PRACTICAL AND MONEY-SAVING USE OF THE SAWDUST STOVE IN GHANA

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ABSTRACT

The sawdust stove (SDS) has been introduced in Ghana as a cook stove using a renewable energy resource (RER) - sawdust, for almost thirty years now. Over these years however, the sawdust stove is not as widely in domestic use as the wood stove and charcoal "pot" even where sawdust abounds. This study therefore sought to find the reasons behind the non-adoption of the sawdust stove, and based on the findings, recommend practical and money-saving ways of using the stove. Literature review on sawdust stoves and field studies revealed a stove model without a separate ash compartment. The absence of the ash compartment lowered the sawdust combustion efficiency of the stove. The stoves were also not constructed from any design, but made from scrap metal, empty cans and drums. A model, with a separate ash compartment, was proposed and constructed from mild steel and compared practically with the existing model. From practical use of the proposed model it was found that the sawdust stove could provide a relatively long period of steady heat output. For instance, a three kilogram (3 kg) capacity sawdust stove provided a

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steady heat output for up to 10 hours without tending or stoking. It was also found that the rate of combustion of the sawdust could be considerably increased by adding a piece of charcoal to the base of the lit sawdust. Among the drawbacks to the use of the sawdust stove, the problem of accessibility to sawdust stands out. Where however, sawdust can be obtained inexpensively and easily, considerable savings on fuel can be made from hybrid use of the sawdust stove with the charcoal or gas stove.

KEY DESCRIPTORS: Stove, sawdust, renewable energy, ash compartment, burner

INTRODUCTION

Darrow (1986), in the Appropriate Technology Sourcebook traces the introduction of the sawdust stove (SDS) to the 1970s. He explains that the SDS was introduced for domestic use in many parts of the world for over 30 years ago. In Ghana, the SDS has been in use for almost twenty-five years. Over the years, however, there has been no widespread use of the SDS. Through interviews and practical search for existing SDS, it was found that in the southern sector of the country, in areas where sawdust was available in large quantities, few people used SDS. In northern Ghana, where availability of sawdust was relatively less, the use of SDS was even much less. The thrust of this paper is efficacy of the SDS as an energy-saving device and sawdust as an alternative energy source. Field surveys revealed that in the urban areas, driven by the scarcity and consequent high cost of fuel wood, sawdust is burned on open wood fires in an attempt to reduce fuel wood consumption and save costs on fuel wood. This is a rather inefficient use of sawdust as a heat source as the heat produced in this manner is dissipated in all directions.

One way of using the sawdust more efficiently would be burning in a SDS where the heat generated is more directional. The use of sawdust briquettes as fuel is one other way in which sawdust has been used to generate heat for cooking. If the briquettes however, are burned in open fires, the efficiency is comparable to any ordinary open fire. Trials for this technology revealed that in open fires sawdust burns as the same level as fuel wood. The SDS, which is enclosed controls and minimizes energy waste. As such, where the sawdust is accessible and inexpensive, the SDS compared to wood fuel is cost and energy saving.

Besides the potential economic gain in burning sawdust in the SDS when used for cooking and heating in general, it is hoped that the increased use of sawdust as fuel in the SDS would help ease the problem of sawdust disposal. By so doing, sawdust use serves the purpose of waste management. Against the backdrop of the current waste management menace engulfing the whole nation and for cities such as Kumasi, where sawdust improper disposal of sawdust is choking drains and causing flooding and the unsightly scenes of sawdust mounds are being used by dwellers as safe places for household and human waste disposal, the use for sawdust in SDS would help curtail the situation. In addition, due to the slow and even sneaky combustible nature of sawdust when burned in the open it presents the added menace of health hazard. Children, animals and even adults who stray into the dump might not notice the burning which often occurs deep beneath the heap and can be trapped or sucked in by it. One finds that, not only is the disposal of sawdust a waste management problem but its improper disposal presents the added case of illegal disposal by irresponsible residents. As reported by the Ghana Statistical Service (2005) "solid waste disposal has been a problem in the country, with inadequate dumping sites as a contributing factor."

The "inadequate dumping sites" problem becomes quite acute in localities where the only dumping site available is farmland or potential farmland. This happens to be the case around urban centers. The point is sawdust consists mainly of lignin (woody material) which is not easily biodegraded (Barnet, 1978). Thus when the sawdust is poured over an area of land, that parcel of land is effectively insulated from plant growth, that is, it becomes temporarily (2 -3 years) a barren land. (Barnet, 1978). Besides the possibility of reducing valuable farmland, dry sawdust is easily carried by wind into surrounding residential areas. The inhalation of such dust by humans especially children and the elderly, can become a possible source of respiratory illness. In addition to the environmental and health hazards posed by the improper disposal of sawdust, there is always the danger of the sawdust catching fire from carelessly thrown cigarette butts or at times, intentional fire set in an attempt to reduce the accumulated sawdust. The smoldering sawdust becomes a life-threatening fire- trap where unsuspecting children and animals could fall victim to.

