Review Article

A REVIEW OF IMPROVED COOKER STOVE UTILIZATION LEVELS, CHALLENGES AND BENEFITS IN SUB-SAHARAN AFRICA.

ABSTRACT

Many attempts to enhance cooking stoves have been implemented in sub-Saharan Africa (SSA). These programs aim to limit indoor air pollution, reduce the usage of fuel (charcoal), which reduces deforestation, alleviate the financial burden of energy costs on low-income people, and improve user health by lowering environmental toxins. Other objectives include reducing global warming and improving the social well-being of people in developing countries. The efficiency of the Improved Cookstove (ICS) programs has gotten mixed evaluations. Several of the projects fell short of their planned objectives, however some did. The use, challenges, and benefits of programs to enhance cookstoves across sub-Saharan Africa are examined in this article. It starts by looking at a few specific Cookstove technologies, which are divided into groups according on the fuels they burn and whether or not they are mobile. It has been found that factors such as the technical compatibility of the stoves with social expectations, the conformity to local needs and cultures, the attitude of the users, who are frequently reluctant to adopt new technology, and the price of the stove all affect how challenging the programs are. Also, "bottom-up" strategies ensure the program's success by involving users and regional artisans in the creation of a self-sustaining sector.

1.0 INTRODUCTION

1.1 BACKGROUND AND OVERVIEW

A clean, sound, and supportable climate is viewed as the underpinning of human existence. (Correa, et al., 2022). In order to accomplish sustainable development, there is a need for clean and efficient energy. A third of the world's population, or about 2.4 billion people, cook over open flames or inefficient stoves powered by kerosene, biomass (wood, animal manure, and crop waste), and coal, which causes dangerous indoor air pollution. In 2020, household air pollution was thought to be the cause of 3.2 million annual deaths, including over 237 000 deaths of children under the age of five. 6.7 million premature deaths per year are attributed to the impacts of household and ambient air pollution combined. Exposure to household air pollution increases the risk of developing non-communicable diseases such as lung cancer, chronic obstructive pulmonary disease (COPD), ischemic heart disease, and stroke. The highest health costs associated with the use of polluting fuels and technologies in households are borne by women and children who are often in charge of household tasks like cooking and collecting firewood. To reduce indoor air pollution and safeguard public health, it is crucial to increase the use of clean fuels and technology. These include biomass stoves that fulfil the emission targets in the WHO Guidelines, solar energy, electricity, biogas, liquefied petroleum gas (LPG), natural gas, and alcohol fuels. (World Health Organization , 2021). In addition, household air pollution (HAP) accelerates environmental change on a global scale. Biomass burning pollution and fuel demand-related deforestation speed up environmental change, which has significant effects on global health. (Donegan, 2018).

Accomplishing general admittance to clean cooking solutions by 2030 will require a significant speed increase in the direction of progress, as companies keep on rising out of the monetary aftermath of the COVID-19 pandemic (Clean Cooking Alliance, 2022). There is, consequently, the critical requirement for developing more clean and improved cook stoves for improving both the health of the public and environment. The reception of such cook stoves will prompt better ignition of the fuel, and further developed heat transfer prompting a decrease in charcoal demand and furthermore possibly lower expenses of cooking. (Berko, 2018). With a proceeded focus and designated execution endeavours, clean cooking can directly convey gains across 10 of the SDGs and add to an enabling climate for accomplishing the whole Agenda 2030. (Global Alliance For Clean Cookstoves, 2020).

Wood fuel (charcoal and firewood) make up over 70 percent of the national energy consumption in Zambia as only about 25 percent of the population has access to electricity. It is among the most important domestic fuels for low-pay families in Zambia. The nation's low pay is ceaselessly impacted by the low accessibility of maintainable, clean, and dependable energy. Cooking with solid fuels and inefficient cookstoves has adverse effects on human health and the environment. One initiative for sustainable energy provision in urban Zambia has been the introduction of improved cookstoves (ICS) based on sawdust pellets to replace traditional cooking on charcoal braziers that have dominated usage in homes since the 1930s. (Mulenga, 2019). In order to improve household air quality, requires defining “clean” for health at point of use. The WHO has set guidelines for the quality of indoor air. The guidelines discourage the use of charcoal in homes. An improved cookstove (ICS) depicts a stove with higher effectiveness or lower emissions than a customary stove, yet can incorporate an extensive variety of use. (World Health Organization (WHO), International Energy Agency

(IEA), Global Alliance for Clean Cookstoves (GACC), United Nations Development Programme (UNDP), Energising Development (EnDev) and World Bank, 2018)

Household energy consumption in urban Zambia is dominated by charcoal. Charcoal is widely available, affordable, and the first choice for domestic cooking for more than 75% of urban Zambians, regardless of income. The charcoal value chain also functions as an economic and social safety net by providing livelihood and employment opportunities for men, women and youth (Tetra Tech, 2021).

