Performance Assessment Of Local Biomass Powered Cereal Drier Used By Small-Scale Kenyan Farmers

Madaraka F. Mwema, Kimayu S. Musau, Ngugi J. Mburu

Abstract: Recent studies have revealed that drying maize using biomass driers increase the quality of grains, delays insect infestation, mold and aflatoxin contamination in relation to direct sunlight drying. Most importantly, biomass drying takes shorter time. It is therefore important to undertake performance of these driers to investigate the possibility of empirical control of such systems in remote areas. In this paper, we present results of thermal performance of typical biomass-powered drier (batch type). The results show that under natural convection, temperature behavior within the drying chamber is unpredictable. However, the use of exhaust fan (forced convection) gives predictable temperature distribution within the drying chamber. For burner shutter open at 50% and using maize cob as the fuel for forced convection, the drying chamber attained a maximum temperature of 93˚C after 28 minutes and minimum temperature of 69˚C after 37 minutes in the lower tray (tray 1). For burner shutter open at 100%, the drying chamber attained a maximum temperature of 91˚C after 41 minutes and minimum temperature of 67˚C in tray 1. With burner 50% open, tray 2 attained a maximum temperature of 62˚C after 30 minutes and minimum temperature of 56˚C after 40 minutes. With the burner 100% open, tray 2 attained a maximum temperature of 61˚C after 39 minutes and minimum temperature of 52˚C after 52 minutes. From these results, the optimal operating conditions of the burner operation were achieved when the shutter was open at 50%. It took 76 minutes to dry 5kg of maize with about 0.8kg (including dampness from rains) moisture content in tray 1. It took 140 minutes to dry the same quantity and moisture content of maize in tray 2. These results show that it is possible to control empirically biomass cereal (maize) driers.

Index Terms: Aflatoxin, Biomass, Drying, Empirical control, Maize, Temperature

1 Introduction

MAIZE is the major subsistence crop in Kenya. However, the drying of this cropis one of the main challenges farmers face. Currently, most farmers rely on direct sunlight drying, which researchers have found inefficient in terms of maintaining the quality of the Crop. Kenya National Cereals & Produce Board (NC&PB) offers commercial drying services to farmers at various centers located at different parts of the country. They use a continuous type of drier, which uses electricity to run motors for conveyor belts and petroleum fuel as a source of heat energy. This facility is notaccessible to most farmers, especially small-scale farmers and it is expensive since it involves transport of the cereals to these centers, which are few countrywide (Njau, 2008).As a result, alternative methods of drying are being sought. Although solar dryers have been identified as the ideal alternatives, their cost limits their adoption by small-scale farmers in Kenya (Agona, 1998). In such dryers, the cost of collectors is uneconomical for subsistence farmers in Kenya. Recent studies have revealed that drying maize using biomass driers increase the quality of grains, delays insect infestation, mould and aflatoxin contamination compared to drying using direct sunlight (Kaaya&kyamuhangire, 2006).

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As such, various designs of biomass-powered cereal driers have been developed for applications in rural areas. Figure 1 illustrates a typical biomass maize drier, which has been widely used by small-scale farmers in Western Uganda and Eastern parts of Kenya (Axtel& Bush, 1991; Centers for disease control and prevention, 2004).However, slight variations in design exist across different areas and farmers. The positioning of the heater, type of biomass and flow of heat inside the drying chamber are some of the variable design aspects in these driers. Several studies have been done on small-scale biomass driers. In their investigation on effect of biomass drying on quality of cereals, Kaaya and kyamuhangire (2006) achieved a maximum temperature of 52.4°Cand minimum temperature of 39°Cunder natural convection.Mutyaba (2000)achieved similar results in his characterization of biomass-heated natural convection drier. Drying time for biomass cereal driers has been widely studied. The drying time for these driers is shorter than direct sunlight and ranges between 3 to 6 hours.The effect of biomass drying on germination, aflatoxin contamination and mould incidence of cereals has also been investigated. However, thermal performance of these driers has not been widely studied. Performance studyis important for effective use and temperature control during drying. Since biomass driers are mostly used in rural areas, it is not necessary to installtemperature controls and monitoring systems as this would increase their cost and make them unaffordable to local and small-scale farmers. Therefore, there is need to study thermal behavior of different designs of biomass driers. The objective of this study is to characterize, thermally,a typical biomass cereal (batch) drier.Through this characterization, the study investigates whether it is possible to empiricallycontrol biomass driers.

