Designing Affordable Solar Dryer for the Small Scale Holder

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Abstract: The local farmer preserves the farm produce either by drying over the cooking tripod flue or by the use of natural sunlight. The quantity of produce that can be accommodated over the cooking flue is limited and the traditional solar drying is inefficient because the produce is exposed to vagaries of nature, birds and occasionally to rodents. The produce is preserved for use during the lean period, sold when the price is right and stored to provide seeds for the next planting season. The cost of building the typical glass covered solar dryer is generally beyond the means of the average rural farmer. There is therefore a need to find cheaper construction materials to replace the major cost components such as glass. Two solar dryers with glass and plastic covers have been designed and constructed for the purpose of assessing the suitability of plastic sheet as a replacement for glass. The drying performance of the two dryers has been compared. The results from the plastic covered solar dryer compare favourably with those of the glass dryer. It is therefore concluded that glass can be replaced with plastic sheet without significant performance loss.

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Key Words: transparency; incident; angle of inclination; absorption coefficient; reflection coefficient; tracking; dimensionless parameters.

1. Introduction

The harvest season for most grains and seeds in Aba district starts around July. Unfortunately however this is the same period when the rain fall starts to peak, a situation which is unfavourable for drying. The farmer needs to preserve the harvest both for use during the lean months and to sell when the price is right for maximum returns. The local farmer does not have the facilities to store and preserve fresh produce as the mechanised farms do. The capital outlay required for such an undertaking is well beyond the capability of the average rural small scale holder. The local farmer is well aware that there is more money to be made if fresh produce storage facilities are used but it is an option he, as an individual, cannot afford. Where fresh produce storage facilities are available the cost of leasing a small space is well beyond his means. Drying, as a result, is the option that the local farmer traditionally uses for farm produce preservation.

Before the grains and seeds can be stored they need to be dried. There are two main methods used in drying for preservation: the natural sunlight and heat from the cooking flue. Solar drying is prevalent especially where the grains and seeds are in reasonable quantity. Wood that used to be the main source of fuel for drying fairly large quantities of grain (Achara 1987) has shown is now hard to come by because of deforestation.

1.1 Cooking Tripod Drying:

After harvest, maize not yet husked is hung in bundles over the cooking tripod. The flue heat from cooking dries the grains. This fresh but mature produce would be dried and preserved to provide the seed for the next planting season, food during the lean months and extra cash when sold to other farmers the next planting season. The quantity that can be dried is limited by the space above the cooking tripod. To accommodate a fairly large quantity, the farmer resorts to drying in batches. The batch that the farmer considers dry enough but still not yet to the pre-determined storage level, makes way for a new batch while still hanging within reach of the warm cooking flue gases. In this traditional method of preservation, the farmer has learnt that for the seeds and grains to survive till the next planting season they cannot, at this stage, be completely removed from above the cooking tripod. If completely removed before the dryness level is reached, the tendency is for insects/pests to attack and destroy the grains. The farmer however, has to watch out to ensure the seeds and grains do not over dry. If the seeds and grains over dry, grinding to make meal becomes difficult and on occasion, the seeds cannot germinate when planted/sewn the next planting season.

For seeds, a woven basket with cover to prevent the ingress of insects and rodents is used. The basket is woven from material sourced locally from palm trees. The basket filled with seeds is hung over the tripod for drying. The seeds when completely dry, are transferred to huge clay pots that serve as silos. Traditionally this basket serves other purposes for example the drying and preservation of fish and meat

1.2 Natural Sunlight*:*

The other technique for drying the harvest is by the use of natural sunlight. In this technique the grains and seeds are spread on a mat without any protection from inclement weather. To ensure that his produce is not destroyed, the farmer has to detail a member of the family to keep watch over the grains. The person on watch has to drive the birds and domestic animals away from the area and when the weather threatens, has to hurriedly pack up before the rains arrive. The pitfalls in this arrangement include the use of scarce human resource to keep watch over the grains, the unpredictability of the weather and the introduction of sand in the grains when hurrying to pack up as the rains threaten.

In this study, the construction of affordable solar energy dryer is considered. Two types of dryers have been designed, constructed and trialled and the results analysed. The basic difference in construction between the two designs is the transparent cover. The most common transparent cover for solar energy devices is glass but the small scale rural farmer is unable to provide one. There is a need therefore to look elsewhere for alternative transparent cover that is cheap to procure and yet in performance, comparable to glass cover. Any alternative material selected must be transparent to incoming solar radiation and able to block long wavelength radiation to reduce heat loss from the solar dryer. Glass cover itself is not entirely transparent at all wavelengths of solar radiation. However energy loss by reflection and absorption is considered insignificant.

