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SAZAWA CHARCOAL STOVE DESIGNED FOR EFFICIENT USE OF CHARCOAL

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Abstract
Energy is the critical input in development activities. Without efficient supply and use of energy, there cannot be sustainable development. Development and promotion of energy technologies improves living standard by contributing to poverty reduction. Developing countries are in energy crisis, as the majority in rural areas have no access to energy sources apart from biomass and human energy. Women spend most of their time collecting firewood instead of undertaking productive activities. In urban areas charcoal is the major source of fuel for cooking purposes in households, Small and Medium Enterprises (SMEs) and institutions. Based on statistics 90% of Tanzanian have no access to electricity.
TaTEDO is one of the stakeholders, who develop and promote various energy technologies. In this paper development of improved charcoal stove called Sazawa has been presented. Sazawa consumes less charcoal compared to traditional charcoal stove. The Sazawa stove consist of ceramic double liner and insulation material, which reduce heat losses.

*Key words; Improved charcoal stove, Efficiency, Deforestation, Poverty, Employment***.**

1. INTRODUCTION

More than 90% of the country's population derive their energy requirements for cooking heating and provision of process heat from wood fuels (charcoal and firewood). Utilization of wood fuels through traditional technologies i.e. stoves, ovens and kilns is characterised by low efficiency with tremendous heat energy losses through conventional heat transfer methods [1]. Through adaptive research and development (R&D) activities TaTEDO has managed to improve efficiency of developed charcoal stoves through designing and selection of proper materials. Improved efficiency of charcoal stoves has resulted to reduction in quantity of charcoal stove consumption as well as cost in terms of time and money, because amount of charcoal and time used in cooking has been reduced by 50%, as such rate of deforestation reduced too. In this paper, Sazawa charcoal stove one of the developed improved charcoal stove at TaTEDO has been presented. Since energy is an important input in every economic activity, ensuring clean energy provision will both contribute to the poverty reduction and environment conservation. Small Entrepreneurs trained by TaTEDO have established small workshops dealing with production of Sazawa as it requires small investment capital.

2. The charcoal stove

Improved Charcoal Stove (ICS) development originated from traditional charcoal stove, which was introduced by Indian traders in 1900's in Tanzania. Since 1990 [7], TaTEDO has been dealing with development of Renewable Energy Technologies (RETs), adaptive researches, development and promotion of the technologies to the communities through awareness creation as well as training on technology. Various types and designs of different sizes have been developed and disseminated in the country. SAZAWA charcoal stove among the stoves developed by TaTEDO uses charcoal as fuel (Figure 1).

Sazawa charcoal stove is made of metallic part called cladding, two clay liners and binding materials mainly is the mixture of cement, water and vermiculite or rice husk ashes as a substitute to vermiculite. Binding materials are used to bind together the two clay liners and the cladding. Other parts of Sazawa include a bent round bar that acts as pot rests, legs, handles, metallic belt, ashes collector and door for primary air inlet. Sazawa intends to save significant amount of charcoal consumed to cooking meals in household.