2 materials and methods
Figure 1 shows a typical biomass cereal drier, which are mostly used in rural areasby farmers to dry cereals such as maize, beans and among others. The most critical sections for this study are labeled on the figure.

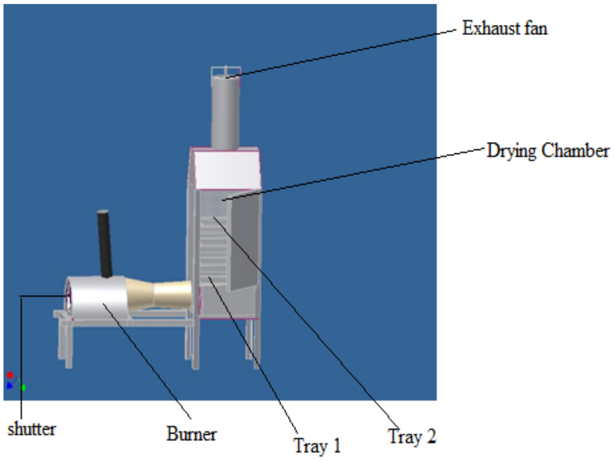

Figure 1. *Biomass Cereal Drier*

2.1 Comparing the operating conditions for natural convection and forced convection of biomass cereal driers
The cereal drier (figure 1) was run with and without the fan at the exhaust to characterize the temperature behavior within the drying chamber for forced and free convection of the drier respectively. Using a digital thermometer, the temperatures at lower tray (tray 1) were recorded.

2.2 Operating conditions at different openings of the burner
Temperatures at trays 1 and 2 were recorded when the shutter of the burner was 100% and 50% open. Figure 2 below illustrates 50% shutting of the burner opening during drying.

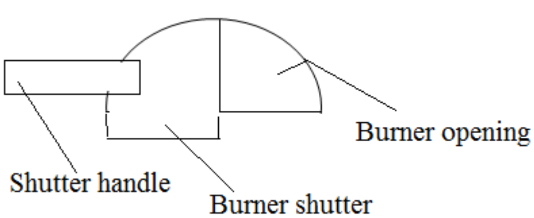

Figure 2. *Burner at 50% open*

2.3 Temperature variation within the drying chamber
With charcoal and maize cobs as fuel, temperatures at trays 1 and 2 were recordedfor 45 minutes at interval of 2 minutes.

2.4 Evaluating the effectiveness of heat transfer from the burner todrying chamber
The biomass drier was run for40 minutes and the temperatures inside the burner (annulus) and inside the drying chamber were recorded at interval of 2 minutes.

2.5Drying rate at different parts of the drying chamber
A sample of 5kg maize, with a moisture content of 28% (dry basis) was obtained from postharvest department.Then, the sample was spread on tray 1 for drying.During drying, the weight of the sample was measured at interval of 10 minutes and recorded. This was repeated until there was no further reduction in weight of the sample. Using a similar sample, this procedure was repeatedon tray 2.

3 RESULTS

3.1 Comparing the operating conditions for natural convection and forced convection of biomass cereal driers
The graph (figure 3) below shows the temperature variation within the drying chamber (tray 1) of the biomass cereal drier when operating at natural convection (fan not running). From the graph, it is clear that the temperatures rose uncontrollably to more than 160˚C and the behavior of temperature variation with time in the drying chamber cannot be predicted as it is characterized by peaks and falls.

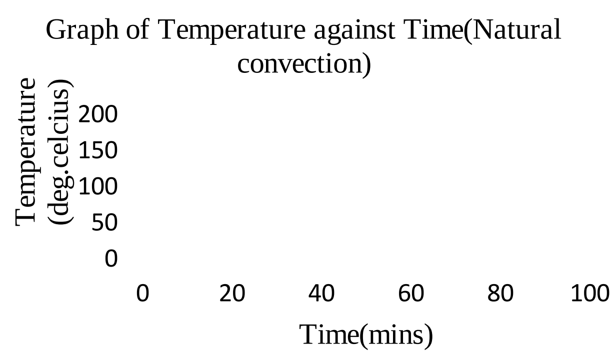

Figure 3. *Temperature variation with burner 100% opened with fan not running (Natural convection)*

The graph (figure 4) below shows the temperature variation within the drying chamber (trays 1 and 2) of the biomass cereal drier when operating at forced convection (when the fan is running). The temperature increases from room temperature (25˚C) to 92˚C and 64˚C for tray 1 and tray 2 respectively and then falls to a minimum temperature of 50˚C.