On national development, it is stated, "One area which proves to be a developmental challenge to Ghana is the source of cooking fuel used by households in the country, because of the impact on the environment. Information suggests that over three quarters of households, urban or rural, depend largely on the natural environment (wood and charcoal) for their domestic fuel requirements" (Ghana Population Data Analysis Report, 2005).

Increased use of the sawdust stove and sawdust, in this light, would provide a way of recycling and otherwise waste product. This in its turn could play a developmental role in terms of sound environmental management. The possibilities of financial gain and sound environmental management that can be derived from an increase in the use of sawdust stoves and thereby of sawdust needs to be exploited for poverty reduction and national development.

This study was thus initiated to determine in a practical way, the real benefits and problems associated with the use of the sawdust stove, present a refined model and the benefits to be derived from adopting it. Thus, the findings provide useful information for making recommendations to the potential user on practical and money - saving use of the sawdust stove. It is worth noting that mention is not made of rice husk, although in some literature, the sawdust stove is also referred to as a sawdust/rice husk stove (Darrow, 1986). The reason is that rice husk is a good source of organic fertilizer, and should be used preferably as such, unless where its abundance allows its use as fuel.

Besides the introduction, the paper opens up with the methods used to gather relevant information for the study. This is followed by the findings made. From the findings, a stove model is proposed. The basic construction and principle of operation of the proposed stove model are described. Profiles of the heat output of the stove during a normal rate of sawdust combustion and at an accelerated rate of combustion are obtained, via experimental testing. This is followed by a comparison between the existing model and the proposed model of sawdust stoves. Conclusions are drawn from the study and recommendations made.

RESEARCH METHODOLOGY

The methods used to gather background information for the study comprised literature review, field surveys and experimental testing.

Literature Review

A review of the literature on sawdust stoves begins with a model described by Saubolle (1974). The model is made from an empty oil can, with the top opened. A hole is made in the base of the can. To use such a stove, one end of a long stick was placed in the hole and sawdust packed around it. When the stick was removed, an air tunnel was formed in the centre of the sawdust. The stove was then placed on stones. This allowed air intake from the bottom. The stove was lit from the top or from the bottom. The stove was for cooking and the utensil was placed directly on the metal can. Other models, which differ from the model described above, include Wartluft's Double Drum Sawdust Stove (Wartluft, 1975) and that by Huntington (1975). These were developed for space heating in temperate climates and differ from Saubolle's model in that they have separate ash compartments (SACs).

Field Survey

The objective of the survey was to find which SDS models that were in existence in the country and those that were being used. Reasons for using or not using the stoves were also sought. This was carried out by students from selected regions, who served as key informants on their communities. Information was also garnered during the Third Trimester Field Practical assessment trips. This informal survey showed that the SDS was hardly used except for a few households mostly in the Brong-Ahafo (parts of Techiman) and Eastern (Samreboi) Regions, where sawdust is plentiful and can be inexpensively acquired. One was found in use in Bolga, in the Upper East Region. The rest were a handful of disused ones, scattered in the three northern regions. These were introduced some years back during intermediate technology transfer exercises by the GRATIS Foundation. GRATIS is an intermediate technology development organization. Dissemination of knowledge on the SDS was through the regional Intermediate Technology Transfer Units (ITTUs), now Regional Technology Transfer Units (RTTU). A sample of this model was constructed from an empty oil can and tested for its ease of operation, fuel combustion efficiency and robustness.

SAW DUST STOVE TECHNOLOGY DEVELOPMENT

Existing Model

The field survey revealed a stove model that resembles the model described by Saubolle (1974). The metal cylinder is not constructed from any design but made from scrap metal such as empty oil or paint cans, or even old gas cylinders, with the tops opened. The stove model found in the country differs from Saubolle's model in that it has no hole in the metal base. A metal pipe is passed through the side of the cylinder, near its base, to stop near the centre of the base plate, as illustrated in Fig.1 (a).

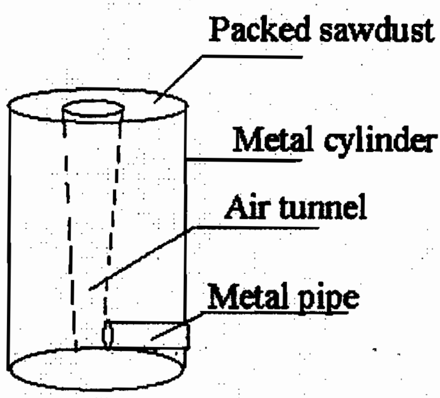


Fig. 1(a) SDS model without separate ash compartment.

