Drying Groundnuts: Adapting the EasyDry M500 Portable Maize Dryer for Groundnuts (the EasyDry G600)

AflaSTOP: Storage and Drying For Aflatoxin Prevention

January 2017
TABLE OF CONTENTS

I. Executive Summary ................................................................. 4

II. Background .............................................................................. 5

III. Adapting the EasyDry M500 to Dry Groundnuts ............................. 6
   a. Drying principles of maize vs. groundnuts ..................................... 6
   b. Changing the EasyDry M500 pulley sizes for high air velocity and low temperature .......... 7
   c. Changing the EasyDry M500 bed size for low air velocity and temperature ................. 8
   d. Investigation on burning groundnut shells vs maize cobs ......................... 9

IV. Conclusion .................................................................................. 9

LIST OF FIGURES

Figure 1: Operating principles of the EasyDry M500 ........................................ 5
Figure 2: Extending the EasyDry M500 sidewalls ........................................... 8
Figure 3: EasyDry M500 loaded to capacity with 400 kg of groundnuts .................. 8
Figure 4: Extended EasyDry M500 bed .......................................................... 8
Figure 5: Extended bed loaded with 600 kg of groundnuts .................................. 9
Figure 6: Increasing the combustion fan pulley size .......................................... 9
Figure 7: Groundnut shells alight in mesh-lined furnace grate ............................. 9
Figure 8: Drying air temperature close the maximum value of 50°C .......................... 9
I. Executive Summary

Discussions with the Clinton Foundation in Malawi raised the question whether it was possible to use the EasyDry M500 to dry ground nuts in shell. The Clinton Foundation is considering whether more rapid drying will reduce the overall aflatoxin content in the ground nuts later in the processing cycle.

The recommended storage moisture for ground nuts is 8% moisture content, and the recommended heat to dry the ground nuts in shells according to literature appears to be 50 degrees centigrade.

Adapting the EasyDry M500 for low drying air velocity and temperature drying was also possible but required some design changes. The EasyDry G600 adaptions include an increase in bed surface area, which was required to reduce the drying air velocity. This was achieved by adding or changing:

- new plenum,
- 1 collapsible panel,
- 1 center support stands and
- 2 side bed supports.

pulley size changes (engine = 5”, combustion fan = 4” and primary fan = 3”)

Additional tests are needed to establish drying times, fuel consumption, and ground nut quality.

As with drying maize smallholder farmers, ground nut aggregators will only adopt the EasyDry G600 if they can recover their costs of drying. Discussions with the Clinton Foundation indicate that within Malawi this might be difficult.
II. Background

The AflaSTOP Storage and Drying for Aflatoxin Prevention project seeks to identify the most promising storage options which arrest the increase of aflatoxin and drying options that will enable smallholder farmers to utilize these identified safe storage options. The AflaSTOP initiative has designed and piloted a low capital expenditure portable maize dryer called the EasyDry M500 (M for maize and 500 for the batch capacity) with funding from the Bill and Melinda Gate Foundation and USAID. For more, visit [www.easydry.org](http://www.easydry.org). The EasyDry M500 dryer is a portable, on-farm drying solution that can be built by the informal manufacturing sector using local materials and is easy to maintain and repair. It offers a solution that closely resembles the traditional method of lying shelled maize out in the sun to dry, with the major difference in that forced hot air is used as the drying mechanism and is capable of operating under inclement weather conditions since it relies on burning biomass (maize cobs) to generate the required heat, and not the sun. This enables smallholder farmers to dry their maize down post-harvest to the moisture levels which meets the market requirements and is not discounted which increases the farmers’ marketing flexibility and reduces fears of postharvest losses which are incurred if the weather is inclement after shelling. The dryer is either transported (as a service) on two motor bikes, pickup, truck, trailer or hand cart to or stored at the location (as an on-farm investment) where maize is shelled or dried making the service applicable to smallholder farmers who do not want to incur transport costs to and from a dryer.

