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Full Length Research Article

Construction and Comparative Evaluation of a Fired Briquette and Mold Oven

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Biomass; the plant matter for generating heat or electricity via direct combustion or gasification was used in the construction of a briquette and mold oven, this was done locally to substitute fuel scarcity and reduce the threat of global warming in Nigeria. The performance evaluation was carried out using water boiling test (WBT). The results obtained from the tests carried out on the biomass briquette oven (BBO) were compared with the mold oven. The result of the test indicates that the briquette oven (BBO) used an average of 69g of wood to boil 1 liter of water in about 8 min (5 liters in 38 min) as against 326g of wood to boil the same 1 liter of water in about 25 min(5 liters in 126 min) using the mold oven. The thermal efficiency of the BBO (67%) was better than the mold oven (16%). The firepower of the mold oven (3422 kW) was higher than the BBO (2192 kW) which is in agreement with the burning rate as the mold oven fire consumed more wood per unit time for the same task. In most aspects of oven performance, the BBO was better than the mold and thus, it is recommended for use.

Key words: Biomass Briquette Oven, Mold Oven, Thermal Efficiency, Firepower

INTRODUCTION

Human being has harnessed biomass derived energy product since the time when people began burning wood to make fire. Biomass is the plant and animal matter used either to generate heat or electricity via direct combustion, gasifier or steam turbine; this replaces fossil fuels for generating electricity or heat. Families can replace smoky kerosene, electric kitchen oven, microwaves with biomass just as small scale businesses can extend their working hours and new businesses can start up (Justin, 2012). Biomass is the most commonly used source of rural energy in Nigeria through direct combustion because fuel wood is the cheapest and most accessible source of fuel even in urban households. The use of biomass is common in Asia especially in the area of gasification, where many companies in India and China have added gasifier to their product list (Bridgewater and Evans, 1993). Biomass includes husk, wood, leaves, pellet and generally, every non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms. This shall also include products, by- products, residues and waste from agriculture, forestry and related industries. Biomass has high but variable moisture content and is made up of carbon, hydrogen, oxygen, nitrogen, sulphur and inorganic elements. The utilization of biomass is a very important source of energy in many parts of the world, especially for areas remote from supply of high-quality fossil fuels (Yang *et al*., 2004).

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Biomass are mainly used in ovens which are closed containers used for heating, cooking, and drying. It is used mostly in cooking and pottery. They provide even, dry heat to all surfaces of food inside them. An indoor oven can have electric heating element, biomass briquette, natural gas or coal. Outdoor ovens are often made of brick or clay and are buried in hot coal. An oven which is used for making pottery is called a kiln while ovens used for heating or industrial processes are called a furnace (Martineze *et al*., 2009).

Justification

There is the growing threat of global warming, and the burning of fossil fuel contributes a large part of the total greenhouse gas. In addition, the cutting down of trees for firewood removes some of our carbon buffering ability as well as producing more carbon when it is burned inside an outdoor oven (Clarke,1981). Biomass briquette oven is constructed to combat this by using waste from sawmill and husk for faster growing materials. It is also beneficial because, it uses materials that are already in the carbon cycle, unlike fossil fuels. In a heat value, biomass products cost less than natural gas, propane and fuel oil. Coal is a little bit cheaper but it is worse for the environment and does not possess the benefit of biomass. Biomass is not a new technology, but the scientific improvement is making it new every day. It is an easy inexpensive way to heat your home or business. This construction is cheap and none pensive for the substitute of fuel scarcity, most especially in Nigeria where fuel availability is not stable and the price rises every day. It aimed at reducing carbon dioxide emissions, a significant contributor to global warming, as carbon dioxides acts as a "greenhouse" gas by trapping heat absorbed by the earth from the sun, because it does not release "new carbon" into the atmosphere unlike fossil fuel. The imported are expensive and are not always available, this is why there is need for local construction to improve technology (Sheth and Babu, 2009) hence, the objective of this research include construction and evaluation of a fired briquette oven

MATERIALS AND METHOD

Materials

The materials used for this research were sourced locally from Apata, Gate, Dugbe and Challenge markets in Ibadan, Oyo State, Nigeria. Aluminum was used for constructing the oven based on its characteristics, properties, low maintenance cost, fast track fabrication, guaranteed performance through quality control, malleability, reflectivity, surface finishes, design flexibility, workability, durability and availability. The construction of briquette mode was achieved using iron plate with 5mm thickness in order to support the mold. The biomass briquette was molded using sawdust due to its availability. Other materials for the construction include: insulator, wire mesh, screw nails, electrode, iron rod, door handle, angular bar, hydraulic jack. The specifications of the materials used are given in the Table 1.