The mold is placed at the centre of the base plate, in contact with the end of the pipe, and sawdust packed around it and compacted. The mold (stick) is taken out leaving an air tunnel in the sawdust.

The stove is lit by passing a glowing splint through the pipe. It can also be lit by placing a piece of burning cardboard or paper in the air tunnel through the top. The first observed setback that militated against the adoption and widespread use of the SDS in Ghana had to do with the stove model propagated. In either of the models described earlier, the burner compartment also serves as the ash compartment. When the stove is in use, some ash settles at the bottom of the stove. This ash can and does reduce the air intake of the stove, resulting in increased smoking and low combustion efficiency. The sawdust in these stoves also tends to cave in during use and block the airway of the stove. When this happens, profuse smoking occurs, often preventing further cooking.

The smoke and low rate of combustion, by themselves, can discourage the use of the sawdust stove. The smoke from the sawdust fire is rather acrid and can be quite irritable to the eyes. This is easily perceived by any user. Not easily perceived though is the health threat posed. The sawdust fire is a smoldering one, and the reddish glow, visible in the dark, is a sign of incomplete combustion. This incomplete combustion leads to the production of harmful gases, one of which is carbon monoxide (CO), (Anderson, 1975). The above shortcomings of the stove implied that an improved model was required that will increase the combustion efficiency, thus reducing the harmful by-products of the stove.

With regards to the materials for construction of the stove, it appeared a lot of emphasis was placed on the use of metal scrap, used oil cans and similar items. Of course these are cheaper in cost, but very unaesthetic and unappealing. The metal can also buckle up when it gets hot, especially when the utensil sits directly on the stove. This, together with the setbacks mentioned earlier, in no small way, contributed to the very low patronage of the sawdust stove.

To add to these setbacks was the problem of lighting the stove. Lighting the stove through the metal pipe (Fig.1 (a)), was found to be time-consuming and at times quite frustrating. This is because in the course of lighting the stove by this method, one partially blocks the ventilation duct. This causes increased smoking during lighting. The lighting problem is evidenced by the several lighting methods suggested in the literature on sawdust stoves. Some suggest the sprinkling of paraffin oil on top of the compacted sawdust, while others suggest the placing of folded paper in the stove and lighting it (Saubolle, 1974). It should be noted that when the sawdust is well dried, it is lit easily by the latter method.

Fanning the stove, during lighting, would have facilitated its lighting a great deal. However, fanning is not effective in the earlier model (Saubolle, 1974). The reason is that most of the air from the fanning simply passes out from under the stove as there is no deflecting surface to force it up the air tunnel. Fanning the sawdust fire through the metal pipe, in the model found in Ghana, is not easy either. The pipe is not wide enough. This most probably accounts for fanning not being mentioned as a necessity in the lighting of these stove models.

There were also a few over-enthusiastic inaccuracies reported on the working of the SDS. For instance, the sawdust fire was supposed to be smokeless and at times "burning blue." From personal experimental observation, the sawdust fire is a smoldering one and always smokes. This, among others, had also been observed much earlier by Anderson (Anderson, 1975). These problems associated with the SDS, did not endear the stove to users, and soon it was put aside.

The Technological Challenge of the Existing Model

The study revealed a major technological challenge or limiting factor to the use of the existing SDS models with or without a separate ash compartment. For those who would use the existing SDS, a problem arises when it comes to getting the sawdust from the place where it is produced to the house for use. Access to charcoal or fire-wood is easier as these are brought practically to the consumer by traders. The problem of accessibility of sawdust often proves to be a serious detracting factor in the use of SDS in general. A possible solution to the problem of accessibility of sawdust would be to enact proper disposal requirements. Such requirements may encourage sawmill operators to dispose of sawdust, produced as production waste, to SDS users and other sawdust users inexpensively. Presently, sawmill operators periodically open up and allow the general public to come in and take whatever wood waste they may require. This frees the production sites of wood waste.

An alternative solution to the problem of accessibility of sawdust is the use of other granular and compactable material as fuel for the sawdust stove. Such material could be chopped up grass or slightly pounded grass. This is an indirect way of compacting grass for use as fuel, a method proposed in some literature (Micuta, 1985). Broken up pieces of wood and twigs, which are difficult to use in the traditional fire place for cooking can be compacted in the sawdust stove. With regards to the construction deficiencies observed, a stove model is being proposed by the author, which, it is hoped, will improve on sawdust combustion efficiency and the robustness of the stove.

PROPOSED ADAPTION

One specific feature of the proposed stove model is that it has a separate ash compartment (SAC).

