ARPN Journal of Engineering and Applied Sciences

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COMPARATIVE PERFORMANCE OF SELECTED EAR-CORN DRYING TECHNIQUES

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ABSTRACT

Drying of the ear-corn is a difficult process, which usually depends on manager experience. As a result, there is large chance to improve the method in terms of preserving quality, decreasing cost, and increasing capacity. A study was conducted at Okara and Pind Dadan Khan during the October 2010 and June 2011, respectively. The objectives of study were to evaluate selected ear-corn drying techniques namely sun drying, solar passive ear-corn drying, and heated-air ear-corn drying and to perform the cost analysis of these three techniques, and analyzed the comparative performance of these techniques based on field data. Solar passive dryer was constructed in Okara and Pind Dadan Khan to dry ear-corn; the test results indicated that dryer was found capable to dry 0.5 tons of ear-corn from 26.1 to 18.9% moisture content in October in four days and from 26.4% to 20.1% in June in two days. During sun drying 25.9% moisture content was decreased to 19.1% in October and 25.6% to 18.4% in June. A heated-air dryer developed at Agricultural and Biological Engineering Institute, National Agricultural Research Centre, Islamabad was also evaluated. The tests results showed that dryer had capacity to dry 4 tons ear-corn from 26.5 to 20.4% moisture content in 9 hours using heated air. Finally, the cost analyses of these three ear-corn drying techniques were also performed.

Keywords: solar energy, drying techniques, ear-corn, storage, comparative performance.

INTRODUCTION

The economy of Pakistan has a large contribution from agriculture sector. After wheat and rice, corn is third most important cereal crop in Pakistan. Corn has significantly high yield potential as compared to other cereals. Its production was 3.4 million tons in year 2010. It is also used as a fodder source for domestic animal nutrition (Anonymous, 2009-10). The handling and storage of food must be emphasized to reduce post harvest losses. The moisture content in the seed is one major factor which affects the storage quality of corn. Corn harvesting methods have undergone a major change since the 1950's, evolving from earn-corn harvesting. These systems leave high-moisture in seed and field-shelling systems triggers drying of corn seed in field. Artificial drying by the means of fossil fuel of corn is an energy intensive agricultural operation.

During storage of corn seed, quality of seed is affected by mechanical damages and the presence of microorganisms and insects, which can be avoided by means of moisture control in storage seed. Seed drying is very important post harvesting technique, which assures seed quality by avoiding microorganism and insect attack on seeds (Carvalho and Nakagawa, 2000). The recommended stage for harvesting corn is when physiological maturity is attained in standing field and it contains high moisture content (Dias, 2001). The moisture content from these ears can be reduced either by sun drying, heated-air drying or solar drying.

Over the last two decades, open air sun drying has slowly became limited because of the requirement for a large area and time, the possibilities of quality degradation, high level of dust and atmospheric pollution from the air, cloudiness and rain, interruption from animals and man, infestation caused by birds and insects and inherent difficulties in controlling the drying process (Imre, 1995).

Corn in Pakistan is cultivated as multipurpose crop for food, feed and fodder. Currently, corn grown in Pakistan is sufficient for domestic needs. Autumn corn matures in fall and is harvested, when the percentage of moisture content is higher than required for safe storage. The average moisture content of ear-corn at harvesting time is between 30 to 42%, which is to be reduced up to 18 to 20% for its shelling (Wilcke and Morey, 2009).

Extended periods of severe weather conditions during field drying can result in losses of both corn yield and quality. Therefore, this research was undertaken to study different ear-corn drying techniques in order to find an appropriate technique for ear-corn drying, and to perform cost analysis of these techniques based on field.

MATERIALS AND METHODS

The present research was conducted to evaluate selected ear-corn drying techniques for drying spring ear-corn (June) in Pind Dadan Khan and autumn ear-corn (October) in Okara at farmer's field. The Pind Dadan Khan is located at 32° latitude, 73° longitude, whereas Okara is located at 31° latitude, 72° longitude. Three techniques; sun drying, solar passive ear-corn drying and heated-air ear-corn drying were used. The selected ear-corn variety was Pioneer Seed 6339.

(a) Description of various ear-corn drying techniques

Major components of the solar passive ear-corn dryer were drying chamber, inlet openings for ambient air entrance, outlet openings and a door for loading and unloading of ear corn. The drying chamber was of greenhouse type. The natural air moved inside the chamber from inlet openings due to temperature variation and moist hot air moved upwards to roof and escapes from two ventilation holes. Figure-1 showed the solar passive dryer.

Figure-1. Solar passive ear-corn dryer.

