Energy for Sustainable Development 41 (2017) 69–80

Contents lists available at ScienceDirect

Energy for Sustainable Development

Review

A review of *injera* baking technologies in Ethiopia: Challenges and gaps

Kamil Dino Adem *, Demiss Alemu Ambie

School of Mechanical and Industrial Engineering, Addis Ababa Institute of Technology, Addis Ababa University, P.O. Box 385, King George IV Street, Addis Ababa, Ethiopia

ARTICLE INFO

Article history:
Received 7 January 2017
Revised 3 August 2017
Accepted 11 August 2017
Available online xxxx

Keywords:
Biomass stove
Injera baking stove
Gasifier stove
Electric *injera* baking stove
Patent on *injera* baking stove
Solar *injera* baking stove

ABSTRACT

Most of the people living in the Third World cook/bake food using biomass as their primary energy sources. There are a number of efforts undertaken to improve the efficiency, lessen the indoor air pollution and reduce emission of a three-stone-open-fire stove by introducing improved cooking stoves. The major purpose of this review is to organize, and document research and development efforts, showing gaps for researchers and developers working in the area of improved biomass and other stoves more specifically for baking *injera*. The information in the review, which is mostly in chronological order, is obtained from governmental and non-governmental reports, patents and journals written in the area of *injera* baking stoves. The most important results of the review show that a number of efforts were undertaken to improve *injera* baking stoves, though there were no organized reviews earlier to show the efforts made by various institutions. The review also shows that other alternative energy sources for *injera* baking stoves have been used to address the problem of the majority of the people living in rural areas. In the end, the review indicated a research direction for the future in relation to the supply of alternative energy sources such as solar, biogas, gasifier and electric power for *injera* baking stoves.

Contents

* Corresponding author.
E-mail address: kamil.dino@aau.edu.et (K.D. Adem).

http://dx.doi.org/10.1016/j.esd.2017.08.003
0973-0826/

Introduction

The number of people in the world using traditional biomass energy is 2.7 billion (IEA, 2015). In Ethiopia, 95% of the population relies on the use of traditional biomass for cooking application (IEA, 2015) among which 50% of the energy is used to bake *injera* — traditional pan cake like bread. Due to the low efficiency of *injera* baking biomass stoves, large amounts of firewood are used, resulting in high indoor air pollution, greenhouse gas emission and rampant deforestation. The attempts to improve the *injera* baking stove resulted in incremental change in efficiency and reduction in emission of pollutants without major breakthrough hitherto.

Injera together with '*wot*' (sauce) is the major staple food eaten by Ethiopians and Eritreans as well as people from some areas of Somalia and Sudan (Asfafaw et al., 2014) both living in their country and abroad. The standard *injera* weighs 310 g and it is 52 cm in diameter. *Injera* is a pancake-like thin bread which is flat at the bottom and has many "eyes" on top and looks like a 'thin sheet'. The majority of *injera* is prepared from the local indigenous grain *teff*. *Teff* (*Eragrostistef*) even if eaten by most Ethiopians and Eritreans, was not appreciated until recently. Researchers found out that *teff* is gluten-free which makes it very attractive for healthy nutrition (Kaleab, 2014). The details of the *injera* baking process which starts from preparation and ends in baking is described by Stewart and Getachew (1962).

Most of the people living in Ethiopia bake *injera* using biomass on open-fire stoves. The inefficient open-fire stove consumes large amounts of firewood and produces high indoor air pollution and CO_2 emission. A three-stone-stove or a three-stand-stove is where three stones with a similar size are made from clay. The three stones are placed in a triangle to support or carry the baking pan with a diameter of 60 cm and thickness of 20 cm on average. Then, firewood is inserted into the openings between the stands for burning. While burning is taking place below the pan, *injera* is baked on it. In the process, 90% of the energy supplied is lost to the environment. Moreover, the cook and her child is exposed to large amounts of CO and PM which is above the WHO standard set for safe cooking (Beyene and Koch, 2013).