This is created by using an intermediate plate (Fig. 1(b)) that divides the cylinder space into an ash compartment and a burner compartment. The SAC reduces the tendency of ash and partially burned sawdust of blocking the ventilation duct of the stove and increases the air intake of the stove. This in turn will improve the sawdust combustion efficiency and so reduce harmful emissions from the stove. The other feature is that the cylinder is of 2mm mild steel, which is capable of withstanding greater cooking pressures. This makes the proposed stove model more robust and of course more expensive. The extra expense is expected, however, to be offset by savings made from the relatively longer time use of the stove.

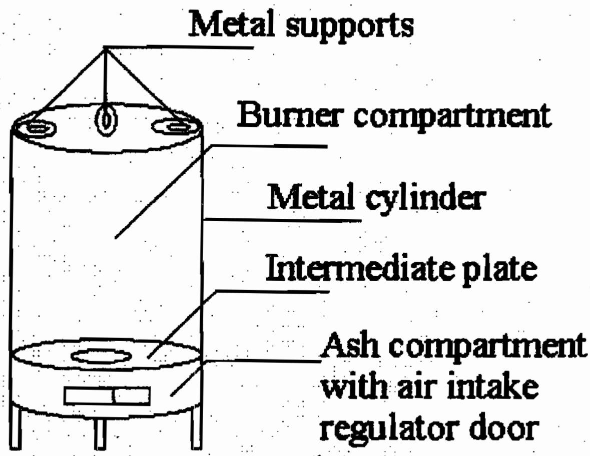


Fig. 1(b) SDS with separate ash compartment.

Construction of the SDS with a Separate Ash Compartment (SDS-SAC)

This proposed adaption SDS model consists basically of a metal cylinder. About three quarters (3/4) of the height of the cylinder down, an intermediate metal plate is placed on ledges welded to the inner part of the cylinder (fig.1 (b)). This plate divides the cylinder into a burner compartment above it and an ash compartment below it. Metal rings, welded to the top of the cylinder, serve as supports for the cooking utensil. Angle iron stands raise the stove from the ground. A sliding door over the ash compartment serves as an air-intake regulator. A wooden mold, a compacter and a fan (Fig.1(c)) are integral accessories of the stove. The lower part of the mold has a diameter slightly less than that of the hole in the intermediate plate, so as to fit into the plate during loading the stove with saw dust.

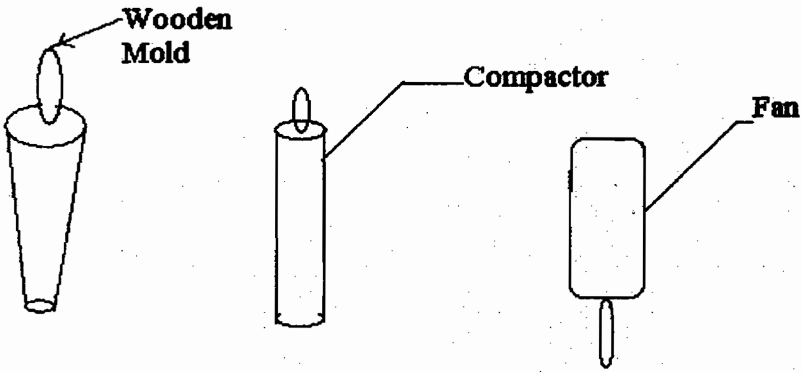


Fig.1(c) Accessories to the SDS

Preparing the SDS-SAC for Use:

Preparing the SDS-SAC for use involves two major activities: Loading and lighting the stove.

Loading:

The lower part of the wooden mold is placed in the hole in the intermediate plate. Moderately dry sawdust is packed around the mold to the brim. (If the sawdust is very dry, fine dust of it rises during loading and can be uncomfortable). The compactor is used to compact the sawdust down to about five centimeters (5cm) or two inches (2 in) below the top of the metal cylinder. This space allows the utensil to sit on the supports without touching the sawdust; and rising hot air and smoke to escape from under the cooking utensil when the stove is lit. After compacting, the mold is gently taken out. This leaves an inverted, truncated conical tunnel, in the shape of the wooden mold. The tunnel rises from the intermediate plate to the upper level of the compacted sawdust,

(Fig.2). The stove is now ready for lighting.

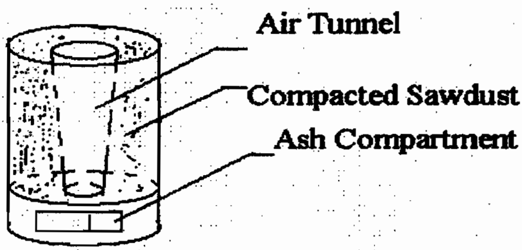


Fig. 2 Compacted Sawdust and Air Tunnel

Lighting Up:

The stove can be lit in several ways. For a neat "standard way", a stiff paper (cardboard) is folded and bent as shown in Fig. 3. It is then inserted, through the ash compartment, into the lower part of the air tunnel created. The paper may be moistened with paraffin oil (e.g. kerosene) to make it easier to light. When the burning cardboard is placed in the air tunnel, air convection current is set up. The ensuing draught, up the tunnel, causes the lower part of the sawdust lining the tunnel, to light up. The paper (or cardboard) lighter is then taken out. The fire is fanned gently through the ash compartment. The increased ventilation decreases the smoke emission and enables the fire to burn faster up the tunnel.