The major components of heat-air dryer were wheel adjustment assembly, a frame, plenum chamber, grain container, an engine, a gas fired furnace, and an axial flow fan. The axial flow fan forces the hot air through plenum to ear-corn bed, the hot air reduced the moisture of the ear-corn and moves upward and finally exits from top. This dryer was modified for drying ear-corn after its preliminary testing. A typical view of the heated-air dryer is shown in Figure-2.

Figure-2. A typical view of heated-air dryer.

The ear-corn was spread on the ground in open space where maximum solar radiations were available. Total corn loaded was 500 kg (0.5 tons). The solar radiations provided heat and the natural air helped in removal of the moisture from ear-corn.

(b) Methodology and instrumentation

Three to four tests were conducted in sun drying, solar passive drying and heated-air drying during fall and autumn.

Solar passive dryer

The solar passive drying chamber was installed at the selected site at Okara. The G.I pipes were used to make a frame. These pipes were welded from a nearby workshop to make it 6.0 m long, 3.0 m wide and 2.1 m high. Afterwards the frame was shifted to the experimental site where it was fixed. The roof of the rectangular shape dryer was covered with polythene plastic sheet. Nylon rope was used to tie the plastic sheet, to minimize entrance of air and protected from rainfall and wind. Six exhaust plastic pipes were fixed on either sides of the solar passive dryer with length of 0.3 m and 0.1 m diameter to minimize the relative humidity. Two ventilation holes were made on the roof of the solar passive dryer for removal of humidity of inside air. A door towards east side of dryer was made to give easy access of earn corn loading. Total corn loaded was 500 kg (0.5 tons) for each experiment performed in that solar passive dryer. Ambient air temperature, inside air temperature, ambient air relative humidity and inside air relative humidity were recorded after every hour, whereas, moisture content of ear-corn was recorded twice a day. A T-type digital thermometer was used to measure ambient air temperature, inlet temperature of the drying chamber, and exit air temperature from the drying chamber after every hour. Exit air temperature was measured by placing a thermometer at exhaust pipes. Inside air temperature and air relative humidity were measured by placing thermometer inside the solar passive dryer. The ambient air temperature and ambient relative humidity was measured by placing thermometer under the shade. Moisture content was measured at 9 am and 6 pm, daily.

Heated-air dryer

The relative humidity of ambient inlet and outlet air of the drying chamber was measured with "MANNIX" digital thermo-hygrometer. Plenum air temperature and relative humidity was measured by placing the thermo couple of the thermometer in plenum. The outlet air temperature and relative humidity was measured by placing digital thermo-hygrometer at the top of drying chamber, from where the air went out. The moisture content of the ear-corn was measured by using the Dickey John moisture meter by placing it on a smooth surface. A cup attached with the instrument was filled with maize grains and afterwards continuously dropped these grains in the moisture meter to measure the moisture content of maize grains. The air mass flow rate was measured by using velometer. In mechanical dryer the velometer was placed in the air duct, from where the forced air passed and values were recorded when reached to constant. Plenum pressure in mechanical dryer was measured by using Velocicalc plus Multi-Parameter. The data was recorded manually with the time interval of one hour during the test period.

Sun drying

The ear-corn was spread at place, where the sun was available throughout the day. Ambient air temperature and ambient air relative humidity were recorded on hourly basis, whereas moisture content of ear-corn was recorded twice a day. Inside air temperature and air relative humidity were measured by placing thermometer inside the ear-corn. The ambient air temperature and ambient air relative humidity was measured by placing thermometer

VOL. 9, NO. 4, APRIL 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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under the shade. Time was recorded from initial moisture content to final moisture content.

RESULTS AND DISCUSSIONS

Performance of solar passive dryer during fall 2010

The average ambient and inside temperature during these tests was 31^0C and 35.2^0C, respectively. It showed that there was an increase of 4.2^0C in inside temperature due to solar passive dryer. The average relative humidity of ambient air and air inside the solar passive dryer were 40.8% and 48.6%, respectively showing 7.8% increase in inside air relative humidity as compared to ambient air relative humidity. The increase in temperature was because of solar radiation trapped, and heated up the inside air. The average initial moisture content of ear corn was 26.1% and final moisture content was 18.9%, respectively (Figure-3). This showed the decrease of 7.2 percentage point in moisture content of ear-corn in 4 days. Similar results were explained by Folaranmi (2008), he stated that the test results gave temperature above 45^OC in the drying chamber, and the moisture content of 50 kg of maize reduced to about 12.5% in three days of 9 hours each day of drying.