![Figure 1: Operating principles of the EasyDry M500](image)

The dryer can be assembled within 10 minutes by erecting the modular shallow-bed and connecting it to the drying air supply unit. ± 500 Kg of “wet” maize (±10 x 50 kg bags, ±5 ½ x 90 kg bags, ±4 ¼ x 120 kg
bags) are loaded onto the shallow-bed and the furnace is ignited. The heated clean air needed for drying is generated through convection heat transfer by blowing ambient air over heated heat exchanger (HX) channels. The HX channels are heated by drawing hot furnace exhaust gases through them and out the chimney. The hot exhaust gases are constantly generated by steadily burning fuel (maize cobs) in the downdraft furnace. The heated air is blown into a canvas plenum with maize suspended on a perforated mesh bed above it. The air pressure builds up in the canvas plenum and forces heated air past the maize kernels with surface moisture drawn away. The maize is stirred at 30 min intervals to allow the moisture trapped in the lower layers closest to the heated air to escape. Once dry, the maize is offloaded for storage. The dryer can dry the 500 kg “wet” maize (~20% moisture content) down a safe storage moisture content of +/- 13.5% within four (4) hours (+/- an hour depending on the actual moisture content of the maize) and 500 kg of maize of ~16% moisture content to below 13.5% within 90 minutes. Multiple batches can be handled per day depending on starting moisture levels and operating hours.

Much like traditional maize drying techniques, small-holder farmers dry groundnuts in the traditional way by laying the harvested plants upside down with pods exposed to the sun, reducing the moisture from between 30 - 40% moisture to below 8 % for safe storage. As with maize, this process takes a long time (sometimes weeks) and is greatly depended on the intensity of the sun with large quantities spoiling if not dried properly in a short amount of time. Just like maize, large mechanical groundnut dryers exist but are very expensive and not readily available for small-holder farmers to access.

The purpose of this document is to outline the design changes required to adapt the EasyDry M500 for groundnut drying since several groundnut value chain stakeholders expressed interest.

III. Adapting the EasyDry M500 to Dry Groundnuts

The logical approach was to try and adapt the EasyDry M500 for drying groundnuts by only changing minor details so that it could easily be converted back for drying maize again in the maize harvest season. This would allow the owner/operator to repay the unit quicker and make profit quicker as the unit’s utilization would increase over two crops and their respective drying seasons, which in East Africa are close but do not overlap for maize and groundnuts.

The testing performed below was done in between groundnut harvest seasons due to project time line constraints when no wet in-shell groundnuts were available. The conclusions reached are purely theoretical and requires actual drying of wet groundnuts to determine the drying rates and the cost benefit analysis of these proposed design changes.

a. Drying principles of maize vs. groundnuts

The mechanical drying principle of drying groundnuts in shell closely resembles that of drying maize where hot dry air is passed over the exterior shell surface, absorbing moisture from the outer layer and wicked away by the drying air. Hydrostatic pressure then causes moisture to move outwards from the nut through the shell, drying it in the process.

The drying performance and throughput capacity of a mechanical driers are greatly tied to the air volume passing thought the crop being dried as a higher volume of dry air has a higher water vapor carrying capacity before saturation. Therefore, increasing the air volume passing through the groundnut bed would be the better tactic over slowing the furnace and minimizing the heat since the engine driving the fans is burning fuel at the same rate regardless of which approach is followed. Literature sited suggests two approaches for drying groundnuts, each impacting their own cost benefit analysis. Both approaches keep the drying air temperature below their respective maximum recommended values with one promoting an
increased drying air velocity which is unsaturated by the time it exits the bed and the other air just saturated by the time it exits the top of the bed.