There have been studies in the literature of solar energy dryers but unlike in the current work, non could be found that considered the cost implication to the rural small scale farmer. Folaranmi (2008), for an example, has studied solar energy dryer where the heat needed for drying is generated in a separate compartment and then transported to the dryer. The cost of a dryer unit of this type will still be beyond the resources of the target user, the small scale farmer.

2. Heat and Mass Balance

All modes of heat transfer are involved in solar drying devices but radiation and convection are predominant. For a given incidence, the energy balance is resolved by summing the following: the incident solar energy, energy absorbed by the wet grain and the base surface, energy absorbed and reflected by the transparent cover and that reflected from the drying grain. The energy absorbed by any surface varies with the time of the day since reflectivity depends on the incident angle. This can explain the reason why some solar installations tract the sun. Tracking the sun could however be an expensive undertaking especially in small and medium scale installations. For locations between latitudes 0 and 46^o and where the tilt of the solar dryer is fixed, (Cooper 1970) has shown that the variation in absorption rate is insignificant for solar energy devices having transparent cover and angle of inclination not exceeding 60^o. The absorption and reflection coefficients are assumed constant.

For convenience and to aid understanding of the physical processes taking place, the heat transfer in the solar dryer may be considered in two parts: that external to the transparent cover and that within the dryer itself. In reality however these are coupled. The main distinction between the two is that while within the dryer heat transfer by convection and mass transfer occur simultaneously especially at the early drying stages, there is no significant mass transfer effect outside the dryer. Within the dryer also the heat reflected to the transparent cover is unable to escape since it is within the infrared spectrum. Unless the base of the dryer is adequately insulated, considerable conductive heat losses would also occur.

The convective heat transfer term has in appearance a simple expression (the product of heat transfer coefficient, the surface area and the temperature difference) but in reality the heat transfer coefficient, a member of the product, is complex to express. It depends on the fluid flow characteristics, the geometry of the system under consideration as well as the physical properties of the fluid. Usually, the evaluation of the heat transfer coefficient is based on the correlation of data obtained from experiments using dimensional analysis. There are four dimensionless parameters used in the literature to relate the heat transfer coefficient and these are the Reynolds number, the Nusselt number, the Grashof number and the Prandtl number. In this study, the only relevant convective transfer is the free or natural convection. (Jacob 1947) has expressed the Nusselt number as a function of the Grashof number and the Prandtl number and shown that the Grashof number increases with the magnitude of convection. The Grashof number increases as the flow changes from laminar to turbulent. In this study, the convective heat transfer is by natural convection and all flows are within the laminar regime.

3. Solar Dryer Design

Two identical solar dryers have been designed and constructed with transparent cover as the only major difference. Each of the dryers measured 1.0m long by 0.4m wide and 0.2m high to form a rectangular box. One end of the 0.4m side is hinged and the framework lined with sealing material to provide tight seal when the hinged ends is closed. Material for the dryer is timber board 0.3m wide and 25mm thick joined to make up the dimensions. The interior of both boxes is lined with locally sourced black plastic sheet derived from bin bags. The top of one of the boxes is covered with transparent plastic sheet and the other with glass. Holes 8mm in diameter are drilled at 50mm intervals all around each of the boxes, just below the transparent cover to aid the escape of moisture formed during the drying process. This is the main difference between this study and others found in the literature, where transparent covers other than glass, have been investigated. In this study moisture is considered a waste product and the aim is to get rid of it as soon as possible whereas the other studies considered the distillation of brackish water where the moisture when condensed forms the main product. Qasim (1978) studied a solar still greenhouse combination in which polyethylene was used to cover the greenhouse. Similar work by Kumar et all (1981) as well as Moustafa and Brusewtz (1997) employed a wick-design in the desalination process. Kumar et al (1980) further studied the performance of solar stills with reference to the moisture deposition on the transparent cover.

Wood has been selected for the framework and main body of the dryer because of its fairly good thermal insulation properties, it is readily availability and cheap to buy locally. The choice of materials for construction is driven by the requirement in the study to design and build a solar dryer whose cost is within the financial capabilities of the rural farmer. The glass covered dryer is only used as a comparator to the performance of the transparent plastic covered dryer. Figure.1 is a schematic sketch of the dryers.