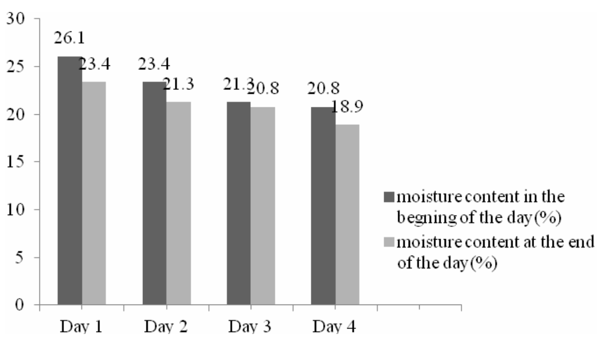

Figure-3. The reduction of moisture content of ear-corn in a solar passive dryer on daily basis for fall crop-2010.

Performance of solar passive dryer during spring 2011

The average ambient air and inside air temperature during these tests was 39.1^0C and 43.5^0C, respectively. It showed that there was an increase of 4.4^0C in ambient air temperature due to solar passive dryer. This increase was because of solar passive dryer, though this was not such a high increase required for fast drying of ear-corn, as explained by Irtwange (2009), the average ambient temperature ranged between 28-33.5°C, collector outlet temperature ranged from 35-47°C, storage unit from 34-45°C and drying chamber from 32-42°C. The average relative humidity of ambient air and inside air in the solar passive dryer was 40.3% and 48.6%, respectively showing 7.8 percentage points increase in inside relative humidity as compared to ambient air relative humidity. Falade *et al*. (1985) stated similar results on a fairly clear day with an indirect passive dryer that was used for deep-bed drying of corn. The average initial moisture content was 26.4% and final moisture content was 20.1%. This showed the decrease of 6.3 percentage point in moisture content of ear-corn in two days (Figure-4).

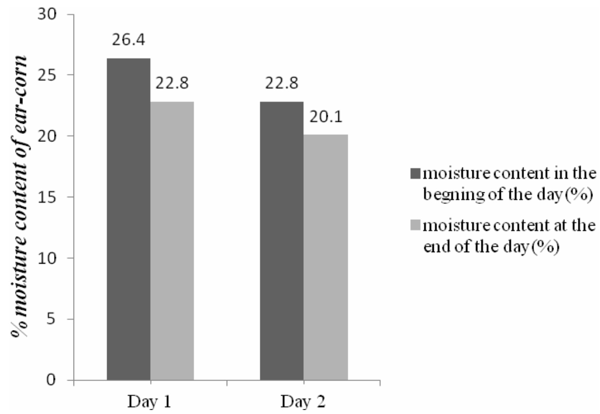

Figure-4. The reduction of moisture content in a solar passive dryer on daily basis for spring crop 2011.

Sun drying during fall 2010

The average initial moisture content of ear-corn was 25.9%, and average final moisture content was 19.1% during the 4 tests conducted. This indicated that 6.8 percentage point moisture content was reduced of ear-corn during fall in 4 days period using sun drying technique (Figure-5). It is indicated from the Figure that on average 1.7 percentage point moisture content of ear-corn was reduced per day.

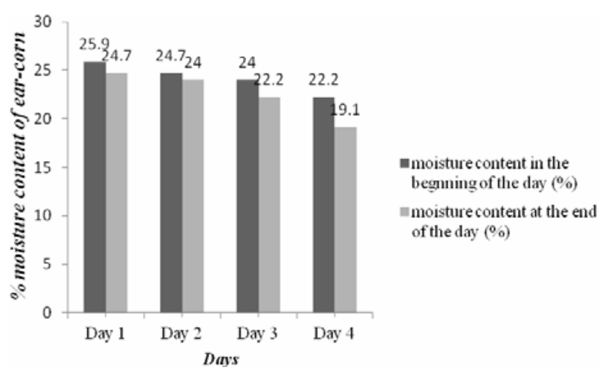

Figure-5. Graphical presentation of reduction of moisture content during sun drying in fall, 2010.

Sun drying during spring 2011

The average initial moisture content of ear-corn was 25.6% and average final moisture content was 18.4% during the sun drying tests conducted in Spring, 2011 (Figure-6). This indicated that 7.2 percentage points moisture content was reduced during sun drying of spring 2011 crop in two days period. This mean on average 3.6 percentage point moisture content was reduced per day, while drying ear-corn of spring crop-2011. It can be further stated that reduction in moisture content of ear-corn per day was almost twice more in sun drying of spring ear-corn as compared to autumn ear-corn.