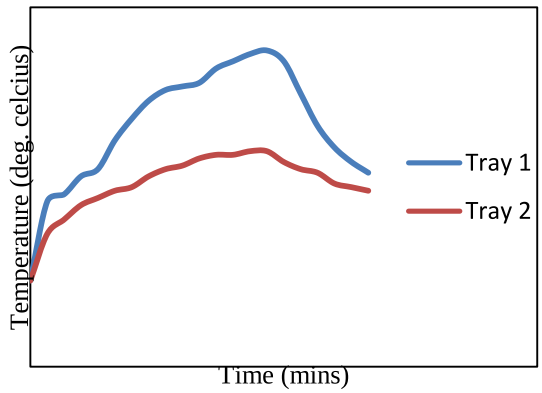

Figure 4. *Temperature variations with time on tray 1 with fan running (Forced convection)*

3.2 Operating conditions at different openings of the burner

As shown in figure 5, at burner opening of 100%, it took 40 minutes for tray 1 to achieve maximum temperature (91˚C) while at 50%; it took 25 minutes for tray 1 to achieve maximum temperature (93˚C). At 50%, tray 1 achieved aminimum temperature of 72˚C. At 100%, tray 1 achieved a minimum temperature of 68˚C.

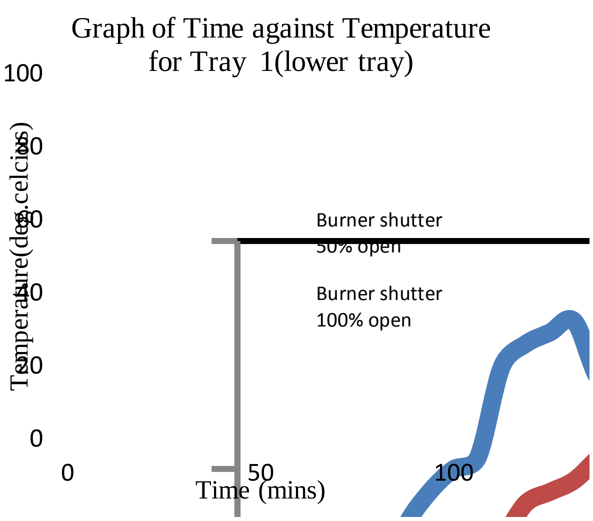

Figure 5.*Temperature variations on lower tray (tray 2) at 50% and 100% opening of the burner*

As shown in figure 6, at burner opening of 100%, it took 40 minutes for tray 2 to achieve maximum temperature (61˚C) while at 50%; it took 30 minutes for tray 2 to achieve maximum temperature (64˚C). At 50%, tray 2 achieved a minimum temperature of 56˚C. At 100%, tray 2 achieved a minimum temperature of 52˚C.

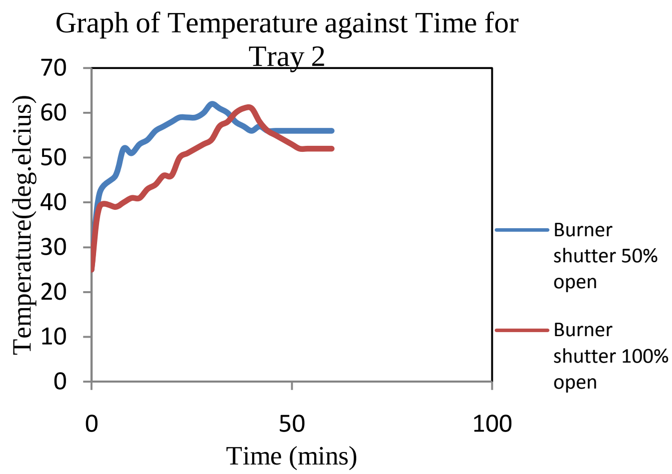

Figure 6. *Temperature variations on lower tray (tray 2) at 50% and 100% opening of the burner*

