about 1˚C more as compared with the ambient temperature because the temperature was regulated to dryer the product at 50˚C. The average air temperature in the dryer was 52˚C more than the daily average ambient temperature 27˚C recorded between 10am to 2pm.

From Figure 3.1, the trend of the graph shows that the temperature starts to increase from morning and reaches its peak value in the afternoon, where the sun insulation is highest. As a result, the temperature on the bottom tray reached a maximum value of 54˚C after four hours of heat supply. A higher temperature was recorded on the bottom tray which was nearest to the point where heat was supplied from the briquette than the top or middle tray. To maintain this temperature a thermostat was used to regulated the temperature in the dryer.

3.2 Emission

The difference of the emitted gases was minimal. The CO emission has 0.09%, NO has 1.36 ppm, NO_2 emission has 2.47ppm while the emission of unburnt hydrocarbon has 0.015%. This emission was due to the uncarbonized sawdust in the briquette and the binder used. The emission of CO and CO_2 was reduced in the emitted zone than burning charcoal and firewood (Zhang *et al*., 1999). The emission of unburnt hydrocarbon, NO and NO_2 were also reduced more than that of carbon.

Briquette sample	Emission gases of burnt briquette (g/kg)				
	CO	CO_2	Unburnt hydrocarbon	NO	NO_2
A	101.3	1175	39.7	0.21	0.40

3.3 Efficiency of the dryer

Thermal Efficiency of dryer

The dryer efficiency based on the heat input and output in drying air:

$$ŋ = \frac{T_1 - T_2}{T_1 - T_a}$$

Where

T_1 is inlet temperature to the dryer (^oC)

T_2 is the outlet temperature from the dryer (^oC)

T_a is the ambient temperature (^oC)

$$ŋ = \frac{110 - 54}{110 - 30}$$

ŋ = 70%

1 kg of briquette will generate 16.31 MJ of energy

Therefore H_r (10.01MJ) will require $\frac{10.01}{16.31}$ = 0.614 kg of briquette

But 1 kg of briquette was used for the drying operation efficiency in generating energy from briquette is therefore $\frac{0.614}{1} \times 100 = 61.4\%$

The efficiency in generating heat from briquette is 61.4%

4.0 Conclusion

The locally made dryer was developed to use briquette and to reduce emission to dry product of a required temperature of 50˚C. Selected materials were used to develop the dryer so that it withstands a lot of heat from the briquette. Stainless steel was used in the combustion chamber to withstand corrosion for a long period of time. The emit gases were calculate when measured and was compared to be lesser than charcoal emission when burning. The dryer has a capacity of 5 kg per batch. The efficiency in generating heat from briquette is 61.4%. The dryer efficiency based on heat input and output is 70%.

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