According to the world Bank (2014), dependence on solid fuel cooking in Sub-Saharan Africa (SSA) is a huge and developing issue. Nearly 700 million Africans (82%) utilize strong energies, for example, wood, charcoal, manure, crop waste, and coal, for their essential cooking needs-a number that will arrive at 850-900 million before the decade's over (The World Bank, 2014). This elevated degree of solid fuel use joined with family dependence on wasteful and risky traditional cookstoves, establishes a first-request general wellbeing emergency: HAP from solid fuel cooking kills almost 600,000 Africans yearly and is currently perceived as the second-biggest health risk factor. (The World Bank, 2014).

The world can't accomplish its objectives of tending to environmental change without moreover tending to the fuel energy need of millions for homegrown and institutional cooking. (Berko, 2018). However, the opposite is the case with rural areas of Zambia, where the population rely heavily on wood fuel. Charcoal is mainly preferred in urban households generally because it is easier to transport and store. However, it is burned using a traditional Mbaula (brazier), a small, round stove fabricated with metal by local tinsmiths. Charcoal use contributes to deforestation and air pollution, especially when burned indoors, also damages people’s health (Atteridge, et al., 2013).

Therefore, there is urgent need for development of an effective and efficient cook stove that can use various raw materials such as few woods, briquettes, pellets etc for improving the environment by reducing deforestation and health of the general community.

1. LITERATURE REVIEW

Most of the accessible literature on improved cooker stoves exhibits the evolution of cook stoves (from traditional to improved cooker stoves), design, fabrication, and testing. Over the long haul, these advancements have helped reduce greenhouse gas emissions and indoor air pollution. In addition, this study is to a great extent founded on multidisciplinary literature, and it draws on other insightful works on industry and improvement that contend that a connection exists between the advancement of stoves and the development of improved multipurpose cooker stoves. Moreover, the review centres on the advancement of improved multipurpose stoves and the optimal efficiency achieved to reduce emissions.

1.1 Historical Review of Cooking Stoves.

In general, it was noted that "suitable technology" went hand in hand with the global issue of deforestation and the significant consequences of high energy prices throughout the middle and late 1970s. This ushering process for cook stove projects is primarily or solely funded by international organizations. (Berko, 2018). Stoves address innovations as old as the revelation of fire and human civilization. The most established and realized stoves date from around 400,000 BC (China) to 500,000 BC (Europe), when men generally inhabited caves and made fires inside a circle of stones. In those chilly times, the reason for the fire was most likely to provide warmth. The utilization of fire to plan and protect food indeed became known in the Middle Palaeolithic, i.e., around 100,000 BC. (Westhoff & Germann, 1995). Following the advancement of domesticated animals and plant cultivation, as well as advancements such as ceramics and the development of mud houses, the stoves reverted to their natural fundamental structure, which has been around for roughly 12,000 years. It is comprised of stones that hold a cooking pot, a grill, or a ceramic platter. Placed inside the house, sheltered from the wind and rain, or outside in the yard, the stove became the focal point of the home. It was variable in size, simple to introduce, and multi-functional. Further, not only did it serve for smoking, boiling, or frying food but also for heating the space occupied by individuals and animals (Kshirsagar & Kalamkar, 2014). To secure the pot an arrangement of three stones was used, and this kind of fire was called the three stone fire (TSF). The TSF Not only made it possible for a cooking pot to rest securely on it, but it also helped protect the fire from the whims of the wind. The fundamental hindrance to a three stone fire is its low efficiency. Users primarily created the improvements to the cook stove design based on their own experiences. Despite human evolution and the advancements in fuel and stoves, the majority of the estimated 75% of people who live in the developing world still use three-stone or shielded fires for cooking (Kumar, et al., 2015). These drawbacks with the TSF are well documented. When using biomass fuel, smoke is vented into the house rather than outdoors, which leads to health concerns, wastes fuel because heat escapes into the open air, and forces the user to gather more fuel, which may cause more deforestation because wood is used as fuel. When cooking, people, especially women, only use one cooking pot at a time, increasing the risk of burns and scalds.

(Woldesemayate & Atnaw, 2020). However, the three-stone fire generally still had the same problems as the open fire, so the shielded fire was changed to a U-shaped mud or mud/stone enclosure with a front opening for fuel feeding and combustion air entry. A "built-in stove" or "mud stove" is an improvement over the TSF. A "built-in stove" is a semi-durable mud structure that encloses fire from at least three directions, other than the ground itself. (Kshirsagar & Kalamkar, 2014). At the top rim of the enclosure, three little humps served as a pot rest, an induction point for secondary air required for improved burning of volatile substances, and an exhaust gas exit. A decrease in the primary air supply to the fuel can cause incomplete combustion, which raises IAP. Laboratory testing of mud stoves revealed rapid boiling, high CO and PM emissions, an average thermal efficiency of about 29%, and a moderate safety rating, primarily due to contained fire. (Kshirsagar & Kalamkar, 2014). According to the sustainable Development report (2022), only 15.7% of the population of Zambia cook using clean fuels and technologies. (Jeffrey Sachs, 2022). Due to the exposure to the fire, the TSF is not safe.