3.3 Temperature variation within the drying chamber

At time 0, temperature at tray 1 and tray 2 is the atmospheric temperature (25˚C). The burner is opened at 100%. As the burner heats up, the temperature inside the chamber increases to a maximum. The temperature then drops to a minimum. For tray 1, the temperature rises to 90˚C after 28 minutes and drops to 54˚C after 40 minutes. For tray 2, the temperature rises to 60˚C after 24 minutes and drops to 50˚C after 40 minutes. Similar trend is observed when the burner is opened at 50%. Tray 1 reaches maximum temperature of 94˚C while tray 2 achieves maximum temperature of 64˚C

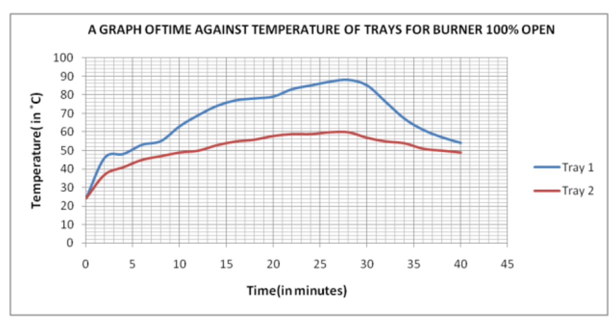

Figure 7. *Temperature variation with time using 2Kg of maize cobs*

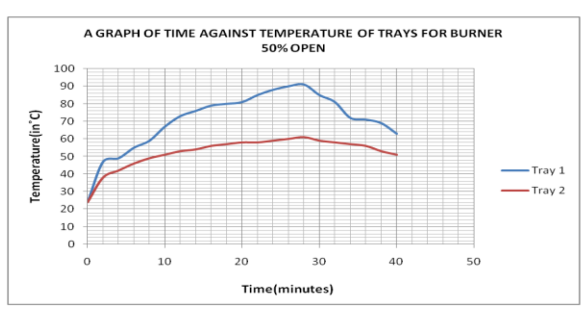

Figure 8. *Temperature variation with time using 2Kg of maize cobs*

3.4 Evaluating the effectiveness of heat transfer from the burner to drying chamber

The annulus temperature represents the heat available for transfer to the drying chamber. From the figure 9, the maximum heat loss (temperature difference of 120˚C) occurs after 28 minutes of operation of the biomass drier. However, the heat loss decreases beyond 29 minutes.

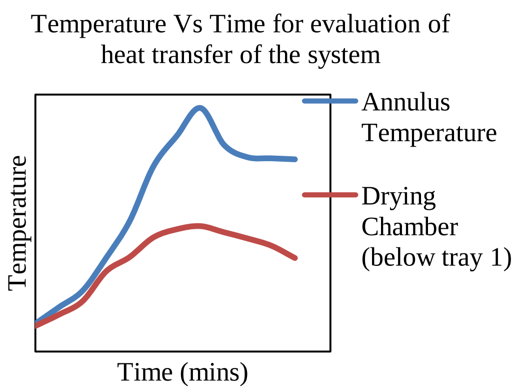

Figure 9. *Illustrating effectiveness of heat transfer from burner to the drying chamber*

3.5 Drying rate at different parts of the drying chamber

After about 80 minutes,there was no further change in mass of the sample (figure 10).

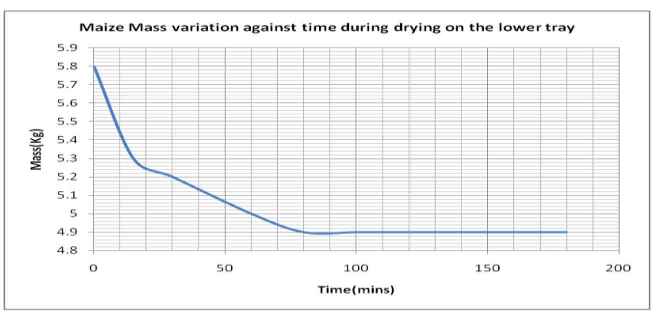

Figure 10. *Mass variation with time during drying on the lower Tray (Tray 1)*

After 170 minutes, there was no further change in mass of the sample (figure 11).

