REPORT

Comparative Dryer Performance Testing: Artisan vs. Formal Fabricators

AflaSTOP: Storage and Drying For Aflatoxin Prevention

November 2015
The AflaSTOP: Storage and Drying for Aflatoxin Prevention (AflaSTOP) project is identifying the most promising storage options to arrest the growth of aflatoxin and designing viable drying options that will allow smallholder farmers to dry their grain to safe storage levels. The project works to ensure that businesses operating in Africa are able to provide these devices to smallholder farmers. It is jointly implemented by ACDI/VOCA and its affiliate Agribusiness Systems International (ASI) under the direction of Meridian Institute. For more information on AflaSTOP and other key reports and resources, visit: www.acdivoca.org/aflastop-publications.

This work was carried out as a partnership between Catapult Design and Agribusiness Systems International (ASI) through the AflaSTOP project to identify potential drying technology suited to support post-harvest handling devices for maize smallholder farmers.
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1 Background

Agribusiness Systems International (ASI) contracted Catapult Design to research, design and field test a new maize drying technology suitable for commercialization that is adapted to the needs of Kenyan smallholder farmers, permitting them to confidently, easily, and cost-effectively dry maize down to safe, long-term storage moisture content regardless of weather conditions. Performance testing of various maize drying prototypes identified the Portable Shallow-bed Batch Dryer (henceforth referred to as “the dryer”) as having the highest potential for further development and possible commercialization. A proposed manufacturing strategy for commercialization currently being explored is evaluating whether informal “Jua Kali” fabricators can reproduce a working demonstration dryer (built by the prototyping fabricator – Kenya Stove) effectively and if so, disseminate the technology in a similar fashion that is currently being observed in the agricultural equipment market. An alternative proposed manufacturing avenue for commercialization is to assess whether formal fabricators (based in bigger industrial settings) would be interested in producing the dryer design (since the design is simple enough for the informal sector to produce) and if so, at what price point would they do so.

The dryer’s inner workings, including related material selection and fabrication techniques were demonstrated, discussed and self-documented by eight (8) informal fabricators during a two (2) day workshop (29, 30 June 2015) held at Kenya Stove. Four (4) informal fabricators covering a spectrum of fabrication capacity and geographical areas were selected and contracted by AflaSTOP to each manufacture a complete dryer. Three (3) formal fabricators covering a spectrum of fabrication capacities and sophistication were invited to a demonstration day (1 July 2015) with two (2) attending on only one (1) pricing the dryer. A contract was executed for the fabrication on one complete dryer unit by a top rated intermediate fabricator within the Kariobangi area of Nairobi.

The next step was to conduct quality, function and performance testing of all the dryers, comparing and contrasting them to the demonstration dryer’s material selection, workmanship and performance. These evaluations were conducted from 27 - 31 July 2015 to asses if both the formal and the informal sectors were capable of manufacturing the design and to highlight any concerns that may require design changes to be incorporated and possible next iteration of the dryer.

The purpose of this document is therefore to report back on the evaluation of the various dryers and to make design recommendations for a possible following iteration and to recommend what commercialization and go-to-market strategy poses the most promise for in-country manufacturing with possible widespread distribution through informal fabricators or private sector networks of agricultural dealers.

2 Visual - Material Selection, Workmanship and Function

The main objective of a visual evaluation exercise was to assess if the respective dryers were built to acceptable Kenyan fabrication standards and whether each dryer and its particular subsystems function correctly according to the respective design specifications under local environment conditions when compared the demonstration unit. Each dryer unit was compared to the demonstration unit where it was evaluated for quality with regards to material selection, design documentation referencing, workmanship, finish and function with problem areas highlighted. A 1 to 5 rating scale was used with accumulative scoring totaling a top score for each dryer’s subsystems and ultimately the dryers as complete units. This scoring was then shared with the respective fabricators with explanations and recommendation to rectify problem
areas given. Below follows a summary table containing the respective scoring of each dryer followed by a brief discussion of overall takeaways from each subsystem. The highlighted cells (in orange) indicate the top scoring unit in each sub classification.

