UNIVERSITÄT HOHENHEIM

Institut für Agrartechnik, FG Agrartechnik in den Tropen und Subtropen

Report

Title: Energy efficient injera baking with biogas in Ethiopia

Bilhate Chala

Several experiments and efforts have been exerted to produce and optimize a biogas mitad (clay plate used for baking injera) for the past 9 years. Previous trials on the injera baking have identified that the inner cone systems were crucial for an even heat distribution on the clay plates. Four kinds of cones were produced for the current trials, namely the higher cone, lower cone, fixed cone and adjustable cone. The key modification was the reduced diameter of the mitad to 40cm, unlike the previous 50- 55cm (Fig. 1). The experiment was started at the institute of agricultural engineering (Hohenheim University) and run from August through October, 2018 with an extended test period from January to March 2019.

(a) (b)

Fig. 1 Previous injera mitad setup which accommodate a diameter of 50-55 cm plate (a) and the modified injera mitad setup which accommodate a diameter of 40-42 cm plate (b)

The thermal efficiency of the biogas burner was determined following the Water Boiling Test (WBT) protocol. Thus, the burner was found 47.3% thermally efficient. The value indicates that it has better efficiency than most biogas burners available in the market. Thus, it requires lesser biogas to cook the same amount of food compared to the traditional burners (Fig. 2).

Fig. 2 water boiling test

Subsequent trials on even heat distribution and gas consumption rate were executed using same size burner and clay plate. Eventually the real injera baking test was performed in Addis Ababa, Ethiopia. The setup of the mitad was modified prior to conducting the trials. The inner cone was made adjustable (changeable) while keeping the same external cone size and shape. Moreover, the outer part of the outer cone was insulated with fibre glass and also covered with an additional shielding cone made of sheet metal.

Synthetic biogas, a mixture of methane (~ 56% v/v) and carbon dioxide (~ 44% v/v), was used for heat distribution and heating tests at the University of Hohenheim. The biogas was mixed and collected in a gas bag. The static pressure of the biogas while loading weight on top of the gas bag was about 26 mm H_2O (~ 2.55 hPa). For the field trials in Addis Ababa, actual biogas from active toilet-based digester was used. The methane content of the biogas was high (~89%).

The trials in Hohenheim helped to identify the right combination of the new inner and outer cone sizes with the new burner regarding flame pattern and even heat distribution on the clay plates. Besides, the gas consumption patter was also examined.

(c) (d)

Fig. 3 different arrangement of inner cones (a) small cone (b) big cone (c) fixed cone (d) adjustable height

Heat distribution on plate

The heat distributions of the clay plate with combination of the outer cone to different inner cones are depicted in Fig 4. The infrared (IR) image was captured for 25 minutes in 5 minutes interval. The plate temperature was measured until reached well above optimum temperature for baking injera (180°C – 200°C). For each cone type, two trials were conducted with low and high biogas flowrates. Thus at the end of the 20th minutes the plate temperatures of all combinations had already reached the required temperature for injera baking.

The heat distribution of the plate while using the big cone at higher biogas flowrates and small cone at low biogas flow rate was interesting. The fixed cone also showed good heat distribution at low biogas flow rate. The heat distribution of the plate while using the fixed cone with a high biogas flowrate was not good. The big and adjustable cones with a lower flowrate showed the same result. The small cone generally showed better a performance regarding even heat distribution at both low and high biogas flow rates. Subsequent trials on the performance of the injera baking were undergone using these cones.