Figure 1 Types of stoves (a) Three-Stone Fire stove and (b) mud stove (Donegan, 2018)

Zambia, on the other hand, use the conventional Mbaula stove, which burns charcoal and has the pot mostly sitting on the fuel. Due to inadequate insulation and an excessive number of holes, it produces a lot of cold extra primary air and has a low combustion temperature. Charcoal serves as the main fuel source for this type of stove. (Luzi, et al., 2019). 83.4% of homes in Zambia use biomass for cooking. More than 46% of the families use a three-stone open-fire stove, primarily burning wood, and more than 36% use traditional stoves (mbaula), primarily burning charcoal. Only 0.4% of people in the population use improved stoves. (Luzi, et al., 2019). Figure 2 shows the traditional brazier (Mbaula).

Figure 2 Traditional Mbaula (Mulenga, 2019)

The constant handling and cracking of charcoal when using a brazier result in sores and cuts on the hands. Burn dangers exist, and smoke is produced. Additionally, it soils pots and hands. Smoke from a brazier keeps you awake at night because it gives you migraines, intoxicates you, and makes it impossible for you to breathe. (Mulenga, 2019).

1.2 Improved cook stoves and pellets stove

Since 1970, stoves with increased efficiency have been made available in developing nations. The goals have been to lessen deforestation, shorten cooking times, lessen the negative effects of environmental pollution on health, save money, and increases cooking satisfaction. (Urmee & Gyamfi, 2014). Despite that, the only region where the number of individuals without access to clean cooking continue to increase in Sub-Saharan Africa. Between 1990 and 2020, Sub-Saharan Africa's access deficit has doubled; since 2000, it has increased by more than 50%, reaching 923 million (898–946). (The Energy Progress, 2022). The "Improved Cookstove" is a cookstove that was created using specific scientific principles to help with improved combustion and heat transfer, to improve emissions, and to work more efficiently. (Kshirsagar & Kalamkar, 2014). It may also use contemporary building materials to achieve this goal. An ICS design seeks to address the disadvantages of traditional stoves while maintaining their affordability and usability. The use of insulation, a fuel-grate under the burning fuel, low density and specific heat walls to contain the fire, a short internal chimney above the fire, suitably designed channels to force heat into the pot, and provision of any of these design tactics are popular. There are several ICSs that can boost fuel efficiency by over 30% and cut emissions by 40-75%. (Kshirsagar & Kalamkar, 2014). Using a cleaner fuel to cook is the healthiest choice to solve the problem of indoor air pollution. (Warwick & Doig, 2004). A clean and efficient stove not only reduces 6,600 Ibs (3 metric tons) of carbon dioxide emissions annually, but it also provides the users with a number of benefits like less time and effort spent gathering firewood and less exposure to toxic cooking smoke. (Community Markets for Conservation, 2019). The improved cooker stove has been created separately by numerous research teams. The primary objective of enhancing cooking technology is to raise implementation success rates by striking a balance between technical stove performance and user needs. (Simon, et al., 2014). The burden on the world's forests has been extensively acknowledged as a result of improved woodstoves. (Lillwhite, 1984). They have worked on the carbon monoxide (CO) emissions from cook stoves in developing nations. The "water boiling test" protocol, which has become a recognized international standard method, was applied in these experiments. For each experiment, a pot with a known volume of water was set on the cook stove. The ability to test emissions and stove efficiency simultaneously is an additional benefit of this method. (Kumar & Shukla, 2015). Other methods and protocols currently in place for testing the performance of an ICS include Controlled Cooking Test (CCT), and Kitchen Performance Test (KPT). The WBT is used most often to quantify the energy transferred from fuel to cooking pot. (Simon, et al., 2014). Improved stoves must be resilient, satisfy user demands, and adhere to cultural norms in order to raise adoption rates and, ultimately, lower indoor air pollution and deforestation over the course of the stove's working life. (Donegan, 2018). Figure 3 Shows an improved cooker stove by mini moto.

Figure 3 improved cooker stove by mini moto (Mulenga, 2019)

