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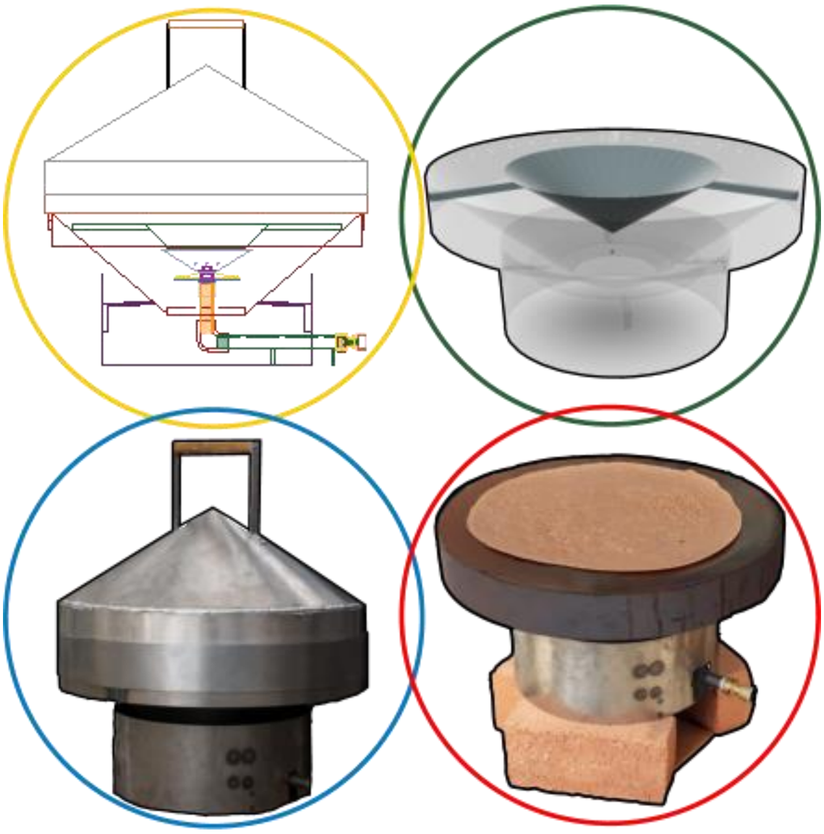
Optimization of a biogas stove and Mitad for Injera baking



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ABSTRACT

The present thesis is about the transformation of the Injera baking process from fuelwood to biogas by optimizing a biogas stove for Injera baking. Injera is a staple food in Ethiopia and other East African countries, made from the indigenous cereal *teff (Eragrostis tef)* as well as from millet, sorghum, maize, wheat or rice. Cereals are further processed to a fermented sourdough and traditionally baked on a three-stone open fire supported clay plate called *Mitad*.

Baking Injera is the most energy intensive household activity in Ethiopia, which is strictly related to severe health issues caused by a massive indoor pollution and to an excessive fuelwood consumption engender a widespread deforestation. Aggravated by the poor thermal efficiency of the three–stone stove of just 7 – 12 %, other ways have to be found to bake Injera under improved conditions for humans and the environment.

A possible solution provided in this work is embodied by the use of biogas, which burns smoke– and odour free. First of all, a biogas stove was tested and modified to optimize the thermal efficiency while controlling several parameters such as nozzle diameter, gas pressure, burner–to–pot distance and pre–aeration. The thermal efficiency of the biogas stove was determined by applying *DIN–EN–30–2–1:2015* norm. A Box–Behnken design was applied to investigate the main effects and interactions of the nozzle diameter, burner–to–pot distance and the gas flow rate on the stove efficiency and to identify the optimal operating parameters to achieve the maximum efficiency of the biogas stove. Results showed a maximum thermal stove efficiency of over 51 % at a nozzle size of 5 mm, a burner–to–pot distance of 10 mm and a normalized gas flow rate of 500 – 550 l/h.

Afterwards, a biogas powered *Mitad* prototype was manufactured and optimized focusing on an even heat distribution on the *Mitad* plate´s surface, adequate gas consumption, low heat losses and best thermal efficiency. The heat distribution of different setups was recorded by a thermal imager (Fluke Ti20) and evaluated afterwards.

The test showed the following results: When the Controlled Cooking Test introduced by the Clean Cooking Alliance was carried out, an average thermal efficiency of 18.71 % was determined with an average gas flow rate of 587 l/h. An even heat distribution across the whole baking surface was recorded due to the ability of Injera, distributing the heat among the batter. A Converted Specific Fuel Consumption (CSC) of 5.2665 MJ of fuel input per kg baked Injera was measured in average, which is just one quarter of energy input compared to the traditional three–stone *Mitad* for baking one kilogram of Injera.

A final Injera baking session was conducted to further test the applicability of the optimized *Mitad*. Thereby a thermal efficiency of 20.22 % and a Converted Specific Fuel Consumption (CSC) of 4.8028 MJ fuel input per kg of baked Injera was recorded.

To conclude, it has been achieved to reach a reduction of fuel input of 78.83 % compared to the traditional three–stone *Mitad*.

Key words: Injera, biogas, thermal efficiency, heat distribution, Specific Fuel Consumption