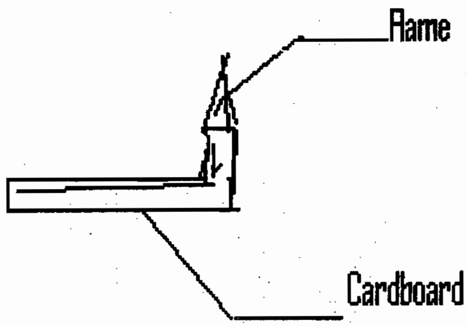


Fig.3 Cardboard lighter

Another way of lighting the stove is to put broken pieces of grass into the lower part of the tunnel from the top. The grass is then lit from the bottom with a match or other source of fire, through the ash compartment. The stove fire may also be lit by dropping a piece of burning charcoal onto the grass from the top. A thick cloud of smoke billows, due to the partial blocking of the ventilation tunnel.

Fanning the fire gently through the ash compartment enables the grass to burst into flame. The smoke is reduced considerably when this occurs. As soon as the sawdust in the lower part of the tunnel is glowing nicely, the stove is ready for use. While in use, the fire burns gradually up the tunnel until the whole length of the tunnel is beautifully aglow.

A comparison, through practical use of an existing model and the proposed model, was carried out and the observed differences summarized in Table 1. When the sawdust is well-dried, both stove types burn well, except for the caving in of sawdust in the model without the separate ash compartment SAC.

Table 1: Comparison of Proposed SDS-SAC and Existing Stove Model with no SAC

Existing Stove Model	SDS – SAC
Construction material: Thin metal scrap with a tendency to buckle when heated	Thicker metal cylinder (2mm mild steel). Does not buckle when heated
Smokes more than the SDS-SAC, a sign of lower combustibility	Smokes less, a sign of relatively higher Combustibility
Sawdust often caves in during use and blocks the air way of the stove, leading to excessive smoking.	Sawdust does not cave in. Ash falls through hole in the intermediate plate to the ash compartment. No blocking of ventilation duct.
Sawdust fire in this stove is not used to the full and cooking can be stopped prematurely when excessive smoking occurs.	Sawdust fire in this stove can be used to the full.

Source: Field Survey, 2007

Money-Saving Use of the Sawdust Stove (SDS-SAC):

An example of savings made by using the sawdust stove (SDS-SAC) is based on practical experience of the author's domestic fuel use. Table 2 below presents a summary of the type and quantity of fuel used and the duration of use.

Table 2: Hybrid Use of Gas, Charcoal and Sawdust

Type	Quantity	Approximate Duration of Use
Gas	One (1) 14 kg cylinder	3 months
Charcoal	2 bags	One (1) month
In using gas, charcoal and sawdust:		
Gas	One (1) 14 kg cylinder	4 months
Charcoal	2bags	8 months
Sawdust	3 bags	One (1) month

Source: Experimental Observation

From the above observations, there is no significant change in the duration of use of the gas. In charcoal use, however, the duration of use has been considerably extended. This is so because the charcoal was almost completely replaced by sawdust. The replacement however, is convenient where charcoal was already being used. In this however, a well ventilated area is required due to the acrid smoke of the sawdust fire, even when the smoke is barely visible. The gas stove was used when it was necessary to skip the time required to load and light either the charcoal pot or the SDS. In bad weather conditions, when cooking had to be done indoors, the gas stove or charcoal pot was used. The charcoal was used mostly to cook or heat up water to be used as preheated water for cooking and for other domestic hot water needs. For these needs, the sawdust stove easily replaced the charcoal pot to a large degree.

For the eight months duration of use, fourteen extra bags of charcoal would have been required. These are replaced by twenty-four bags of sawdust. The sawdust was obtained virtually free from a nearby sawmill, except for a token payment for loading and offloading the sawdust. The sawdust, otherwise, had to be taken out of town in a pickup truck for disposal by the sawmill operators. So the operators were only too glad to give the sawdust away freely. Considering the amount of sawdust used in the period and the amount of charcoal that would have been required in the same period, saving on fuel cost, through the use of the sawdust stove, is possible only if the sawdust can be obtained inexpensively. A comparison of the SDS-SAC and the Charcoal Stove (pot) is made in Table 3.