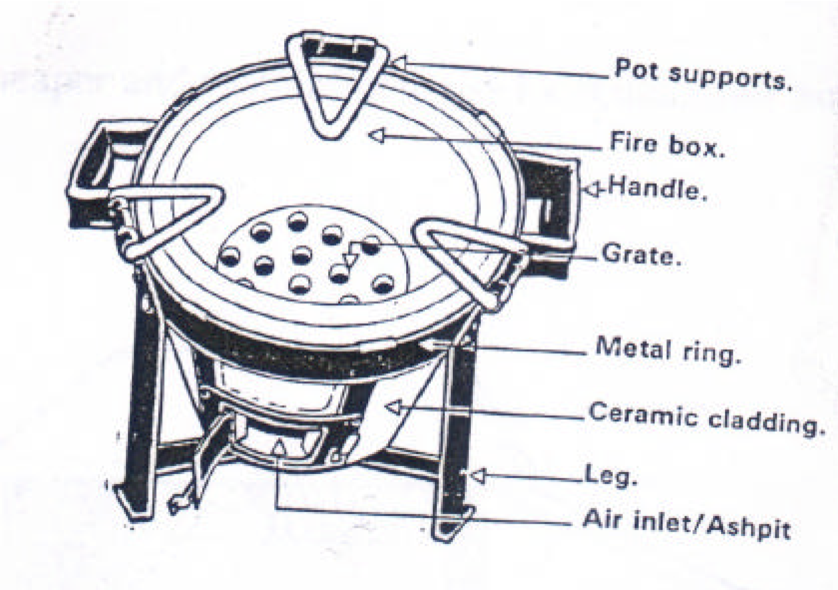

Figure 1: Different parts of Sazawa charcoal stove.

Figure 2: Sazawa Charcoal Stove

Sazawa Specifications
Firebox mean diameter, D: 250mm
Height, H: 220mm
Charcoal stove useful heat efficiency, $?_c$: 44.3%
Fuel type, : Charcoal
Primary holes diameter, d: 15mm-22mm
Use: Cooking.

3. Performance of Sazawa

The metal outer part of Sazawa, supports the ceramic liners and provides and provides legs for the stove. The ceramic double walls liners present in Sazawa stove has two fold purposes; first it works as a firebox, and secondly as a stove housing;

3.1 As firebox

At the bottom, the ceramic liners have holes, which are punched while the liner is wet, diameter of each hole depends on the size of the respective liner. It ranges from 15mm to 22mm. Diameter for liners ranges from number nine (# 9) to number eighteen (# 18) and a total number of holes is increases from 19 to 44. After being dried for recommended number of days depending on the weather, the ceramic liner undergoes firing in the kiln at temperature of 900^0C for about eight hours. The main reason of firing is to impart resistance to hot shocks as well as improving hardness. The presence of holes not only facilitate primary air supply (air supports combustion) but also provide means of passage of ashes to ashes collecting tray after combustion of charcoal in the firebox.

3.2 As a stove housing

Apart from being a firebox ceramic liner of Sazawa accommodate burning charcoal. Ceramic liner has grate with punched holes, these holes are punched before drying and firing, the other function of holes apart from allowing air and falling of ashes is to accommodate burning charcoal. Presence of ceramic housing lowers construction cost of sazawa through avoidance of using large amount of metallic sheets for cladding fabrication. Large percentage of Sazawa charcoal stove surface is covered by ceramic liner, whose raw materials is clay and rice husk ashes which are not imported like metals.
Since there is no direct contact between metallic cladding and burning charcoal, due to the double walls of clay liner and insulation materials there exist significant reduction in heat losses due to conduction. Both ceramics and insulation materials have low heat conductivity coefficients, thus furthermore minimizing heat losses through conventional heat transfer methods. Table 1 shows efficiency of charcoal stoves developed by TaTEDO, including Sazawa as tested by the former Mechanical Engineering Department (Energy Technology Section) currently the Department of Energy Engineering of the Prospective College of Engineering & Technology [2]. Heat energy efficiency was analysed by two methods, these are boiling test and constant heat output method.

4. Experiments on Sazawa

4.1 Boiling Test Method on determining Sazawa efficiency

In this method, efficiency, $?_c$ is defined as the ratio of useful heat energy to the input heat energy[5];

$$h_C = \frac{Useful\,heat\,energy}{Input\,heat\,energy} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Useful heat energy is the sensible and latent heat absorbed by boiled water whereas input heat energy is the one, which was released from the burning charcoal. With this definition, the useful heat energy efficiency of charcoal stove ,$?_c$, can be expressed mathematically bellow ;

$$h_C = \frac{M_W C_{PW}(T_b - T_i) + M_{We} L_V}{M_{Charcoal\ fuel\ used} CV_C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where;