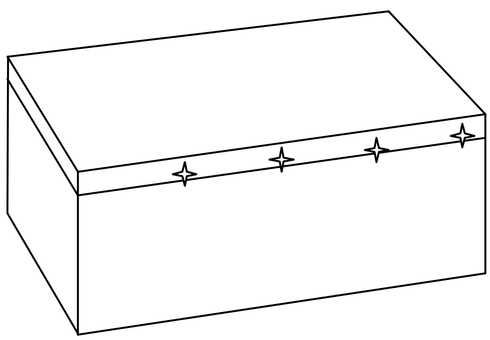

Figure.1 Solar Dryer Design

4. Testing

The experiments in this study were carried out in Aba, Abia State Nigeria, a city that lies at latitude 5^{o} 10' north of the equator and between harvest months of July and November. The period chosen for the tests was dictated by the time in the year when the farm produce that require drying are abundantly available. Although other grains and seeds were tried, the tests finally settled on maize/corn and melon seeds because they were more readily available. In the original design 12mm holes were provided for moisture escape. Later, in the course of the tests the 12mm holes were replaced by the 8mm design in order to prevent the ingress of rodents into the dryer. In each batch of the tests, two equal weights of the seed or grain were measured out and fed to the dryer through the hinged window ensuring even spread of the seeds or grain on the base. The maize used was husked and the melon seed was the type already washed and stored in a basket to drain some of the excess water. The decision was taken at the outset to reduce human handling to the barest minimum once the tests have been set up for compliance with the requirement to release human resources otherwise employed to keep watch in the traditional drying process. At the end of each day, the grains or seeds were weighted to check the weight loss for the day and whether the target weight had been reached. This was the only handling allowed. However weighing the grains served another purpose of turning over the grains and seeds to prevent the burning of the side directly exposed to the incident solar energy.

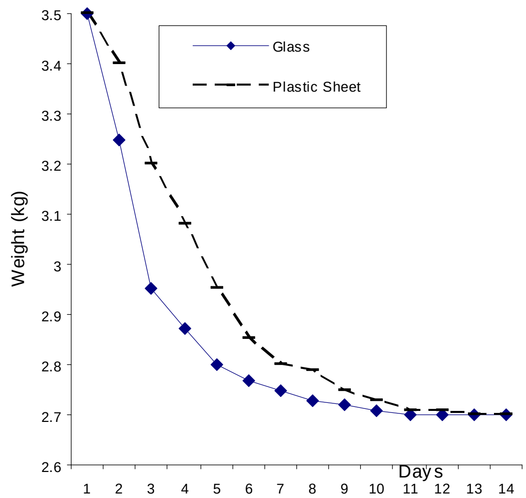

Figure.2 Performance of Glass and Plastic Dryers (High moisture)

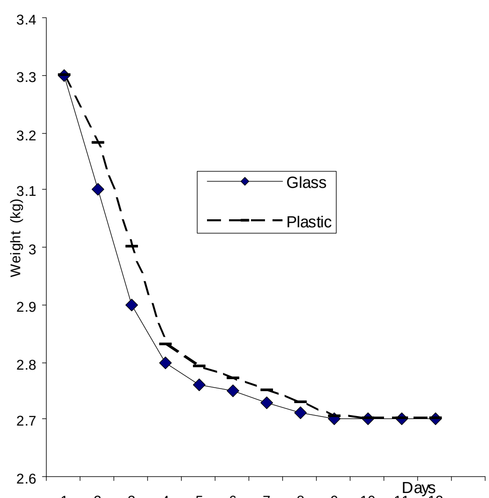

Figure.3 Performance of Glass and Plastic Dryers (low moisture)

5. Result and Discussion

Maize and melon seeds as common produce in the Aba district have been dried in transparent plastic sheet and glass covered dryers and the weight losses measured at the end of each day. Typical results for melon seeds are recorded in figures 2 and 3. The produce in these figures is considered dry when the weight loss has reached a predetermined level.

Earlier in the drying process when the grains were very wet the drying was found to be sluggish because of the water vapour that settled on the inner transparent surface and inhibited the amount of solar energy transmitted. This phenomenon appeared to cause a physical reduction of the transparency of the cover and an increased reflection of solar energy back to the outside environment. At the initial stages, when the water moisture build-up was highest, the 8mm holes near the top of the dryer could hardly cope with getting rid of the moisture. The interest in this study is to find a cheap dryer design option which can be considered simple enough to construct as well as within the financial means of the average local farmer. As a result, the glass covered dryer on the bases of cost is used only as a performance comparator with the plastic sheet covered dryer. Figure. 2 is the result of weight loss as a function of time in days plotted for both the plastic sheet and glass covered dryers when the initial moisture content was high. This batch has an extra 6% of moisture by weight. Similarly figure.3 shows the result also for melon seeds when the pre-drying initial water content is considerably reduced. In the early period of these experiments, the glass covered dryer performed better than the plastic dryer but with time the two curves describing the performance tend to converge. This finding is consistent with those of Howe and Tleimat (1967) who in a study of solar distillation of brackish/salty water showed that the performance of a plastic covered build was about 82% that of glass distiller. In general, the plastic dryer performs considerably more poorly at high initial moisture content and this can account for longer period (13 days) for the two curves in figure 2 to converge. The agreement in weight loss between the two dryers gets better as the water content at the pre-drying stage is reduced, figure. 3 and convergence occurs earlier in 11 days. In all cases in the performance, the plastic dryer lags behind the glass dryer and this may be attributed to the fact that the plastic dryer has the tendency to clog up with moisture more easily than the glass dryer. This misty cloud inhibits the amount of solar energy transmitted into the inner part of the dryer.