Table 3: Comparison of the SDS - SAC and Charcoal Stove Fires

Charcoal Stove Fire	Sawdust Stove Fire
Smokes less than SDS fire due to the more complete combustion of the charcoal.	Smokes much more, due to incomplete combustion of the sawdust.
Smoke less acrid (less smarting in the eyes)	Smoke quite acrid (smarts the eyes)
Burns faster i.e. higher rate of combustion than SDS fire	Burns slowly (smoulders) i.e. lower rate ofcombustion.
Can and does have to be stoked when long time use is required.	Cannot be stoked, but burns for a much longer time. than a comparative charcoal fire.
Can be used indoors with reasonable ventilation	Cannot be used indoors. Suitable for use only in open well-ventilated place.

Source: Experimental Observation – 2007/2008

Increasing the Rate of Combustion of Sawdust in the Sawdust Stove (SDS-SAC)

It was observed that if a piece of charcoal (about 80gm) was added to the sawdust fire, the fire, on being fanned, burned with a flame, a sign of a higher rate of combustion. At the increased rate of combustion, water boiled faster than when the charcoal was not added. When the charcoal is added, there is initially some extra smoking. The smoking decreases considerably however, when the sawdust bursts into flame.

Observed Heat Output Profile of the Sawdust Stove (SDS-SAC)

From practical use of the stove, it is observed that as the sawdust fire burns gradually up the tunnel, the heat output of the stove rises. When all the sawdust lining the length of the air tunnel is aglow, the heat output tends to be steady. This is because the supply of fresh sawdust that keeps the fire burning is only the sawdust lining the air tunnel. Each layer of sawdust is scorched up by the fire at the base of the air tunnel and catches fire consequently, as the previous layer turns to ashes. As the sawdust burns, the air tunnel widens from the center outwards. It is only the sawdust lining the air tunnel that burns, so heat from the sawdust fire is mostly directed upwards. The surrounding unburned sawdust reduces heat transfer through the wall of the stove.

Method and Selection of materials for tests

To confirm the observed heat output trend (profile) of the sawdust fire (SDS-SAC), heat output tests were carried out. "Heat output" here refers to the useful heat output from the sawdust fire. The useful heat output of the stove was measured indirectly by measuring the temperature variation of water heated on the stove. The measurement of the temperature changes of water is based on the assumption that the heat capacity of the water and the pot is constant, that is (mw Cw + mpCp) = constant (say k). Then the heat output of the stove (**Hout**) that goes to heat up the pot and the water will be **Hout** = **k** $\Delta\theta$. In which case, **Hout** is directly proportional to the temperature change, $\Delta\theta$, where mw, mp are the masses of the water and the aluminium pot respectively; and Cw and Cp, the specific heat capacities of the water and the material of the pot respectively. The proportionality of the heat output and the temperature change is valid only where $\Delta\theta$ is measurable.

A 3kg capacity SDS-SAC was constructed and used throughout the study. This size of the stove was based on the average size of the existing SDS models found, that is those without separate ash compartments. Sixty (60) liters of water was used. This is the capacity of a size 20 aluminium pot that was used in all the tests. This amount of water also, from practical experience of using the stove (SDS-SAC), can take up the maximum heat output of the stove without boiling. The issue of the water not boiling is essential in that this allows the temperature changes of the water to be measured easily. If the water boiled, the temperature change measurements would be more involving, since then, the heat change of steam has to be considered.

Confirmatory Tests of Observed Heat Output Profile of the sawdust stove (SDS-SAC):

Materials for the confirmatory heat output tests

(i) A 3 kg capacity sawdust stove (the proposed model)
(ii) 3 kg of dry sawdust
(iii) an alcohol- in- glass thermometer (0 -110°C)
(iv) 60 liters of water
(v) a size 20 (i.e. a 60 liter capacity) aluminium cooking pot. The pot is covered with a wooden lid that has a hole in it to accommodate the thermometer
(vi) a watch
(vii) a top loading balance (0 – 5kg; 0.1kg readability)
(viii) 80 gm of charcoal

Method

Test I: Confirmatory heat output test at normal rate of combustion

Three kilograms (3 kg) of sawdust was weighed out and the stove loaded with it. The sawdust was compacted and lit as shown earlier under the heading "Preparing the stove for use". The aluminium pot was put on the stove. Water was fetched from the tap and its initial temperature measured. The water was then poured into the pot up to the 60 liter mark. The thermometer was fitted firmly into the hole in the centre of the lid, such that its bulb was completely immersed in the water, when the lid was put on the pot. Thermometer readings were then taken every thirty minutes until almost all the sawdust was burned up.

Test II: Confirmatory heat output test at increased rate of combustion.