Below follows testing and the recommended design changes to the EasyDry M500 for both of these approaches that requires future research on drying wet grounds to validation on which approach is better suited to the EasyDry M500 when considering the cost benefit analysis.

b. Changing the EasyDry M500 pulley sizes for high air velocity and low temperature

Currently, the temperature of the air being passed through the maize bed can range from 50 - 90°C due to the variance in ambient conditions as incoming drying air temperature and humidity having an effect on how a constant heat source increases the temperature and decreases the humidity of a constant volume of air. Literature however suggests that heating groundnuts above 50°C for extended period of time will degrade quality and taint the flavor. Keeping the drying air temperature below 50°C with limited design changes to the EasyDry M500 can be achieved by either lowering the furnace temperature or increasing the volume of air being heated by the heat exchanger (HX). Research suggests that maize cobs will be available during the groundnut harvest season so it was therefore decided to keep the furnace design as is for the initial stages of testing and explore other biomass options if required.

The cheapest and most elegant way to increase the airflow though the HX was to simply decrease the 450 mm fan pulley relative to the driving pulley on the engine as this increased the fan RPM at the same engine RPM. There was however a balance of how fast the 450 mm fan should rotate as faster drying air build more static pressure against the furnace and slowed the combustion rate and furnace temperature down. Preventing this required a similar decrease in the combustion fan’s pulley size enabling it produce more suction pressure. Alternatively, the fan pulley sizes could remain the same sizes as per the original design with the engine pulley increasing in size to have the same effect.

A major consideration when adjusting airflow as per the above mentioned method was the air velocity of the drying air passing through the groundnuts. Moving air too slowly would decrease the rate that the moisture horizon moves through the bed slowing the drying process down and moving air too quickly would waist energy and increase cost since the drying air escapes before saturation.

The best way to assess what changes were required was to take an EasyDry M500, load it with as much groundnuts as the bed could hold, experiment with a variety of pulley size configurations and measure the airflow and temperature through the bed.

The original 1.8 m x 1.8 m x 0.6 m maize drying bed was first used and filled with unshelled groundnuts which only managed to hold a 200 kg batch, making for a difficult economic argument. Increasing the sidewall heights by adding extra perimeter material resulted in a batch size of 400 kg which seemed more economical. The next step was to fire the dryer as is to see if any changes were required when considering groundnut drying characteristics and if so experiment with off-the-shelf pulleys to monitor the airflow and temperature of the drying air.
It is known from all the maize drying that the optimal airflow for maize drying with the EasyDry M500 at a grain bed depth of 16 cm (500 kg of shelled maize) is achieved at a plenum static pressure of 0.25” water pressure and that the temperature suffers at a higher static pressure due to the furnace slow down. The static pressure for a full extended groundnut bed however only managed 0.1” of water pressure due to the larger air gaps between pods when compared to the gaps between maize kernels, resulting in faster airflow through the groundnut bed when compared to maize. This had two implications: a hotter furnace and faster than optimal airflow. This ultimately resulted in drying air fast approaching 50ºC even with the increased airflow through the HX with the test having to be abandoned due to excessive drying air temperature. The next step was the reduce the primary fan pulley and repeat the experiment.

Originally the EasyDry M500 had a pulley configuration as follows: engine = 4”, combustion fan = 3”, primary fan = 4” and ran at 1350, 1800 and 1350 RPMs respectively. The first iteration saw only the primary fan pulley decreased to 3” increasing its RPM to 1800 with the furnace fired and the engine started. Even though this alteration resulted in a higher static pressure (due to the air velocity increase) and a drying air temperature closer to 40ºC, the air velocity through the bed was too fast and therefore inefficient and may not be cost effective. More research on drying wet grounds with this configuration is recommended as some literature suggest that the drying rates achieved at these higher air velocities could be as or even more economical when compared to that bigger batch and slower drying air configurations.