Table 1: Artisan vs. formal fabricated dryer visual evaluation

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
<th>Artisan Unit 1 - David</th>
<th>Artisan Unit 2 - Gilbert</th>
<th>Artisan Unit 3 - Joseph</th>
<th>Artisan Unit 4 - Moses</th>
<th>Formal Unit 5 - Nyaweco Engineering</th>
<th>Demo Unit 6 - Kenya Stove</th>
<th>Top Score Possible</th>
<th>Top Scoring Unit</th>
</tr>
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<tbody>
<tr>
<td><img src="image" alt="Portable Shallow-bed Batch Dryer" /></td>
<td>Portable Shallow-bed Batch Dryer</td>
<td>88</td>
<td>78</td>
<td>58</td>
<td>55</td>
<td>72</td>
<td>99</td>
<td>120</td>
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<td><img src="image" alt="Portable Shallow-bed Batch Dryer - Drying Air Supply" /></td>
<td>Portable Shallow-bed Batch Dryer - Drying Air Supply</td>
<td>74</td>
<td>58</td>
<td>49</td>
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<td>82</td>
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<td><img src="image" alt="Drying Air Supply Unit Main Body Assembly" /></td>
<td>Drying Air Supply Unit Main Body Assembly</td>
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<td>47</td>
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<td>69</td>
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<td><img src="image" alt="HX Assembly" /></td>
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<td>1/6</td>
</tr>
<tr>
<td><img src="image" alt="5.5 HP Engine and V-Belt Drive" /></td>
<td>5.5 HP Engine and V-Belt Drive</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>8</td>
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<tr>
<td><img src="image" alt="Portable Shallow-bed Batch Dryer - Shallow-Bed Assembly" /></td>
<td>Portable Shallow-bed Batch Dryer - Shallow-Bed Assembly</td>
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<td>20</td>
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<td>4</td>
<td>5</td>
<td>6</td>
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<tr>
<td><img src="image" alt="Canvas Rainfly" /></td>
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<td>3</td>
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<td>0</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

0 = Missing 1 = Poor 2 = Fair 3 = Good 4 = Very Good 5 = Excellent
2.1 Portable Shallow-bed Batch Dryer - Drying Air Supply

2.1.1 Drying Air Supply Unit Main Body Assembly

The material selection, design documentation referencing, workmanship and finish varied greatly from dryer to dryer. Overall the units were constructed satisfactorily with two artisan units showing concern with workmanship. A third artisan clearly ran out of time (each artisan was given 3 weeks to complete the build) and delivered an unfinished unit that showed a lot of potential if given more time to complete his build. The unavailability of standardized sheet metal gauges was evident with material thicknesses varying from the recommended material thickness to sheet metal that brings durability into question. All of the fabricators missed some minor design details with one of the artisan fabricator neglecting to include a crucial performance component (the 450 mm scroll). It was clear from the missing details and components that detailed design drawings supplemented by self-documentation are still not sufficient to ensure an accurate reproduction of the demonstration unit. Having a physical unit to copy seems to be the best way to ensure no details are missed.

2.1.2 HX Assembly

Extensive discussions around the need for tight tolerances within the HX were held during the artisan training with the resulting HX fabrication confirming the importance of such discussions vs. handing drawing over for fabrication. All the artisan fabricators produced satisfactory and functional heat exchangers without the use of sophisticated fabrication machinery or tools. The formal fabricator did however not participate in the importance of tight tolerance discussions and it was evident from the misaligned panels and large gaps that performance would be an issue.

2.1.3 Axial Fan Assemblies

The fans were considered to be to most challenging performance component to fabricate and extensive time was spent explaining the design during training. Two artisan produced fans that rivaled the demonstration unit’s in workmanship and tolerances with the other two artisans failing entirely. One of the failing artisans outsourced the fan fabrication to a supposed engineering firm, illustrating that the complexity of the fan designs were intimidating for some fabricators. The main problem with the both artisan’s fans were that they were built in reverse, resulting in dryers that could not be used for complete performance testing since the drying and combustion airflow were in the wrong direction. Shaft eccentricities and improper balancing were also concerns in these fans.

Another unforeseen problem was the fact that the formal fabricator decided to substitute the fans with variable blade cast axial fans without consulting the design team. It was clear that they did not understand the imposed static pressure in the grain bed since the surrounding scroll that created pressure was so far removed that air flowed straight past the blade edges once back pressure was introduced. The formal fabricator was contacted to correct their errors and...
returned a unit that still comprised of the substituted fans but were retrofitted with tighter tolerances around the scroll to enable static pressure.