To confirm that the rate of combustion of the sawdust in the stove was increased when a piece of charcoal (about 80gm) was added to the sawdust fire, the stove was emptied and cleaned of ashes from the earlier test. It was then loaded again with 3 kg of sawdust, compacted and lit. The piece of charcoal, the size of which was such as not to block the air intake hole in the intermediate plate, was placed at the base of the air tunnel, on a stand constructed for the purpose and placed in the ash compartment. The stove was fanned through the ash compartment/ventilation duct until the sawdust burst into a flame that rose from the base to the top of the air tunnel. The aluminium pot, which had cooled down by this time (the following morning after Test I) was emptied of the water that was in it and cleaned. A fresh amount of water was fetched and its initial temperature measured. The pot was placed on the stove and filled with the water up to the 60 liter mark. The wooden lid, fitted with the thermometer, was placed on the pot and thermometer readings taken very thirty minutes until all the sawdust was burnt up.

RESULTS AND DISCUSSIONS

The water temperature readings for both tests are presented in Table 4 below.

Reading No.	Time/h	Water temperature with no Charcoal added (T)/°C	Water temperature with charcoal added (Tc)/°C
1	0900	29	28
2	0930	32	55
3	1000	37	64
4	1030	40	73
5	1100	44	78
6	1130	48	81
7	1200	53	84
8	1230	56	87
9	1300	59	86
10	1330	64	85
11	1400	65	82
12	1430	66	79
13	1500	67	75
14	1530	66	73
15	1600	65	70
16	1630	64	66
17	1700	60	64
18	1730	57	61
19	1800	54	58
20	1830	52	55
21	1900	50	54
22	1930	50	52

Source: Experimental Data (2007)

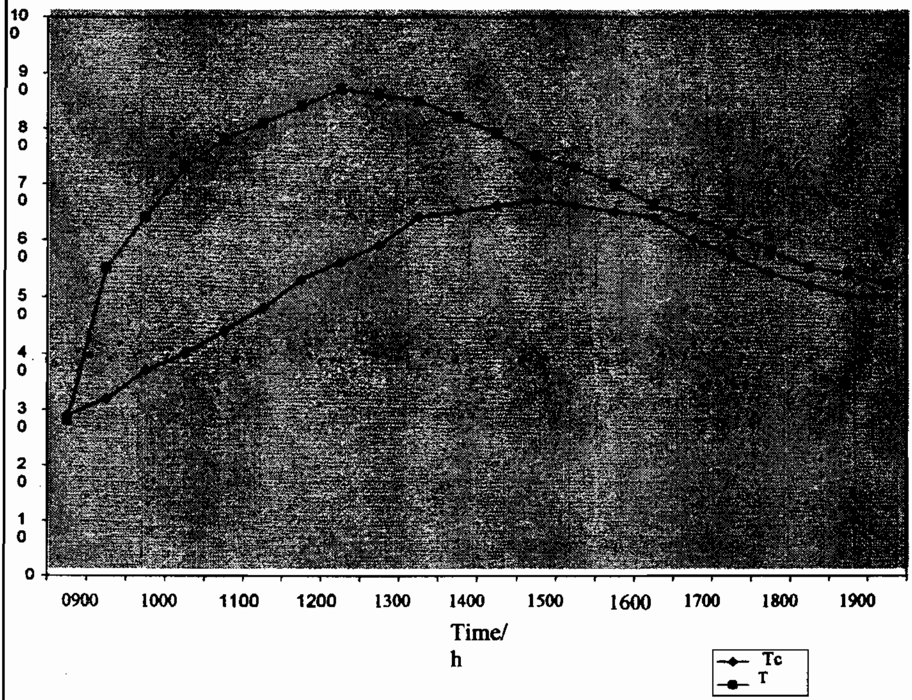
Table 4: Water temperature readings for sawdust combustion with and without charcoal

For the water temperatures with no charcoal added, from an initial temperature of 29°C at 9.00 O'clock in the morning, the water temperature rose to 37°C in one hour. It then rose to a peak of 67°C in six hours from the start of measurements. The time measurements have been recorded starting from 0900h to 1930h, instead of from 0 to 630min, at 30 minute intervals. This form of recording shows not only the time intervals, but also that the combustion of the 3kg of sawdust used in the experiment, lasts from morning through the afternoon to the evening.

At the increased rate of combustion, caused by the addition of a piece of charcoal to the sawdust fire, the water temperature rose, from an initial temperature of 28°C, to a temperature of 64°C in one hour, as opposed to a temperature of 37°C in the same time when no charcoal was added. With the charcoal added, a peak water temperature of 87°C is attained in three and a half (3.5) hours as compared to a peak temperature of 67°C attained in six hours, when no charcoal is added to the fire. That is the water attains a higher temperature in a shorter time when a piece of charcoal is added to the sawdust fire.

The results thus confirm the observation that the rate of combustion and, consequently, the heat output of the sawdust in the stove increases when the charcoal is added. Thus also a way has been found around the hitherto seemingly insurmountable problem of increasing the rate of combustion of sawdust in the sawdust stove. Using the results of the water heating tests, presented in Table 4, a graph of water temperature against time was plotted. The graph is presented in Fig. 4 below.