1.3 Deforestation

Deforestation has disastrous effects on the environment. They range from the devastation of crops and deserts to the erosion of watersheds and flooding. And once the trees are gone, so is the firewood that up to 90% of people in some developing nations rely on as their main fuel source. Simply cooking food is become more and harder for the world's impoverished. The energy equivalent of around two billion barrels of oil is being utilized annually to fuel over one billion cubic meters of wood worldwide. Eighty percent of this, or the majority of the energy utilized by the world's poor, is used for cooking. (Lillwhite, 1984). Reducing fuel use and consequently having an impact on the rate of deforestation was one of the main drivers behind the "first wave" of improved stove distribution. Between 30% and 50% more fuel might have been saved by improved wood stoves than what was required to cook over the 3 Stone Fire. (Partnership for Clean Indoor Air, 2011). ICS have advantages for the environment in addition to the health benefits. More than 300 million tons (Mt) of wood are used to produce solid fuels for cooking each year in Sub-Saharan Africa (Shannon, 2021). An estimated 200,000 hectares of forest are removed annually in Zambia, which is one of the countries with the highest deforestation rates in the world. Due to it predominate use for cooking in households across all income levels in Zambia, the use of charcoal is a major cause of deforestation and forest degradation in Zambia. (Tetra Tech, 2021). (Tetra Tech, 2021), Alternative to charcoal through the use of ICSs seeks to lessen the amount of deforestation directly linked to the manufacture of charcoal by reducing the consumption of charcoal and boosting the usage of alternatives, by making alternative technologies and fuels available, affordable, and culturally acceptable.

1.4 Emissions.

Improved cookstoves (ICS) have been shown to reduce emissions that contribute to global warming, protect forests and ecosystems, and reduce HAP, which has a negative impact on health. (Shannon, 2021). Acute lower respiratory infections are among the illnesses brought on by emissions from indoor air pollution. If exposed to emissions, a child has a two to three times greater chance of developing an acute lower respiratory infection. Up to four times as many women who cook with biomass develop chronic obstructive lung illness, such as chronic bronchitis. The use of coal-burning stoves has been directly connected to lung cancer in Chinese women. Additionally, there is evidence connecting indoor air pollution to cataracts, low birth weight, TB, asthma, and low infant mortality. (Hugh Warwick, 2004). Particulate matter (PM), carbon monoxide (CO), sulphur oxides (SO), and nitrogen oxides (NOx) are pollutants that are related to incomplete combustion and are frequently connected to indoor air pollution (Berko, 2018). The usage of solid fuels and the manufacturing of charcoal in the area contribute to the Kyoto Protocol's greenhouse gas targets of 120–380 Mt CO_{2e} (0.4–1.2% of the world's CO_2 emissions) and up to 600 Mt CO_{2e} when particulate matter is considered. (Lambe, et al., 2015). More than 300 million tons (MT) of wood are consumed each year throughout SSA as a result of the manufacture and usage of solid fuels for cooking. (The World Bank, 2014).The figure below shows black carbon and GHG emissions from solid-fuel cooking in SSA.

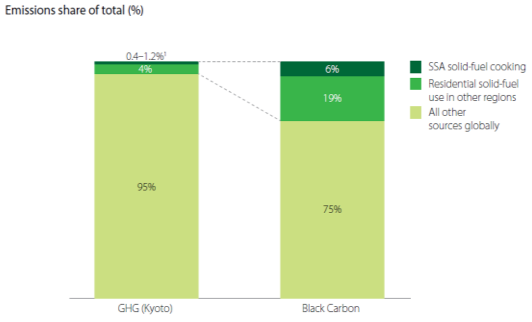

Figure 4 Black carbon and GHG emissions from solid-fuel cooking in SSA (The World Bank, 2014)

To be able to use emissions data to inform decisions, it is crucial to comprehend the typical pollutants linked to poor air quality. (Donegan, 2018). In Zambia 0.4 Gg CO_2eq is produced from solid fuels. (Daka, et al., 2019). While incomplete combustion of wood results in the release of volatile organic gases, much higher levels of particulates, carbon monoxide (CO), and other undesirable substances, some of which are carcinogenic, complete combustion of wood emits carbon dioxide (CO_2), nitrogen oxides (NO_x), and fine particulates. Black smoke coming from a chimney is a definite indicator of incomplete combustion. (Každimírová & Opáth, 2016). Strong, short-lived climate pollutants include black carbon (sooty particles) and methane released by inefficient stove combustion (SLCPs). (World Health Organization , 2021).