2.1.4 Engine and V-Belt Drive

A common problem observed in all of the units was the loose pinned connection tolerances of the engine baseplates. This resulted in excessive play in the engine connection, resulting in excessive belt and engine vibrations when operated. The pulley alignment in one artisan unit also needed attention due to this issue. Variable pulley ratios were also delivered, illustrating that the fabricators did not fully understand the need for a specified rotational speed of both fans and that more effort should be spent to explain the importance of achieving the correct pulley and ultimately fan rotational speeds for proper air flowrates.

2.2 Portable Shallow-bed Batch Dryer - Shallow-Bed Assembly

2.2.1 Shallow-Bed Assembly

Only 1 out the 5 fabricators managed to reproduce the shallow-bed support frame in such a manner that any bed panel would fit anywhere, as per the design (this same fabricator also made a slight improvement on the design). The rest all missed a crucial detail (the fact that the supporting frame is a continuous square) that created major assembly issues. Some fabricators also outsourced the fabrication due to time constraints, resulting in poor workmanship and unfinished units. One bed took over an hour to work out and required the use of a hacksaw to cut out bits to allow it to actually fit together. Other crucial components were also missed by some fabricators (such as the bed overlap to prevent maize from spilling into the canvas) which required in-the-field repairs to allow for further testing. Most fabricators forgot to round off the outer corners to prevent the panels potentially tearing through the plenum.

2.2.2 Canvas Plenum and Rainfly

The availability of the specified plenum/rainfly material in some areas lead to excessive pricing quotations (double the Nairobi based quote), requiring two artisan fabricators to have the same supplier as the demonstration unit (based in Nairobi) produce their plenums and rainflies. One artisan fabricator opted to use cotton canvas (vs. the specified PVC) for both plenum and rainfly with the remaining artisan fabricator using maize storage sacks as a rainfly to save on cost. The connecting duct and plenum sizing were sometimes problematic, requiring in-the-field repairs to allow for further testing. None of the rainflies were sewn correctly with some vertical overlaps being too short to prevent rain spilling into the beds and others missing access flaps to process the drying maize.

3 Performance Evaluation

Maize drying is mainly influenced by drying air velocity and its ability to absorb moisture. The easiest way to promote moisture absorption is to lower the relative humidity of the drying air by heating it above ambient conditions. The hotter the drying air, the more capacity is has to draw moisture out and away from the maize kernels. The drying air velocity and temperature within this design is greatly influenced by the performance of the drying air supply fan (450 mm), the furnace design and combustion air supply fan (300 mm), and heat exchanger (HX) panel tolerances. Both fans will need to produce sufficient airflow against static pressures imposed by the grain bed and the HX to ensure optimal drying performance.
The general testing methodology was to conduct initial “passive” performance evaluations of the crucial components of each dryer and compare their respective performances against the demonstration unit’s as well as existing prototyping test data. The ultimate performance test however was to assess if each dryer could reduce the moisture content of 500 kg wet maize (around 18-22 % Mc) to an acceptable hermetic appropriate storage moisture content (around 13.5 % Mc) within 4-5 hours.

3.1 Critical Component Performance Assessment

3.1.1 Drying Air Supply Fans (450 mm)

Drying airflow and static pressure performance were evaluated first by comparing test parameter values at engine idle; the lowest possible common 450 mm fan RPM obtainable (standardizing the rotational speed to eliminate factory setting discrepancies within the individual engines); and incrementally imposed static pressure at the standardized 450 mm fan RPM by loading each shallow-bed in 100 kg increments and assessing airflow through the system at each interval. The final step was then be to assess what RPM was required by each dryer to achieve the optimal airflow for grain drying (A4 size paper “floating” ever so slightly above the grain).

3.1.2 Combustion Air Supply Fans (300 mm)

Similarly, combustion airflow and static pressure performance were evaluated by comparing test parameter values at engine idle and then the lowest possible common 450 mm fan RPM obtainable (standardizing the rotational speed to eliminate factory setting discrepancies within the individual engines). Rotational correction factors were used where pulley sizes varied from the design specification.

3.1.3 Heat Exchanger (HX) Performance

Heat exchanger (HX) construction was evaluated by assessing air leakage through the interlocking panel seams by constraining the combustion air inlet at the furnace and measuring the negative static pressure produced within the HX and the flow a leaked air out the chimney.

Below follows a summary table containing the respective values of each dryer’s critical component performance. The highlighted cells (in orange) indicate the top performing unit in each sub classification with the notes providing more detail on the evaluation criteria.