VOL. 9, NO. 4, APRIL 2014 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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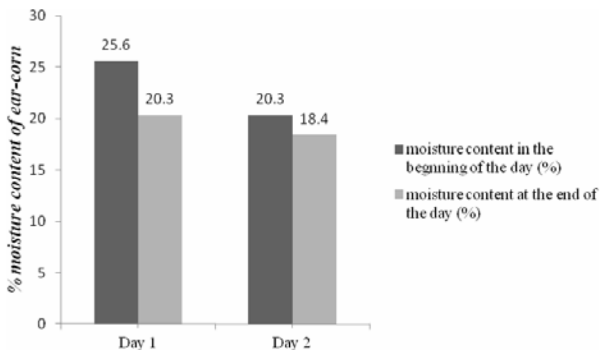

Figure-6. Graphical presentation of reduction of moisture content during for drying spring ear-corn.

Performance of heated-air dryer during fall 2010

The quantity of grain loaded was 4 tons. The average initial moisture content during these tests was 26.5% and final moisture content was 20.4%, which showed 6.1 percentage points moisture content reduction during these tests in 9 hours, similar results were found from the experiments performed by Munir *et al*., (2009) and Ahmad and Mirani (2007). They explored the capability of flat-bed dryer in reducing the moisture content of canola and sunflower as well. The average ambient air temperature was 33.4^{0}C, whereas the average drying/ plenum temperature was 61.3^{0}C and the average exit air temperature was 38.8^{0}C.

Performance of heated-air dryer during spring 2011

During these tests the quantity of ear-corn loaded was 4 tons and drying time was 9 hour. The average initial moisture content was 25.5% and that of final moisture content was 19.4 % during these tests, which indicated that there was 6 percentage points moisture reduction in ear-corn grains during these tests. The average ambient air temperature was 39.1^{0}C whereas average drying/ plenum air temperature was 55.8^{0}C and the average exit air temperature of 45.8^{0}C was recorded.

Cost analysis

Solar passive dryer was fabricated and installed at District Okara and Pind Dadan Khan. Estimated cost of the dryer was Rs 25000 and the useful life of the dryer was assumed 15 years. The depreciation cost according to straight line method was Rs 1500 and interest on investment according to monitory policy statement, 2011, was 12%. Repair and maintenance cost was 2%, so the total annual fixed cost of the dryer was Rs 3590. Annual drying capacity of the system was 5 tons/year, and the fixed cost of drying per ton corn was Rs 718. In variable cost parameters labor cost was Rs 75 as 2 men hours/ton were consumed and the cost for changing the polyethylene sheet was Rs 32 per ton. Then summing up fixed and variable cost the total cost of drying per kg of corn was Rs 0.82.

Table-1. Cost analysis of solar passive dryer.

Cost parameters	**Values** (PRs)
Manufacturing cost	25000
Useful life (years)	15
Salvage value (10% of manufacturing price)	2500
Fixed cost parameters	
Depreciation cost (SLM)	1500
Interest on average investment (12%)	1590
Repair and maintenance cost (2% per anum)	500
Total annual fixed cost	3590
Annual drying capacity of dryer (tons/year)	5
Fixed cost of drying per ton corn (Rs)	718
Variable cost parameters	
Labour cost for loading and unloading (2 man hours/ton)	75
Polyethylene sheet cost (Rs/ton)	32
Total variable cost (Rs/ton)	107
Cost per kg of drying using solar passive dryer (Rs)	0.82

Heated-air dryer was manufactured at Agricultural and Biological Engineering Institute, National Agricultural Research Centre, Islamabad. The estimated cost was Rs 330, 000 and the useful life was assumed 15 years. The annual depreciation cost was Rs 19800 and interest on average investment was 12%. Repair and maintenance cost of the system was 2% and annual drying capacity of the system was 120 tons/year, so the fixed cost of drying per ton corn was Rs 401. In variable cost parameters labour cost for loading and unloading was Rs

150, as 4 men hours/ton were consumed. LPG cost of drying per ton corn was Rs 2000, as 15 kg/ton LPG was consumed and per kg cost of LPG was Rs 135. Diesel cost per ton was Rs 352 and lubricant cost was Rs 35.2. Total variable cost per ton was Rs 2537. The total cost of drying per ear-corn was Rs 2938, which showed the cost per kg of drying autumn ear-corn using heated-air dryer was Rs 2.93.

Table-2. Cost analysis of mechanical dryer for drying autumn crops.