Methodology

The briquette mold was fabricated and constructed following the dimension and specification of the component unit to form the box structure. The main component parts of the biomass mold include:

- Molding Sieve Unit: cut according to dimension of 310mm by 245mm with flat plate and the drilled of 30 holes were made with 20mm drilling bit all over the surface.
- Molding sieve holder: This was also done using the same dimension of 310m by 245mm with flat plate and drilled with 30 holes. The difference between molding sieve and molding sieve holder is that, a square bar of uniform length was welded over the four sides of the plate.
- Molding box: a rectangular box made with dimension of 330mm by 250mm. The angular plate welded with the specified dimension to form this box.
- Molding spike tooth with flat plate: This has 330 by 250mm flat with 115mm uniform rod of 30 pieces welded all over the flat plate.
- Molding flat plate cover: This was measured with the same dimension of molding sieve plate without any holes. It was made to place on molding sieve holder.

Design and fabrication of oven

The oven was constructed using locally according to a dimension of 70 x 32 x 49 cm.

The briquettes were placed at the lower chamber of the oven to serve as heat source for the biomass. The pictorial view for the biomass with briquette is presented in Plate 1.

Plate 1. The Constructed Biomass with Briquettes

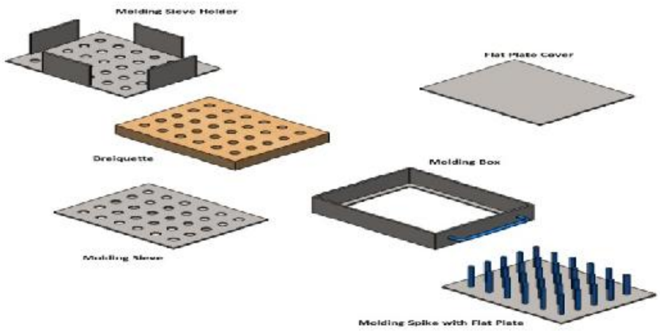

Fig. 1. The component unit of biomass briquette mould

Performance Test of the Oven

The oven was evaluated using standard test procedures (Water Boiling Test, WBT), the parameters evaluated include boiling time, burning rate, firepower, specific wood and sawdust consumption using thermometer, stop watch, weight balance and pan. A known volume of water was into the oven, the stopwatch was started, readings were taken and the temperature was monitored with the aid of thermometer until boiling point was reached. The results were compared with mould oven.

RESULTS AND DISCUSSION

Table 4 is the summary of the three tests results at high power (cold start). The (BBO) used an average of 69g of wood to boil 1 liter of water in about 8 min (5 liters in 38 min) as against 326g of wood to boil the same 1 liter of water in about 25 min (5 liters in 126 min). This is indicative of the fact that the (BBO) is superior to the mold in specific fuel consumption in the high power (cold start) phase. The average rate of wood consumption (burning rate) is high for the mold oven (10.1 g/min) than the BBO (6.7 g/min) Also in this aspect of stove performance, the BBO was better and statistically significant at t_{95} but not at t_{99} against the mold oven; burning less wood per unit time to accomplish the same task. In summary, table blow show the superiority of BBO over mold oven in aspect of oven performance based on the listed parameter for testing. Table 5 is the summary of the three tests results at high power (hot start). This is indicative of the fact that the BBO is superior to the mold in specific fuel consumption in the high power (hot start) phase.

Table 1. Specification of Construction Materials

S/N	Items	Specification	Unit price (₦)	Amount (₦)
1	Aluminium sheet	3 sheets	1500	4,500
2	Iron sheet	1 ½ sheet	1200	1,800
3	Hydraulic jack	1 pack	4000	4,000
4	Insulator	20 sheets	100	2,000
5	Wire mesh	1 yard	200	200
6	Screw nail	1 dozen	100	100
7	Electrode	1 pack	3000	3,000
8	Iron rod	2 pieces	1000	2,000
9	Door handles	1 pieces	100	100
10	Angular bar	4 pieces	100	400
11	Transportation	-	-	2,000
12	Miscellaneous	-	-	3,000
	Total			23,100

The average rate of wood consumption (burning rate) is higher for mold oven at (10.1g/min) than the BBO (3.9 g/min) statistically not significant at $_{95}$ and t_{99}. In aspect of oven performance this table shows that the firepower of the mold oven (1270kW) is lower than the (3277kW) which indicate greater wood consumption over a longer duration. Tables 2 and 3 summarize the superiority of BBO to mold oven based on the testing parameters. Table 4 shows the power phase (simmering) test result in which, the average thermal efficiency of the BBO (36%) is better than the mold oven (6%).