Air pollution is primarily believed to occur outdoors in industrialized nations where fossil fuels are the main sources of emissions. However, indoor air pollution (IAP) is typically thought to be a problem that is related to cigarette use. (Berko, 2018). An estimate of the emissions from various sources of air pollution can be made using the emission factor, which is a relative metric. (Amaral, et al., 2016). The unique composition of the fuel, ambient and combustion temperatures, the rate at which air enters the fire, the mode of burning, and the type of stove being used during the cooking process are just a few of the variables that affect the composition of the pollutants released during the combustion of biomass fuels. (Berko, 2018). This incomplete combustion or the recombination of partially oxidized components during the combustion process are the causes of these undesirable organic compound emissions. Usually, tar aggregates, inorganic particles, and the presence of water combine to produce smoke. The majority of the contaminants that consumers are exposed to can have harmful health impacts of varying complexity. According to toxicology, the circumstance, concentration, time, and extent of exposure, as well as the user's physiological health status, all influence the severity of the effects on users. From a health perspective, CO and the heavier organic chemicals, which together make up the majority of the total suspended particulate matter (PM), are likely the most significant and harmful pollutants. (Berko, 2018). It has been determined that carbon monoxide, even in low concentrations, is a very potent poison, primarily because it reduces the blood's ability to carry oxygen, robbing the body's tissues of their essential supply. Sleepiness, headaches, and loss of consciousness are a few signs of acute CO poisoning. Long-term exposure to these pollutants may cause physiological disturbances, including lowered blood PH and smaller new-borns at birth. (World Health Organization , 2021). Since haemoglobin, the pigment in human blood that carries oxygen, is 200 times more attracted to carbon monoxide than to oxygen, even a small amount of CO exposure can be fatal. Because foetuses primarily rely on their mothers to meet their oxygen needs through blood exchange via the placenta, this is very harmful to them. (World Health Organization , 2021). Acute, subacute, and chronic effects on health are generally the three categories used to describe the main effects of pollution. Acute effects, which arise from smoke inhalation and carbon monoxide poisoning, are the deadliest and are thought to be the most serious, often even killing those who are affected. Pollutants' inflammatory effects on the conjunctiva and mucous linings of the respiratory tract, from the nose to the bronchi, cause sub-acute consequences. The disorders of the lungs and heart, as well as cancer, are the most serious consequences of chronic impacts. Other types of consequences in this group include chronic CO poisoning, conjunctivitis, and corneal inflammation that result in poor eyesight and cataract after prolonged exposure to infrared light. (World Health Organization , 2021)

1.5 Characterization Of Some Fuels

The use of traditional charcoal, kerosene, and LPG cook stoves during indoor cooking has the potential to accumulate large concentrations of pollutants including CO2, CO, Particulate Matter (PM), etc. inside the indoor environment, according to research (KANDPAL, et al., 1994). These cook stoves must be made to burn fuel efficiently enough to assist lessen the pollutants' negative effects on health.

Below is a figure of available fuels used in Zambia

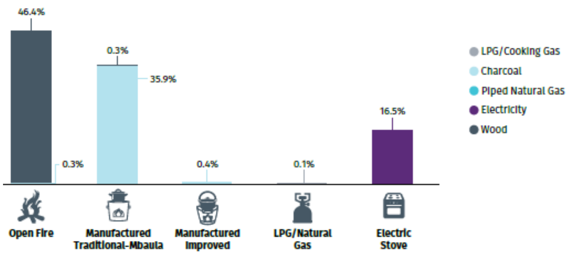

Figure 5 primary stoves for Zambian households (Luzi, et al., 2019)

Table 1 Description of some fuels and their cook stove efficiency

Type of Fuel	Composition of Carbon	Calorific Value (kcal/kg)	Type of Cook Stove-Average Efficiency
Wood pellets	75.25–81.41%	4400	
Briquettes	41.6 to 50.1 wt%	4000	
Charcoal	43%	22000	Coal Cook Stove-32%

1.5.1 Stove Body

Numerous studies show a strong association between stove weight and efficiency, with heavier stoves having lower efficiencies. However, without full combustion chambers, very light stoves with low heat capacity walls (such thin steel) cannot achieve large power outputs, high efficiencies, or a constant burning. The efficiency has typically been greatly boosted by insulating the combustion chamber with burnt pottery, low-density pottery, clay, ash mix, pumice stone, cement/vermiculite combinations, or other heat-resistant insulators. (Berko, 2018). Therefore, it is crucial that all of these be taken into account while designing the improved cook stove.

1.5.2 Thermoelectric Generators (TEGs)

Thermoelectric generators, often known as TEGs, are solid state energy sources that use the thermoelectric effect to convert heat directly into electricity. The Seebeck effect, Thomson effect, Peltier effect, Joule effect, and Fourier effect are some of the additional forces that combine to create the thermoelectric effect. TEGs are commercially available in a range of sizes, shapes, and power levels and have no moving parts (O'Shaughnessy, et al., 2012). According to the life cycle study, in addition to the TEG being ecologically friendly, the demand for alternate power production methods will increase as fuel prices rise. (Lai, 2017) In Figure 6 , the operating principle is shown. Between a heat source and a heat sink is a thermoelectric module that is fixed. The module generates electricity while heat is transferred from the heat source and dissipated via the heat sink. P-n thermoelement pairs make up the thermoelectric module. The electrical connections between the positive (p-type) and negative (n-type) doped semiconductor elements are in series, while the thermal connections are in parallel. The conductors in the module have an even distribution of charge carriers at first. The p-n thermoelements experience a temperature difference as a result of the heat input to the module, QH. (O'Shaughnessy, et al., 2012). The fundamental concept behind TEG is the Seebeck effect of thermoelectric materials, where the voltage produced is directly proportional to the temperature gradient (Cekdin, et al., 2020), as illustrated mathematically below:

$$V = \alpha \Delta T \qquad \text{Equation 1.1}$$

Where T is the temperature differential between the two generator surfaces at K and is the Seebeck coefficient (V K^{-1}) of the thermoelectric materials (TE).