Cost parameters	**Values** (PRs)
Manufacturing cost	3, 30, 000
Useful life (years)	15
Salvage value (10% of manufacturing price)	33000
Fixed cost parameters	
Depreciation cost (SLM)	19800
Interest on average investment (12%)	21780
Repair and maintenance cost (2%)	6600
Total annual fixed cost	48180
Annual drying capacity of dryer (tons/year)	120
Fixed cost of drying per ton corn (Rs)	401
Variable cost parameters	
Labour cost for loading and unloading (4 men hours/ton)	150
LPG (Rs) (15 kg/ton)	2000
Diesel cost per ton	352
Lubricant cost	35.2
Total variable cost Rs/ton	2537.2
Total (fixed + variable) cost of drying per ton of corn (Rs)	2938
Cost per kg of drying using mechanical dryer (Rs)	2.93

The cost analysis of the two systems showed that there is a significant difference in drying cost of ear-corn by solar passive and heated-air dryer; therefore, the cost of drying ear-corn using solar passive dryer is less, but it is dependent on weather conditions, for clear sky weather we may use the solar passive dryer, whereas the use of heated-air dryer was independent to weather conditions. This mean it can be used even in cloudy conditions and speed of drying was relatively fast.

CONCLUSIONS

- The average ambient air temperature during the various ear-corn drying tests conducted using solar passive dryer in fall, 2010 was 31^0C, whereas the average air temperature inside the solar passive dryer was 35.2^0C. This indicated 4.2^0C temperature rise inside the solar passive dryer in fall, 2010.
- On average solar passive dryer took 4 days to drop the moisture content of ear-corn from 26.1% to 18.9% of fall crop, whereas it took 2 days to drop the moisture content of ear-corn from 26.4% to 20.1% of spring crop. This showed twice time is required to dry ear-corn of Fall crop as compared to Spring crop using solar passive dryer.
- On average sun drying took 4 days to drop the moisture content of ear-corn from 25.9% to 19.1% in fall, 2010. This drying time is similar to the drying time required to for solar passive dryer in fall, 2010. Therefore, there is not much difference in these two techniques.
- On average sun drying took 2 days to drop the moisture content of ear-corn from 25.6% to 18.4% for drying spring maize, whereas solar passive dryer also took 2 days to drop the moisture content of ear-corn from 26.4% to 20.1%. This indicated that sun drying performed relatively better for drying spring crop.
- The mechanical dryer took 9 hours to drop the moisture content of 4 tons ear-corn from 26.5% to 20.4% in fall, 2010, whereas for same tonnage of ear-corn it took 9 hours to drop the moisture content of ear-corn from 25.5% to 19.4% for drying spring crop. This indicated almost same time required for drying ear-corn in fall and spring season. However, the gas consumption was more in fall as compared to drying spring crop.
- The cost analysis of the two methods showed that cost of drying of ear-corn using solar passive dryer was minimum as compared to heated-air dryer. But the drying of ear-corn by using solar passive dryer was weather dependent, as it cannot be dried in cloudy conditions. On the other hand, the heated-air dryer may

dry a large amount of ear-corn in short time, but the cost of drying is relatively high. Therefore maize grower may select any drying techniques for their crops depending upon weather conditions and speed of work they required.

REFERENCES

Ahmad M. and A. A. Mirani. 2007. Development and performance evaluation of a mobile flat-bed dryer for sunflower. International Agricultural Engineering Journal.

Ahmad M., A. Mirani and L. A. Anjum. 2009. Performance of mobile flat-bed dryer for canola drying. J. Agric. Res. 47(3): 309-317.

Anonymous. 2009-10. Agricultural Statistics of Pakistan. Ministry of food. Agriculture Division (Planning Unit). Govt. of Pakistan. Islamabad. Pakistan.

Carvalho N.M. and J. S. Nakagawa. 2000. Ciência, tecnologia e produção. 4. Ed. Campinas: Funep.

Dias D.C.F. 2001. Maturação de sementes.RevistaInternacional de Sementes. seed news. 5(6).

Falade A., S.O. Talabi, A. Akinsete, F.K. Danso and A.A. Adejuwon. 1985. A solar grain dryer for rural areas of Nigeria. Nig. J. Solar Energy. 14: 121-130.

Folaranmi J. 2008. Design, construction and testing of simple solar maize dryer. Leonardo Electronic Journal of Practices and Technologies. ISSN 1583-1078. pp. 122-130.

Imre E.E. 1995. A handbook of industrial drying.1st Edition. New York, USA. p. 550.

Irtwange S.V. 2009. Design and development of a passive solar air heated poultry egg incubator. Unpublished M. Eng Project. Department of Agricultural Engineering, University of Nigeria, Nsukka. p. 258.

Wilcke W. and R.V. Morey. 2009. Natural-air corn drying in the upper Midwest. University of Minnesota. USA.