<table>
<thead>
<tr>
<th>ARTISAN VS. FORMAL FABRICATED DRYER PASSIVE PERFORMANCE EVALUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryer Unit #</td>
</tr>
<tr>
<td>Dryer Unit Fabricator</td>
</tr>
<tr>
<td>Furnace Unit Stand Alone @ Engine Idle</td>
</tr>
<tr>
<td>Combustion Air (300 mm Fan) Performance</td>
</tr>
<tr>
<td>Combustion air volume unloaded (CMM)</td>
</tr>
<tr>
<td>Dryer Unit #</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Combustion air SP fully restricted at chimney (inH2O)</td>
</tr>
<tr>
<td>Drying Air Fan (450 mm Fan) Performance</td>
</tr>
<tr>
<td>Drying air volume (CMM)</td>
</tr>
<tr>
<td>Static Pressure (SP) fully constricted (inH2O)</td>
</tr>
<tr>
<td>Heat Exchanger (HX) Construction Assessment</td>
</tr>
<tr>
<td>Static Pressure (SP) of Heat Exchanger (Suction)</td>
</tr>
<tr>
<td>Combustion air volume HX fully restricted (CMM)</td>
</tr>
<tr>
<td>Furnace Unit Stand Alone @ Standardized 450 mm Fan RPM</td>
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<tr>
<td>Combustion Air (300 mm Fan) Performance</td>
</tr>
<tr>
<td>Combustion air volume unloaded (CMM)</td>
</tr>
<tr>
<td>Combustion air SP fully restricted at chimney (inH2O)</td>
</tr>
<tr>
<td>Drying Air Fan (450 mm Fan) Performance</td>
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<tr>
<td>Drying air volume (CMM)</td>
</tr>
<tr>
<td>Static Pressure (SP) fully constricted (inH2O)</td>
</tr>
<tr>
<td>Furnace Unit Connected to Shallow-bed - Unloaded</td>
</tr>
<tr>
<td>Drying air volume @ Engine idle (CMM)</td>
</tr>
<tr>
<td>Static Pressure (SP) @ Engine idle (inH2O)</td>
</tr>
<tr>
<td>Drying air volume @ Standardized Fan RPM (CMM)</td>
</tr>
<tr>
<td>Dryer Unit #</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Drying air volume @ measured at duct (CMM)</td>
</tr>
<tr>
<td>Drying air velocity through maize bed (m/s)</td>
</tr>
<tr>
<td>Static Pressure (SP) @ Standardized Fan RPM (inH2O)</td>
</tr>
</tbody>
</table>

**Furnace Unit Connected to Shallow-bed - 500 kg Maize Loaded**

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<th>5</th>
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<tbody>
<tr>
<td>Drying air volume @ Engine idle (CMM)</td>
<td>45.79</td>
<td>48.36</td>
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<td>58.76</td>
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<tr>
<td>Static Pressure (SP) @ Engine idle (inH2O)</td>
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<td>0.24</td>
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<tr>
<td>Drying air volume @ Standardized Fan RPM (CMM)</td>
<td>59.33</td>
<td>57.71</td>
<td></td>
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<td>58.76</td>
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<td>Performance tests repeated once shallow-beds were fully loaded to assess performance against the highest static pressure imposed by the grain bed.</td>
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<tr>
<td>Drying air volume @ measured at duct (CMM)</td>
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<tr>
<td>Drying air velocity through maize bed (m/s)</td>
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<td>Static Pressure (SP) @ Standardized Fan RPM (inH2O)</td>
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<tr>
<td>Paper test (Yes/No)</td>
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<td>“Yes” indicated sufficient airflow through the maize bed.</td>
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<tr>
<td>Paper test (RPM to float)</td>
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<td>1266</td>
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<td>1515</td>
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<td>RPM required to supply sufficient drying air.</td>
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<tr>
<td>Drying air volume @ Paper test RPM (CMM)</td>
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<td>57.71</td>
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<td>61.05</td>
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<td></td>
<td>Slower airflow will allow for better moisture absorption.</td>
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<tr>
<td>Static Pressure (SP) @ Paper test RPM (inH2O)</td>
<td>0.19</td>
<td>0.24</td>
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<td>0.24</td>
<td>2</td>
<td></td>
<td>Higher SP at lower volume indicates a better fan construction.</td>
</tr>
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</table>
3.2 Drying Performance Assessment at a 500kg Batch Size