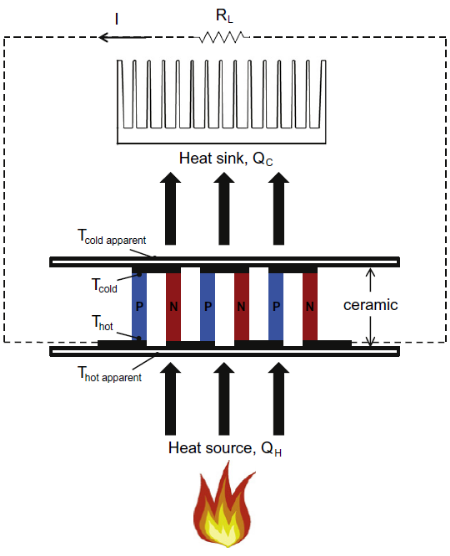

Figure 6 Thermoelectric Power Generation (O'Shaughnessy, et al., 2012)

1.6 Evaluation and Testing of Cook Stoves

1.6.1 Controlled Cooking Test (CCT)

The controlled cooking test (CCT) is intended to evaluate how well the improved stove performs in comparison to the standard or conventional stoves that it is intended to replace. (Bailis, 2004) .The preparation of a standardized meal, such as oil or starch, etc., is required for this test, which is also carried out in a laboratory. More information is provided on the cooking process, including the amount of time and fuel needed. Using the data gathered, the cook stove's energy output and fuel consumption would be estimated. In order to calculate energy consumption, factors like the specific heat capacity (Cp) of the utilized matrix and temperature fluctuations (T) in degrees Celsius (ºC) will be taken into account. (Berko, 2018). The CCT, which was designed concurrently with the Water boiling test (WBT), it offers insight into how test stoves operate when real end users, as opposed to lab technicians, prepare food on them. The CCT serves as a link between real lab testing and field testing. (DeFoort, et al., 2009).

1.6.2 Emission Test

The characteristics that are observed during this test include Carbon Monoxide (CO), Carbon Dioxide (CO2), and Particulate Matter (PM), among others, as also suggested by (DeFoort, et al., 2009). The Portable Emission Monitoring System (PEMS), an Indoor Air Pollution (IAP) meter, and other instruments are utilized to measure the test's parameters. (DeFoort, et al., 2009). To prevent losing any of the generated gases, adequate sampling of the exhaust gas from a cooking burner must be collected. To prevent bigger errors in their identification, all emissions must be captured effectively, keeping in mind that this must be done without impairing the cook stove's functionality. Based on the outcomes of tests conducted on it, the enhanced cook stove may be a potential social intervention to create a clean and healthy atmosphere for the culinary processes' users engage in.

1.7 Challenges.

By lowering indoor air pollution, increasing fuel efficiency, and saving money on fuel costs, improved cooker stoves have the potential to significantly better the lives of people in sub-Saharan Africa. For these stoves to be widely used and utilized effectively in the area, there are a number of issues that must be resolved. Among the challenges are:

1. The affordability of improved cooker stoves can be a deterrent for low-income households because they are frequently more expensive than conventional stoves. There needs to be an effort made to reduce the cost of these stoves through financing options, subsidies, or other strategies.
2. Fuel availability: Improved stoves frequently need a particular kind of fuel, like pellets or briquettes, which may not be easily accessible in all regions of sub-Saharan Africa. There needs to be action taken to guarantee a steady supply of affordable fuel. Cultural preferences: Traditional stoves are frequently preferred because of their cultural significance. Due to cultural or traditional considerations, some households may be reluctant to switch to improved stoves.
3. Maintenance: For households without access to repair services or spare parts, improved stoves may require more maintenance than conventional stoves, which can be a barrier to adoption.
4. Distribution and logistics: It can be difficult to get improved stoves to remote areas and distribution networks are frequently underdeveloped. To increase the adoption of improved stoves, distribution networks and logistics must be improved.
5. Lack of knowledge: It's possible that many people in sub-Saharan Africa are unaware of the advantages of improved stoves or are unsure of how to use them efficiently. In order to spread the word about the advantages of upgraded stoves and show people how to use them effectively, awareness-raising campaigns and educational initiatives are required.

Moreover, the presence of severe market failures and behavioural obstacles require targeted policies to both increase the understanding and internalize benefits and externalities from the adoption of clean cooking. For many households that cook with open fires, traditional three-stone cookstoves serve end-uses related to both cooking and non-cooking, including water- and space-heating. ICSs are often not designed to accommodate the heating of large volumes of water, nor do they always adequately meet space-heating requirements (Ruiz-Mercado & Masera, 2015). Three-stone stoves also serve a variety of social functions and are often embedded in cultural customs and rituals. Most ICSs do not adequately serve these functions (Ruiz-Mercado & Masera, 2015). According to Shankar et al. (2014), very few studies have been conducted to determine which stoves are used in tandem for particular cooking tasks. This type of information would enable cookstove designs to be fit for purpose and better aligned with end-user cooking requirements. Decisions about cooking fuel and technology purchases are influenced by a complex array of technical, economic and socio-cultural factors such as stove performance, affordability, regional diversity and cooking preferences (Crew 1997; Ruiz-Mercado & Masera, 2015).