Statistics at both t_{95} and t_{99} show significant difference of such superiority of the BBO over the mold oven in thermal efficiency. Also the average rate of wood consumption (burning rate) is high for the mold oven (25g/min) than the BBO (15.1 g/min).

The BBO used an average of 148g of wood to simmer 1 liter of water in about 9 min as against the mold oven's 386g of wood to boil the same 1 liter of water in about 9 min. The average turndown ratio of the BBO (69%) is better than the mold oven (40%) with no statistical difference at both $t_{95}$and t_{99}.Table below shows the result of turndown ratio when compare the two oven over the parameters for testing. A biomass oven combined with briquette was constructed using available local materials. The performance was evaluated against a mold oven fired with wood using the Water Boiling Test (WBT). The results of the three tests (3 replicates) carried out on each briquette oven shows that the thermal efficiency, the specific fuel consumption and fire power of the briquette oven were better than the mold oven. It was also determined statistically that the turndown ratio, the efficiency, the specific sawdust consumption and the fire power of the briquette oven was significant at t_{95} and t_{99} against mold oven. Therefore, the briquette oven showed superior attributes in most aspect of oven performance.

Table 2. Summary of test results showing the effect of data variability on statistical confidence based on the tests of each oven (cold start)

	Briquette oven			Brick mold oven			Statistics		
	Mean	SD	Co V	Mean	SD	Co V	Sig with 95% confidence? (table value = .02)	Significant with 99% confidence? (table value = 3.36)	T-test
Time to boil 5 liters of water (min)	38	56	77%	126	41.8	33%	Yes	Yes	-8.48
Thermal efficiency (%)	67	34	50%	16	5	31%	Yes	Yes	- 12.22
Rate of wood consumption (g/min)	6.7	4.7	70%	10.1	9.7	96%	Yes	No	2.77
Specific fuel consumption (g/liter)	68.6	28.4	36%	32	109	33%	Yes	Yes	-2.52
Firepower (kW)	2192	1535.5	70%	3422	152.4	4%	yes	Yes	-9.76

Table 3. Summary of test results showing the effect of data availability on statistical confidence based on three tests of each oven (hot start)

	Briquette oven			Brick mold oven			Statistics		
	Mean	SD	Co V	Mean	SD	Co V	Significant with 95% confidence? (table value = 2.02)	Significant with 99% confidence? (table value = 3.36)	T-test
Time to boil 5 liters of water (min)	33	1.7	3%	126	41.8	33%	Yes	Yes	-5.78
Thermal efficiency (%)	66	71	67%	16	5	31%	Yes	Yes	3.45
Rate of wood consumption (g/min)	10.1	9.7	96%	3.9	1.9	49%	No	No	0.7
Specific fuel consumption (g/liter)	80.2	75.7	94%	326.6	109	33%	Yes	Yes	-7.4
Firepower (kW)	3277	3151	96%	1270	627	49%	Yes	Yes	13.3

Table 4. Summary of test results showing the effect of data variability on statistical confidence based on three test of each oven (simmering)

	Briquette oven			Brick mold oven			Statistics		
	Mean	SD	Co V	Mean	SD	Co V	Significant with 95% confidence? (table value = 2.02)	Significant with 99% confidence? (table value = 3.36)	T-test
Time to boil 5 liters of water (min)	36	11	30%	6	5	88%	Yes	yes	8.12
Thermal efficiency (%)	15.1	8.7	57%	25	1.4	6%	Yes	No	3.17
Rate of wood consumption (g/min)	148.1	396	77%	386	1251	324%	Yes	No	-2.22
Specific fuel consumption (g/liter)	4875	2855	59%	6613	748	9%	Yes	Yes	-9.76
Turn down ration	0.69	0.5	66%	0.40	0.0	5%	No	No	1.43

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