Once fully loaded, the furnace, HX, combustion air fan and ultimate drying performance were evaluated over a three day period by firing all the dryers simultaneously to eliminate the impact of environmental conditions. Units 3 and 4 could not be tested with maize as the artisans who produced them mistakenly reversed their drying air fans, blowing drying air in the wrong direction. Nyaweco Engineering returned their dryer a day late after addressing some of the fundamental fabrication flaws; its performance was later tested alongside the Kenya Stove unit so it could be compared in the same manner as the artisan dryers. All of the remaining dryer supply fan’s RPMs were set at the same airflow by throttling the engines and the furnaces fired to assess heat exchange performance. Cob combustion and engine fuel consumption was tracked with average drying air temperatures and relative humidity compared to environmental ambient conditions as well as the demonstration unit’s performance. The dryers were fired until the desired moisture content of the maize was achieved.

Figure 2: Head to head dying performance testing

Figure 3: Comparison of the ability of each dryer to reduce moisture content over time

1 Reference MS Excel document “PERFORMANCE TEST DATA R1” for complete testing data
As mentioned before, drying performance is greatly dependent on three factors: (1) ambient conditions, (2) the rate that moisture migrates from the internal core of the kernel to the outer surface and (3) the ability of the drying air to absorb this excess moisture from the maize kernels. The latter of these factors are influenced by the drying air temperature which in turn is influenced by ambient conditions. The higher the ambient air temperature, the more difficult it is to perform heat transfer and the lower the resulting HX efficiency. Higher drying air temperature has lower relative humidity (RH) allowing the moisture migrated from the core to be moved away. All of these factors interacted at various levels over different days of testing, resulting in varying drying times.

3.2.1 Drying results of 500kg batch size

The graphs below illustrate this correlation where it is evident that the RH of the drying air (measured inside the plenum) is directly related to drying air temperatures that ultimately contributes to the best drying performance. A higher cob consumption did not necessarily result in better drying times. This was mainly due to fire and therefore heat escaping from the mouth of the furnace caused by insufficient combustion fan suction. Fuel consumption varied due to the fact that engine rpms were set at a drying air fan speed capable of pushing the same quantity of drying air through the grain bed.

Although the demonstration unit had the best drying performance, it is clear from the graph above that all of the artisan units tested (minus the two units could not be tested due to incorrect drying airflow) managed to reduce the moisture content of the maize to the required values within a reasonable amount of time. The formal fabricated dryer did not perform due to the lack of static pressure produced by the drying air supply fan and had to be replaced with another unit to complete its drying cycle.

Figure 4: Ambient Temperatures compared to Plenum temperatures achieved – Day 1
Figure 5: Ambient RH compared to RH in plenums – Day 1

Figure 6: Moisture content reduction over time – Day 1
Figure 7: Fuel Consumption/Hr – Furnace – Day 1

Figure 8: Fuel Consumption/Hr – Engine (l) - Day 1

Figure 9: Ambient Temperatures compared to Plenum temperatures achieved – Day 2

Figure 10: Ambient RH compared to RH in plenums – Day 2
Figure 11: Moisture content reduction over time – Day 2

Figure 12: Fuel Consumption/Hr – Furnace – Day 2

Figure 13: Fuel Consumption/Hr – Engine – Day 2

Figure 14: Ambient Temperatures compared to Plenum temperatures achieved – Day 3
No fuel consumption was measured during this test and this data is therefore not available.

### 3.2.2 Drying results day performance variation discussion

Day 1 saw all 3 units tested achieve similar plenum temperatures, RH with comparable drying efficiencies and times. Day 1 highlighted some unforeseen design concerns that resulted in changes made to the demonstration unit. This change was to increase the combustion air fan speed by reducing its pulley and therefore increasing its ability to generate higher static pressure. This ultimately resulted in more flames and heat making its way through the HX and therefore generating higher plenum temperature, lower drying air RH and faster drying times. Day 3’s testing experimented with increasing the demonstration unit’s drying air speed by reverting back to the original combustion air pulley but increasing the engine rpm to achieve the same static pressure in the furnace. This resulted in higher airflow across the HX panel with lower drying air temperatures passing through the maize bed.
It is clear from the performances achieved by Unit 6 over the 3 days (graph above) that higher combustion air flowrates, static pressure and temperatures with slower drying air flowrates produces the best overall drying performance.