In general, overcoming these obstacles is essential to encouraging the use of improved cooker stoves in sub-Saharan Africa and ensuring that they have a positive impact on the lives of locals.

1.8 Adoption of Improved cooker stoves

Despite several clean cooking initiatives, the shift to improved cooker stoves has been gradual in most low-income countries, and as population growth has countered positive achievements, the number of people using solid fuels has increased. During the original wave of cookstove acceptance, a major misunderstanding was that large-scale dissemination would automatically lead to universal adoption; nevertheless, technological efficiency alone proved to be an insufficient driver of adoption (Barnes et al., 1994; Sesan, 2014; Tafadzwa & Bradnum, 2017). According to Shankar et al. (2014: 268), acquisition should not be considered synonymous with adoption, but rather a first critical step toward adoption. They defined adoption as the "acquisition and substantive use of a technology by a user," emphasizing that correctly and consistently using modern and efficient technologies is a key aspect of the adoption of new modern fuels and technologies, as well as an essential part of the displacement of traditional fuels and technologies. Transitioning to clean, modern energy is critical for reducing energy poverty. According to the 'traditional' energy ladder theory, as household incomes rise, they will shift away from traditional fuels like solid biomass and agricultural leftovers and toward contemporary fuels like electricity and LPG (Smith, 1989; Barnes & Floor, 1996; Masera, Saatkamp & Kammen, 2000). Transitional fuels include charcoal and biomass briquettes, which have a higher energy density than firewood and paraffin, but still pose health and safety risks in terms of toxic fumes, fire hazards, and burn-related injuries, despite being considered an upgrade from the traditional use of solid biomass (Jahan, 2003; Kimenia et al., 2014; Mills, 2016; GACC, 2017; Kimenia & Van Niekerk, 2017). The energy ladder theory implicitly assumes that once families accept contemporary fuels and technologies, traditional fuels and technologies will be automatically replaced. Yet, empirical evidence reveals that home energy transitions are frequently more subtle, and that stacking is more common than direct switching in many cases (Masera, Saatkamp & Kammen, 2000; Hiemstra-van der Horst & Hovorka, 2008, Van Der Kroon et al., 2015). The usage of traditional fuels and technologies following the adoption of more modern fuels and technologies is referred to as fuel or technology stacking

(Gordon & Hyman, 2012). According to Ruiz-Mercado and Masera (2015), while the frequency of fuel and stove stacking is known, the rationale for stacking has not been properly investigated. It is also claimed that homeowners stack fuel and stoves to improve energy security (Pachauri & Spreng, 2012; Ruiz-Mercado & Masera, 2015). They also claimed that fuel stacking allows for greater fuel flexibility, allowing households to be more resilient and less sensitive to variables such as shifting fuel prices, fluctuations in fuel availability, and inconsistent energy services. Further, other measures that can be used to overcome many challenges and broaden ICS implementation in SSA. Some measures that can be put in place are:

1. Education and awareness-raising campaigns: Both governmental and non-governmental groups can strive to inform households about the advantages of ICS for their health and the environment, as well as to train them in their usage and maintenance.
2. Governments can provide subsidies and financing options to lower the cost of ICS for homes and to promote the growth of ICS supply chains.
3. Governments and commercial businesses can collaborate to enhance ICS production and distribution while utilizing the private sector's knowledge of supply chains and marketing.
4. Research and innovation: New ICS models that are more cost-effective, effective, and culturally acceptable for households in SSA can be created by researchers and innovators.

Overall, expanding the use of ICS in SSA will necessitate a multifaceted strategy that takes into account the numerous obstacles to their adoption and makes use of the strengths of diverse stakeholders, such as governments, NGOs, for-profit businesses, and research institutions.

1.9 Benefits

According to a new analysis of the most socially optimal cooking technology in Africa, replacing traditional biomass-burning cookstoves across Sub-Saharan Africa could save more than 463,000 lives and US $66 billion in health costs per year. (Penn, 2023). ICS have been shown to minimize time and fuelwood usage during beans cooking by 14% and 17%, respectively. (Matavel and colleagues, 2022). Further, for families and communities in Sub-Saharan Africa (SSA), improved cookstoves (ICS) offer a number of advantages, including:

1. Health advantages: The biomass fuels used in traditional cookstoves in SSA include wood, charcoal, and crop residues. These fuels produce smoke and indoor air pollution, which can cause respiratory conditions like pneumonia, lung cancer, and chronic obstructive pulmonary disease. Because ICS consume less fuel and have better ventilation, they expose people to less indoor air pollution, which is better for respiratory health.
2. Environmental advantages: Because ICS require less fuel and burn it more effectively, they emit fewer greenhouse gas emissions than conventional cookstoves do. By using less wood for fuel, they help lessen deforestation and the risk of forest fires brought on by open flames.
3. Economic advantages: By lowering the quantity of fuel used for cooking, ICS can help save money for homes. Women and girls, who are often in charge of gathering fuelwood, can devote more time to other pursuits including school, employment, and family care by putting less effort into this chore.
4. Social benefits: As women and girls are frequently in charge of cooking and gathering firewood, ICS can also help to promote social benefits like gender equality. ICS can support women's pursuit of income-generating activities and encourage girls to continue in school by lowering the time and effort necessary for these chores.
5. Benefits for combating climate change: ICS can help cut greenhouse gas emissions and support international efforts to slow down global warming. In many ICS initiatives, there are additional systems for producing carbon credits, which can then be sold on carbon markets to make money and fund the expansion of ICS.

Any key intervention for sustainable development in SSA, improved cookstoves can enhance health, lessen environmental impact, provide economic possibilities, support gender equality, and help to international efforts to combat climate change.

1.10 Impact

ICSs decrease the need for firewood while also enhancing indoor air quality. By doing this, less time is needed to acquire firewood and less deforestation occurs. 2018 (Engypedia) According to the EnDev report on effect 2016, gathering firewood might result in a lack of time for other activities like attending class and studying. (EnDev, 2016). Improved cookstoves can be made to use less energy, remove smoke from indoor spaces, or lessen the tediousness of cooking tasks. Throughout the past century, female education levels have significantly increased. In SSA, girls' primary enrolment rates have doubled since the middle of the 20th century, increasing more quickly than boys' enrolment rates and significantly narrowing the achievement discrepancies between the sexes. 2018 (Engypedia). A better cookstove can also be made to use less energy, remove smoke from the living area inside, or make cooking less laborious. As a whole, it is expected that improved cooking stoves have the same effect as access to electricity and clean water, which both have evidence-based effects on children's attendance at school. Research contend that the time saved by using ICS affects children's attendance at school.

1.11 Recommendations

In an effort to encourage healthy cooking practices throughout Sub-Saharan Africa, consider the following:

1. Governments can develop and enforce comprehensive rules and regulations that encourage the use of clean cookstoves and fuels and assure their accessibility and affordability. Incentives for producers and users of clean cookstoves, and initiatives to improve access to clean fuels are a few examples of these policies.
2. Governments, NGOs, and other interested parties can initiate education and awareness campaigns to spread the word about the advantages of clean cooking for human health and the environment, as well as to encourage the use of clean cookstoves and fuels. These campaigns can involve instruction on how to use and maintain clean cookstoves and can be directed at households, community leaders, and legislators.
3. Increase access to capital, governments and financial institutions should offer financing alternatives to individuals and businesses so they can buy clean fuels and cookstoves as well as invest in the infrastructure needed for their production and delivery.
4. Support the manufacturing and distribution of clean cookstoves: Governments and NGOs can offer assistance with the creation of supply chain networks, training and technical support for manufacturers, and the production and distribution of clean cookstoves.
5. Enhance the manufacturing and distribution of clean cookstoves and fuels, as well as to take use of the private sector's skills in marketing and supply chain management, governments might promote public-private partnerships.
6. Increase funds allocated to Research and development in order to render clean cookstove technology more effective, more economical, and more adapted to the needs and preferences of households in Sub-Saharan Africa.

It is possible to promote clean cooking in Sub-Saharan Africa and reap its health, environmental, economic, and social benefits by putting these suggestions into practice.

1.12 Conclusion

But, due to increasing population pressure and fuel shortages, emerging nations are compelled to search for improved cook stoves that can significantly reduce the need for firewood. A response to this requirement, efforts to advance cook stove technology, and an analysis of what determines successful and unsuccessful cook stove designs based on user friendliness. In conclusion, the adoption of improved cookstoves (ICS) in Sub-Saharan Africa (SSA) has the ability to improve health, lessen negative effects on the environment, expand economic possibilities, support gender equality, and help the global fight against climate change. However, ICS implementation in SSA has been sluggish because of things like low awareness and education, high costs, restricted access to funding, difficulties with the supply chain, and cultural and societal preferences.

A multifaceted strategy, including education and awareness-raising campaigns, financial incentives and options, public-private partnerships, innovation, and research, is required to increase the adoption of ICS in SSA. It is possible to promote the use of ICS in SSA and realize their potential benefits for sustainable development by resolving these issues and making the most of the strengths of many stakeholders, including governments, NGOs, private businesses, and research institutions.

Overall, the use of ICS in SSA is a crucial area for investment and action since it is a significant intervention for enhancing household health and well-being, lowering environmental impact, and supporting global efforts to mitigate climate change.

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