Fig.4 Graph of water temperature against time with no charcoal added (T) and with charcoal added (Tc)



From the graph, the heat output profile of the sawdust fire, with no charcoal added, is similar to that with a piece of charcoal added. In both cases, the heat output of the stove rises to a peak and then declines slowly over a long period. This makes the sawdust stove quite suitable for use where an extended period of steady heat output is required. The heat output profile obtained pertains to any sawdust stove, be it with a separate ash compartment or not. The duration of the heat output however depends on the saw-dust capacity of the stove. A smaller amount of sawdust will burn out in a shorter time.

To prevent smoke from the SDS irritating the eyes, a protective hood-cum-smoke guide, (Fig. 5) was devised to channel the smoke upwards and away from the user. This accessory is quite handy when the dish being cooked requires frequent or constant attention, e.g. stirring.

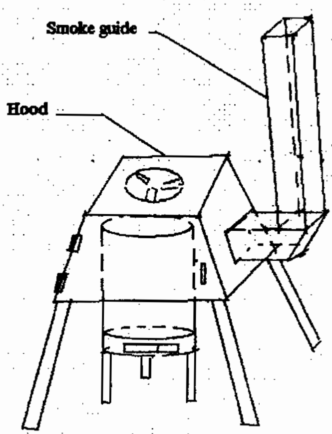


Fig. 5 Hood-cum-smoke guide

A Summary of Observations made from Practical Use of the SDS-SAC

In the course of everyday use of the SDS, the following observations were made:

(a) Duration of heat output:

(i) Depending on the amount of air entering the stove, it takes between 15 to 30 minutes for the sawdust lining the air tunnel to be fully lit up, the more the air influx, the shorter the time. The heat output of the stove tends to be steady once the whole length of the air tunnel is lit. The air tunnel widens from the center outwards as the sawdust smolders.

(ii) The steady heat output state lasts for about six (6) hours, for a three kilogram (3kg) capacity stove (i.e. a stove whose full load of sawdust is 3kg). The heat output then decreases gradually until all the sawdust is burnt up.

(b) Increasing the rate of combustion:

(i) The rate of combustion of the sawdust, and hence the heat output of the stove, can be increased considerably by adding a piece of charcoal (about 80gm) to the sawdust fire at the base of the air tunnel. At normal rate of combustion (that is no charcoal added), 60 liters of water attains a temperature of 37°C in one hour and a peak temperature of 67°C in six hours. At increased rate of combustion (charcoal added), 60 liters of water attains a temperature of 64°C in one hour and a peak temperature of 87°C in three and a half (3.5) hours.

(ii) When the charcoal is added, there is initially some extra smoking. When the fire is fanned, the sawdust burns with a flame due to increased combustion. The flame burns until the piece of charcoal is burnt up.

(iii) The bottom of the utensil turns shiny black during use on the SDS. This is likely to be due to a buildup of wood tar (creosote), as is the case with all wood fires.

(iv) Although smoke from the stove is reduced to an almost unnoticeable level, when the stove is well lit and there is a good influx of air, there is always some amount of smoking from the stove.

CONCLUSION

The SDS-SAC can provide steady heat for several hours. This makes it suitable for keeping water hot or food warm for long periods without stoking. For these same periods of heat output, a charcoal fire would need stoking.

The rate of combustion of sawdust in the SDS-SAC can be increased considerably (almost by 50%) by adding a piece of charcoal (about 80gm) to the base of a lit sawdust stove. Where sawdust can be obtained inexpensively as compared to the cost of charcoal, considerable savings can be made on fuel cost by using the sawdust stove alone or with the charcoal stove.

The use of sawdust in the SDS is one way of recycling a waste product and an environmental pollutant – sawdust. This use contributes to sound waste management and environmental protection and thus to national development. The sawdust stove always smokes, emitting toxic gases, and so is suitable for use outdoors or in open cooking places.

RECOMMENDATIONS

The SDS is recommended for cooking any kind of food, but especially for foods that take a long time to cook, e.g. cowpeas, bambara beans, soups and the like. To cook these foods, the rate of combustion of the stove is increased by adding a piece of charcoal at lighting, to bring the pot to boil. It is then left to boil without any further addition of charcoal. The SDS is most recommended for heating water in large quantities and maintaining it hot over long periods, to be used as pre-heated water for cooking and also for other domestic hot water needs such as bath, dish-washing and blanching.

The use of the SDS can be relatively more convenient for open-air tea sellers and "chop bar" operators who have to be stoking the charcoal "pot" frequently to keep the water hot or the soup warm, for several hours. Larger capacity sawdust stoves are recommended for pito-brewers and hot water vendors.

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