M_w = the initial mass of water in Kg
C_{Pw} = Specific heat capacity of water= $4.2*10^3 JKg^{-1}$
T_b = Boiling temperature of water in degrees Centigrade
T_i = Initial temperature of water in degrees Centigrade
M_{we} = Mass of water lost due to evaporation = (Mass of container with water before water boiling-Mass of container with water after boiling) in Kg
L_v = Latent heat of vaporisation of water= $2.258*10^6 JKg^{-1}$
$M_{Charcoal\ fuel\ used}$ = Mass of charcoal used = (Mass of Sazawa with charcoal before combustion-Mass of Sazawa with charcoal after combustion) in Kg
CV_c= Calorific value of charcoal= $2.8*10^7 Kg^{-1}$

4.2 Constant Heat Output Method on determining efficiency of Sazawa

Like in the previous method, efficiency, **$?_c$**, was determined as the ratio between the useful heat energy to the heat energy absorbed by water as sensible heat only, the input energy is that released from the burning charcoal.

$$h_C = \frac{nM_W C_{PW} T_{Wi} + M_{We} C_{PW}(T_{\max} - T_{wi})}{M_{Charcoal\ fuel\ used} CV_C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where

n = Number of times the water temperature reached 90^0C

M_w = Initial mass of water in Kg

C_{Pw} = Specific heat capacity of water= $4.2*10^3 JKg^{-1}$
T_{wi} =Initial temperature of water in degrees Centigrade
T_{max}= Maximum temperature of water than 90^0C

$M_{Charcoal\ fuel\ used}$ = Mass of charcoal used = (Mass of Sazawa with charcoal before combustion- Mass of Sazawa with charcoal after combustion) in Kg

CV_c= Calorific value of charcoal= $2.8*10^7 Kg^{-1}$

By using both equations, 1 and 2 efficiencies under each formula, were established for various charcoal stove, and the following is the table of results

Table 1: Efficiency and Summary losses

S/N	CHARCOAL STOVE TYPE	EFFICIENCY	
		Boiling Test	Constant Heating
1	Traditional Metal	22.7	15.22
2	Straight wall	36.45	18.49
3	Bell (Bottom), #11	28.94	19.64
4	Sazawa	44.30	23.11
5	Triple legs	27.04	19.68

SOURCE; [2]

4.3 Discussion of the experimental results

The experimental results are represented in the bar chart graphs (Figure 2) as shown below. For all five charcoal stoves, by both boiling test and constant heat output methods, efficiencies are computed by using equations 1,2 and 3. Presentation facilitates easiness of results comparison.

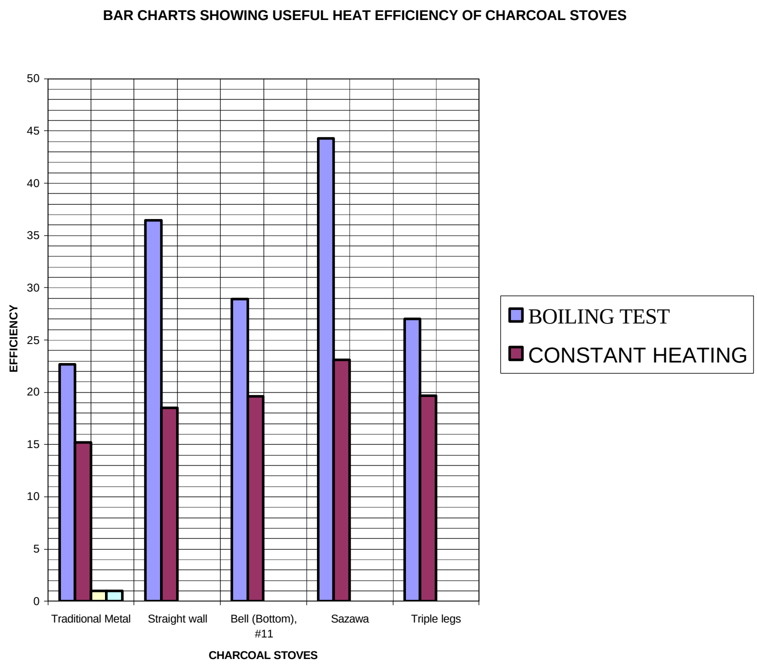

Figure 3: Efficiencies of charcoal stoves determined by both, Boiling Test and Constant Heating methods

From the bar graph it is revealed that for both methods of efficiency determination Sazawa has highest efficiency of all five charcoal stoves.