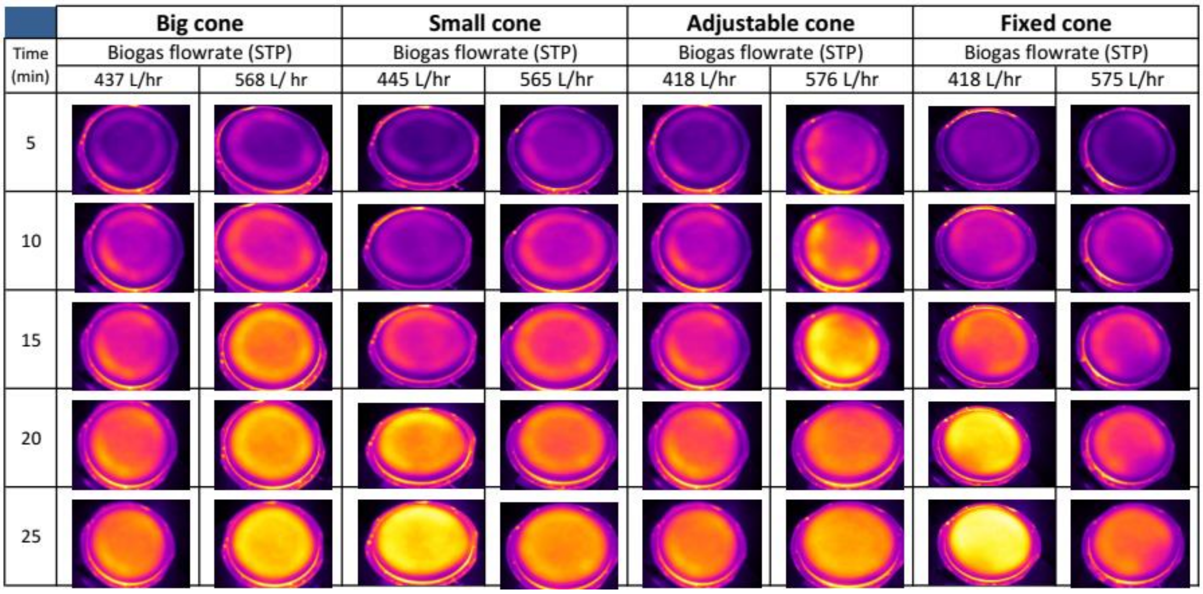

Fig. 4 Heat distribution pattern of the clay plates with different inner cone combination

Baking performance tests

The baking performance test was carried out using the 40 cm wide clay plate and changing the inner cones. For each trial the plate was heated for 25 minutes and checked for even heat distribution and necessary temperature for baking. The biogas used in the baking performance was obtained from toilet based biogas digester.

The first trial was made with smaller inner cone. The biogas flow rate was about 510 L/hr. After the warming up time, the clay plate was polished with rapeseed and the batter was poured; after 4 minutes of baking time the injera was picked form the plate; and after another 4 minutes of warming-up time the next injera was baked. The average biogas consumption per unit of injera baked was 35L (regardless of the warming-up gas consumption), with baking efficiency of 22%. When the biogas flow rate increased to 535 L/hr and warming-up time reduced to 3minutes the baking efficiency was reduced to about 20%. Further increase in the gas flow rate to 600 L/hr did not increase the efficiency beyond 22% (Fig. 5).

(a) (b)

Fig. 5 Injera baking mitad connected with biogas flowmeter (a) and Injera baked with lower cone (b)

The baking performance of the mitad with fixed inner cone was investigated at a biogas flow rate of 605 L/hr. The baking time and warming-up time was 4 min and 3 min, respectively. The efficiency of the mitad (for baking) was determined to be 25%. The average biogas consumption for warming-up and baking an injera was 30 L and 22 L, respectively (Fig. 6 (a))

(a) (b)

Fig. 6 Burning flame with fixed cone (a) and injera baked using adjustable cone (b)

The injera baking performance of the mitad with adjustable height of inner cone was performed after heating the plate from ambient temperature to optimum baking temperature (>180 °C). Each injera took 4 minutes of baking time and another 4 minute for warming up the plate to optimum temperature again. Hence, the baking efficiency and biogas consumption was 26 % at a biogas flow rate of 580 L/hr. The mean biogas consumption to bake one injera was 28 L, regardless of the warming-up time.

Conclusion

The trials from the lab at Hohenheim to the field test at Addis Ababa showed very promising results. Now it is possible to bake injera with biogas using the traditional clay plate with the new burner setup provided by (B)energy. An Additional advantage of the mitad set-up is that there is no need to change the stove to cook other food items, afterwards. Further investigations should be performed on increasing the size of the mitad to the traditional 50-55cm diameter clay plate with adjusted designs/features of the biogas mitad, so as to incorporate the needs and prevailing cultural baking practices of many users.

Activity schedule

R.No	Activities	Week*																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Lab preparation																	
2	Lab trial and data collection																	
3	Data analysis																	
4	Reporting																	
(5)	(Field Testing in ET)																	
*4 months (Aug 1 to Nov 30, 2018) and field testing extended to Mar 30, 2019																		

Acknowledgement

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