c. Changing the EasyDry M500 bed size for low air velocity and temperature

The economical way of diversifying the EasyDry M500’s crop drying potential was to utilize as many of its components already owned for maize drying and add as little as possible where needed. This approach was attempted specifically when it came to the collapsible bed but was unsuccessful due to its size. Firstly, the load capacity was limited to 400 kg and the surface area was too small resulting in inefficient drying air velocity through the groundnut bed. An additional collapsible bed panel and connecting support legs were added which increased the surface area are by 1/3. A new plenum was required to accommodate this increase. The bed was assembled and attached to the drying unit and managed to hold 600 kg of in-shell groundnuts. It should be noted that proccing such a full bed may be challenging depending on the operator and a lesser, more manageable amount may be considered.
The drying unit with a pulley configuration of engine = 4”, combustion fan = 3” and primary fan = 3” was attached and the engine started without the fire being lit to assess the airflow rate. The increased surface area of the new bed proved too large for this configuration as the air velocity did not manage to move a A4 sized paper (a crude but effective indication of sufficient airflow) even at 1800 RPM. Finding an off the shelf pulley smaller than 3” was challenging which meant the engine pulley size had to be increased to increase the 3” pulley RPM. The engine pulley was increased to 5” resulting in an RPM increase of the primary fan from 1800 RPM to 2,250 RPM. This speed is well within the bearing’s maximum permissible speed of rotation of 3,400 RPM. This increase in RPM produced sufficient airflow and the fire was lit to assess air temperature. The static pressure in the bed was only 0.15” of water pressure due to the lower are velocity through the bed and with a combustion fan rotating at 2,250 RPM, the drying air temperature soon reached 50°C and the test was abandoned. The combustion fan pulley was increased to 4” which slowed the furnace down and dropped the drying air temperature to the required safe level of 40°C.

d. Investigation on burning groundnut shells vs maize cobs

Since groundnut shells were on hand, experiments were conducted to assess if manor design changes to the furnace could accommodate burning groundnut shells as a fuel source instead of maize cobs. These changes would have to be revisable to enable the dryer to be converted back to maize cobs with minimal effort and cost. A way to prevent the groundnut shells from falling thorough the fire grate was required since groundnut shells are much smaller in size. A mesh insert was added to the furnace grate and groundnut shells were ignited to study the fire characteristics before effort was spent on a more durable design. It was soon clear that the tight fitting groundnut shells restricted the downdraft combustion air supply and failed to burn at the required intensity that the heat exchanger required to produce the heated drying air.

IV. Conclusion

Adapting the EasyDry M500 to become the EasyDry G600 to dry groundnuts showed great potential.

Changing the original design by adding a perimeter bed sidewall and decreasing the primary fan pulley size to 3” provided sufficient justification for additional research on wet groundnuts to evaluate the cost benefit analysis for drying 400 kg of groundnuts with high velocity-low temperature drying air during the next harvest season.

Adapting the EasyDry M500 for low drying air velocity and temperature drying was also possible but required more expensive design changes. The EasyDry G600 adaptations include an increase in bed surface area was required to reduce the drying air velocity. This was achieved by adding or changing:

- new plenum,
- 1 collapsible panel,
- 1 center support stands and

![Figure 6: Increasing the combustion fan pulley size](image)

![Figure 7: Drying air temperature close the maximum value of 50°C](image)

![Figure 8: Groundnut shells alight in mesh-lined furnace grate](image)
• 2 side bed supports.
• **pulley size changes** (engine = 5”, combustion fan = 4” and primary fan = 3”)

Once again sufficient justification was made for additional research on wet groundnuts to evaluate the cost benefit analysis for drying 600 kg of groundnuts with low velocity-low temperature drying air during the next harvest season.

It is recommended to use a thermometer in either approaches to ensure that the drying air temperature does not reach above the recommended value since a high ambient incoming air temperature may cause the drying air temperature to come close to the maximum recommended value. Increasing the engine RPM slightly will increase the airflow through the HX and decrease the drying air temperature.

A complete furnace redesign will be required if groundnut shells are to be burned for the heat source in place of maize cobs since simply adding an insert to prevent groundnut shells from falling through the grate is not sufficient nor effective.