There is hardly any noticeable difference in drying performance between the dryers in figure.3, however the glass dryer is still marginally better in weight loss than the plastic sheet covered dryer. At the initial stages, the weight loss per given time in both cases is more pronounced than towards the final stages this accounts for the asymptotic drop in the plot at these stages. Towards the end however, the graph tends to level off for convergence as hardly any noticeable weight drop is observed. The trend in figure.2 and figure.3 agree with those of (Oladosu and Egusoje 1985) on glass covered solar energy fish dryer as well as a similar design work by (Arinze, 1985). At one stage in this study, the plastic cover had to be replaced as it was attacked in the night by rodents. The attack left a number of holes on the plastic sheet. After this incident a fine wire mesh was constructed around the dryers to prevent further attack. Although there was no question of the rodents attacking the glass, it was also enclosed within the wire mesh in order to provide a true like-to-like comparison. If the presence of the wire mesh affects the drying performance, this should not alter the performance comparison since each of the two dryers would equally be affected. Some other low cost material would have to be found for the farmer to protect the transparent plastic sheet if the overall construction cost of the dryer is to be kept low as originally planned. The wire mesh if used as cover on the production dryer will significantly add to the overall product cost. As time progressed towards the end of the tests, the plastic cover started to deteriorate in appearance turning yellowish in colour hence increased physical loss of transparency. At this stage, although there was no significant loss in performance, it was decided that the plastic sheet would have to be replaced if it was found necessary to run the experiment again.

6. Conclusion

1. Two dryers identical in all respects but covers have been designed, built and used to compare the performance of plastic sheet covered dryer against the conventional glass covered version.
2. For low product cost, plastic cover can be used since comparison with glass cover has shown that performance loss is minimal.
3. In each case the weight loss at the earlier stages of the drying process is rapid and occurs asymptotically levelling off with time for convergence as the grain/seed becomes drier.
4. To ward off rodent attack, the farmer is advised to cover the plastic top before retiring for the night and in compliance with low cost requirement, corrugated sheet is recommended as a cover.

8. Acknowledgement

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7. References:

1. Achara N, Solar Energy Thermal Option to Rural Communities, 5TH International Conference on Energy Options, IEE, Reading, UK, 1987.
2. Folaranmi J, Design, Construction and Testing of Simple Solar Maize Dryer, Leonardo Electronic Journal of Practices and Technologies, issue 13, July-December, 2008.
3. Cooper, I.P. , The Transient Analysis of Glass Covered Solar Still, PhD Thesis, University of Western Australia, Australia, 1970.
4. Jacob M, Heat Transfer, Wiley and Sons, New York, Vol 1, 1947.
5. Qasim S.R., Treatment of Domestic Sewage by Using Solar Distillation and Plant Culture, Journal of Environmental Science and Health, 13(8), 1978.
6. Kumar A, Sodha M S, Tiwari G N and Tyagi R C., Simple Multiple-wick Solar still Analysis and Performance, Solar Energy 26(2) 1981.
7. Moustafa S M A and Brusewtz G H, Direct Use of Solar Energy for Water Desalination, Solar Energy, 1979.
8. Kumar A, Nayak J K, Sodha M S and Tiwari G N, Double Basin Solar Still, Energy Conversion 20(1), 1980.
9. Howe E D and Tleimat, B W, Comparison of Plastic and Glass Condensing for Solar Distillers, Proceedings Solar Energy Society, Annual Conference, Arizona, 1967.
10. Oladosu, H O and Egusoje P I, National Annual Solar Energy Forum, 1985, Enugu Nigeria.
11. Arinze E A, Design and Performance Evaluation of Commercial Size Natural Convection Solar Crop Dryer, Nigerian Journal of Solar Energy, Vol 4, 1985.

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