5. Advantages of using Sazawa

5.1 Reduction in deforestation rate

The National Forest Policy of 1998 has a goal to enhance contribution of the forestry sector to sustainable development of Tanzania and the conservation and management of natural resources for the benefit of the present and future generations. One of the objectives of that policy is to enhance national capacity to manage and develop the forest sector in collaboration with other Stakeholders. In 1999 it was found that 40.4 Million m^3 of wood, of which 26 Million m^3 of wood were consumed in rural areas as fuel wood (24 Million m^3 of wood consumed for house hold cooking and 2.03 Million m^3 of wood were consumed in rural industries whose priority list include tobacco curing, fish smoking, salt production, brick burning, tea drying, processing of beeswax) and 13.4 Million m^3 of wood [3] were consumed in the urban areas mainly as charcoal. TaTEDO as one of the stakeholders in development of improved of charcoal stove technologies and Sazawa being one of those stoves with high efficiency of useful heat, would reduced consumption of charcoal by 50% and possibly deforestation rate due to such application would also be decreased by the same percentage. It is estimated that annual consumption for traditional stove is 1080/kg per household while for improved charcoal stove is around 370kg/year per household. Annual charcoal saving is about 710kg per household per year, which is equivalent to around 60 trees [4].
Apart from reducing deforestation rate, the following are added advantages of using Sazawa;

Poverty reduction by creating employment and Income generation
The growth in demand of improved charcoal stoves has created employment opportunities and income generation in small enterprises. **Timesavings**; women and children are the main suppliers of firewood accounting to 60% and 23% respectively; men account 13% and house helpers 4%[4]. Using improved charcoal stoves like Sazawa would reduce time utilized in fetching firewood and avail the same to other development activities.

Long shelf life
Shelf life of improved charcoal stove ranges from 30 months to 36 months, furthermore they can undergo repair after end of shelf life or destruction, whereas traditional charcoal stove its shelf life is 6 month only and also cannot undergo repair after end of its shelf life.

Cost reduction
Due to increased efficiency of Sazawa charcoal stove, rate of charcoal consumption is reduced by 50% compared to traditional charcoal stoves. The reduction in charcoal consumption is proportional to cost reduction in terms of money.

Safety
Increase in efficiency reflects improvement in combustion properties of charcoal, and indicates reduction in emissions of smoke and other green house gases, which may endanger health of the user and contaminate biosphere (global warming). Moreover heat losses due conduction and radiation is minimised due the presence of insulation zone and ceramic liner, therefore user is safe from burning.

6. Discussion and recommendations

In particular, factor that contributes to higher efficiency of Sazawa charcoal stove is due to the minimum heat energy losses by convectional methods of heat transfer. This minimum heat loss has been contributed to, by low heat conductivity coefficient of both ceramic materials used as well as for materials used to join inner and outer ceramic liners. The insulation enables Sazawa charcoal stove to maintain low body surface temperatures, which results into low convective losses. Grate of the combustion chamber also influences the high efficiency of the stove.

It is concluded that if many Tanzanians as well as people in other countries where artificial energy is not affordable, use of Sazawa design, could be promoted and contribute to reduction in charcoal consumption which indirectly reduce rate of deforestation rate as well as ensuring safety among users. Furthermore biosphere contamination rate due to emission of greenhouse gases will be retarded as application of Sazawa in cooking ensures charcoal use reduction as compares to traditional charcoal stoves. In another dimension the use of Sazawa by small-scale food vendors could reduce charcoal consumption, this further contributes to cost curtailing resulting in increased profit and hence poverty reduction thereby improving living standards of the majority.

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