### 3.3 Drying Performance Assessment at a 1000kg Batch Size

Since Units 3 and 4 could not be tested with maize, 1000kg of maize remained to be dried. This provided an opportunity to evaluate whether this design could dry a 1MT batch and assesses the performance associated with it. Using Unit 1's furnace and Unit 2's bed frame (this was the best built bed from any fabricator) 1000kg of maize was carefully loaded onto the bed. Slight modifications were needed to contain a deeper grain bed. Drying the same maize with approximately the same starting moisture content of around 17%, 500kg of maize took on average 123 mins, whereas drying 1000 kg of maize took 240 min, almost exactly twice as long and took just under twice as many cobs. However looking at Figure 23, it is clear that fuel was much higher when drying 1000kg of maize. Petrol usage was 2.7 times higher this was because the speed of the engine was increased to increase the static pressure needed to ensure enough air was pushed through the bed to dry the maize. This is not necessarily a limiting factor since the overpowered engine could potentially drive a higher fan speed by simply reducing the fan’s pulley size, effectively speeding the fan up to achieve the required static pressure at engine idle.
Figure 19: Ambient Temperatures compared to Plenum temperatures – 500kg vs 1000kg

Figure 20: Ambient RH compared to RH in plenums – 500kg vs 1000kg

Figure 21: Moisture content reduction over time – 500kg vs 1000kg
4 Conclusion

It is clear from the test data discussed in this document that some artisan fabricators managed to produce dryers that performed satisfactorily, at times even better than the demonstration unit, and managed to dry wet maize down to the desired moisture content within the desired timeframe. This confirms a viable manufacturing avenue for commercialization comparable to that of other agricultural equipment. However, caution should be exercised in how the design is disseminated as small fabrication errors may impact performance gravely. It is also important for the fabricators to understand the basics principles of crop drying so that they understand what possible impact minor variations from the original design may have on drying performance.

The furnace and bed design can accommodate 1000kgs however in this one test it appears that it would be more economical to do two loads and the lower engine speed than increase the time, and fuel consumption to accomplish the larger volume. This would need to be tested further to verify.

5 Design recommendations for possible further iterations

Performance testing of this iteration of the design (the demonstration unit) highlighted some design concerns that should be addressed within the next design iteration. Below follows a brief discussion around observations made with attention to these issues recommended.

5.1 Portable Shallow-bed Batch Dryer - Drying Air Supply

5.1.1 Drying Air Supply Unit Main Body Assembly

The triangular cutouts within the main dryer body (originally added to allow the furnace to cool for transportation) allowed smoke from the furnace to leak into the maize via the drying air supply fan. This occurred due to the fact that combustion air was available from above the furnace and the smoke was not sucked down into the HX as per previous designs. It is recommended to remove these cutouts and add a few small air supply holes just above the fire grate to allow for initial furnace combustion air before the engine is started.
Excessive heat was also detected in the combustion exhaust, making the argument that the available thermal energy is underutilized. It is recommended to explore ways to prolong the residence time of the combustion exhaust gasses within the HX to better use the heat currently going to waste.

5.1.2 Furnace and Fire Grate

Ash accumulated within the bottom section of the fire grate, blocking much needed combustion air. Raising the grate by another 25 mm should alleviate this problem. The fire grate should also be redesigned to form a better seal against the furnace body as the metal expands and warp from the heat. One way to achieve this seal is to have the fire grate rest on angle iron welded to the furnace body with sufficient overlap sealing the grate to the furnace body, allowing for metal expansion without loss of suction through the grate.

5.1.3 Engine and V-Belt Drive

The 2 mm engine baseplate was too thin with it flexing under the slightest shaft eccentricities, resulting in the engine experience excessive vibrations. It is recommended to thicken this sheet metal or add stiffeners to the baseplate to avoid this issue.

5.2 Portable Shallow-bed Batch Dryer - Shallow-bed

5.2.1 Canvas Plenum

Heavy-duty PVC canvas as per the original design specifications is difficult to source in remote locations of Kenya and an alternative, more readily available material should be specified for this application if possible. Performance testing confirmed that cotton canvas will suffice as it holds sufficient pressure, however, durability is questionable.

5.2.2 Rainfly

It was only clear once the rainfly and its center support was fabricated that the pitch of the covering may allow rain water to accumulate on the rainfly and eventually leak into the grain bed. It is therefore recommended to increase the rainfly pitch by extending the center support by roughly 300 mm and adjusting the rainfly to fit accordingly.