Researchers in Ethiopia and abroad have made attempts to improve the efficiency of *injera* baking stoves to save energy, reduce indoor air pollution and CO_2 emission. This includes early efforts by the Ministry of Water, Irrigation and Electricity, i.e. by the Alternative Energy Development and Promotion Directorate, and GIZ-Energy Coordination Office in the late 1980s and early 1990s. Significant achievement is registered by the GIZ-Energy Coordination office-Ethiopia in disseminating around 455,000 improved *injera* baking stoves—*Mirt*,[1] throughout the country (GIZ-ECO, 2011). A number of studies were conducted to see the reduction in specific fuel consumption of *Mirt* compared to open fire baking which was in the range of 30–49% (Workeneh, 2005; Alemayehu et al., 2012; Walelign et al., 2013; Anteneh, 2014; Yosef, 2007; Anteneh and Walelign, 2011; Dresen et al., 2014). However, improving the performance of biomass stoves, especially for baking *injera* still remains to be a challenge for researchers.

This review discusses the following issues: i) early development of *injera* baking stoves, ii) current research, and iii) the way forward in terms of research and development regarding *injera* baking stoves. Since the information collected is mostly from reports from governmental and non-governmental institutions in the country, most of the references are not published in peer reviewed journals.

Our effort will present significant benefits to a wider public. Besides, it will serve as a starting point for researchers who are interested in designing, manufacturing and testing of stoves particularly for the purpose of baking not only in Ethiopia but also elsewhere in the world.

[1] Mirt stove — means 'best' in local language and is used to name a biomass improved *injera* baking stove.

Injera and its baseline baking technology

What is injera?

Injera is a flatbread with a unique taste; it is a circular pancake that is sour and tasty and has a soft-spongy like structure with a thickness of 2–4 mm and a diameter of around 58 cm. The major ingredient for baking *injera* is *teff*, though other cereals such as sorghum and barley are sometimes used. These days, some consumers tend to add a few grams of rice flour for whitening *injera*. The knowledge and skill of baking *injera* is well known by Ethiopians and it has been transferred from generation to generation for a long time. The general structure of well baked *injera* is shown in Fig. 1.[2]

Injera is made from *teff* flour which is mixed with water and allowed to ferment by adding left over batter from the previous baking session as a starter. When it is ready, fire will be lit from the bottom of the clay pan for biomass stoves and in the case of electric *injera* baking stove resistors will be turned on. When the pan's temperature reached around 200 °C, the dough will be poured into the baking pan. The viscosity allows it to be poured into the baking pan rather than rolling out. Finally, the baked *injera* will be removed from the baking pan.

The majority of Ethiopians still bake *injera* using three-stone fire. Starting from1980s efforts have been made to improve biomass *injera* baking stoves and introduce electric *injera* baking stoves for urban dwellers.

Three-stone-fire for baking injera

As the name indicates, a three-stone open-fire stove uses three separate stones to support the *mitad* (clay pan) for baking. The types and sizes of stones used varies according to the availability of the stones. Usually three (10–15 cm) high stones are used to support the *mitad* (Fig. 2a).

A number of developers have used a three-stone open-fire *injera* baking stove as a reference for showing the improvements with various versions of the *Mirt* stove. The specific fuel consumption of a three-stone open-fire stove on average is 929 g of wood/kg of *injera* using CCT protocol for testing (Table 1). Yosef (2007) conducted tests on *Mirt* and three-stone open-fire *injera* baking stove and obtained indoor air pollution parameters for three-stone open-fire stove as 80 ppm for CO and 1.10 mg/m^3 for PM.

Early research and development efforts for improvements of *injera* baking stoves

Biomass injera baking stoves

The need for efficient *injera* baking stoves had not been addressed for a long time until governmental institutions laid the foundation in the 1980s. Early efforts included manufacturing of mud *injera* baking stoves by the *Burayou* Basic Technology Center (BTC), under the Ministry of Education in the early 1980s. The name of the stove was '*Burayou* mud-stove'. The then Ethiopian Science and Technology Commission (now Ministry of Science and Technology of Ethiopia) hired a consultant in 1981 to assess traditional closed stove in selected areas of the country (Ali, 1981). The major aim of this study was to make a survey of the types of stoves in use in the country. The numbers of stoves surveyed were 113 with a diameter of 60–65 cm and thickness of less than 2.5 cm earthen stove (*mitad*). Out of the total, 109 types of stoves were identified for further evaluation. Then, depending on the similarities of the stoves, the stoves were reduced into 20 stove types and finally, six stoves were selected for further testing. The performance evaluation was made based on water boiling test. It was performed at

[2] http://www.diretube.com/articles/read-injera-got-standardized_4311.html.