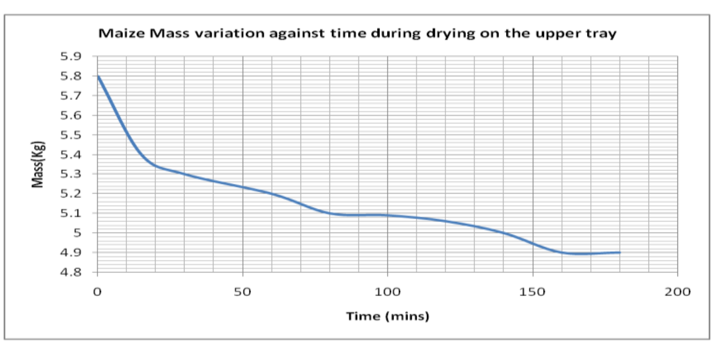

Figure 11. *Mass variation with time during drying on the upper Tray (Tray 2)*

4 DISCUSSION

Under the natural convection, peaks and falls characterize temperature variation within the drying chamber of the cereal drier.With this condition, the temperature behavior within the drying chamber is unpredictable. Beyond 32 minutes when the temperature increases above 80˚C, the temperature variation does not assume any pattern. This is because natural convection occurs effectively when density difference exists between two fluids. Based on design of the drying chamber and the position of the burner, it is difficult to achieve density difference between hot and cold air. An exhaust fanfitted at the top of the drying chamber (figure 1), enhances airflow inside the drying chamber. Since the fan is designed for specific rates of airflow, the temperature behavior within the drying chamber assumes a specific pattern (figure 4).Therefore, for effective temperature distribution within the drying chamber, such designs of biomass cereal driers should have fans fitted at the exhaust of the chamber. For trays 1 and 2, the maximum temperature is attained when the burner is 50% open. This is could be because 50% burner shutter open gives the best air-carbon ratio for efficient combustion of the biomass, which gives optimal energy. Therefore, the burner should be 50% open when carrying out drying on this drier for minimum drying time and efficient utilization of biomass.Furthermore, best air-carbon mixture enhances quick combustion of the biomass, therefore attaining maximum temperature faster than when the burner is 100% open. Therefore, the best operating conditions for such driers are achieved when the burner is 50% open. Temperature distribution within the drying chamber depends onthe heat supply from the burner.The temperature increases to a maximum value as the combustion of biomass takes place.The maximum temperature attained for tray 1 at 50% opening of the burner shutter was 93˚C, which was attained after 28 minutes. The temperature drop beyond this level is because the biomass fuel has been exhausted. These results are in agreement with the findings by (Hall, 1970; Kaaya&kyamuhangire, 2010). In biomass cereal driers, the temperature starts from at atmospheric, increases to maximum and then lowers to almost constant temperature (just above the atmospheric temperature) as indicated by Mutyaba (2000).Finally, heat loss from the burner annulus to the drying chamber is significant aspect for consideration and effective utilization of biomass fuel in drying. The results show that a maximum temperature loss of 120˚C occurs during heat transfer from the burner to drying chamber.The loss occurs through the walls of the drying chamber, annulus and hot air duct. However, effective insulation of these parts of the drierfrom low-cost materials is necessary for reduction of heat loss. It took 76 minutes to dry 5kg of maize with about 0.8kg (including dampness from rains) moisture content in tray 1. It took 140 minutes to dry the same quantity and moisture content of maize in tray 2.According to Kaaya and kyamuhangire (2010), drying time for most biomass driers ranges between 2 and 6 hours. This study confirms these results. From the results, the point at which there is no more change in weight implies that the cereals are dry.

5 CONCLUSION

Under natural convection, peaks and falls characterized the temperature behavior of the drier. This demonstrated the unpredictable behavior of temperature inside the burner. The use of forced convection (running the fan) at the various openings of the burner showed very predictable results. Analysis of the performance of the burner at different opening provideda maximum temperature of about 94oC and minimum drying time when the at 50% burner opening. This was the optimal operating point of the burner. It took 76 minutes to dry 5kg of maize with about 0.8kg (including dampness from rains) moisture content in tray 1. It took 140 minutes to dry the same quantity and moisture content of maize in tray 2.Compared to solar drying; the biomass cereal drier increased the drying rate to between 2-3 hours. The analysis of temperature distribution within the chamber showed a reduction in temperature as we ascend in the drying chamber. Because of this non-uniform temperature distribution, it is very necessary to stir the cereals during drying operation. The temperature rise inside the drying chamber is dependent on the heat supplied from the burner; the temperature increases from room temperature to a maximum of 940C for tray 1(lower tray) as combustion takes place. The temperature then drops gradually as the biomass fuel is exhausted. From these results, it is possible to control empirically the operation of these types of driers.

7.2 Acknowledgments

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7.3 References

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