HEATED AIR DRYING OF GROUNDNUT

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ABSTRACT:- Groundnut contains 25-32% protein and 42-52% oil, therefore, it has the potential to become a significant contributor to edible oil production in Pakistan. It is harvested in October-November in Pakistan, when the weather is cold, and it is not possible to dry it down to a safe moisture level by sun drying. Therefore, the chance for developing aflatoxins in it is high. To solve this problem of the groundnut growers, a low cost mobile flat-bed dryer designed and developed at Agricultural and Biological Engineering Institute (ABEI), National Agricultural Research Centre, Islamabad was evaluated for drying groundnut. The dryer had been found capable to dry about 1818 kg groundnut from 23.3% moisture content to 14% within 2.4h. On average the groundnut drying rate was 3.9% per hour, and the average efficiency of the dryer was 69%. However, typical tests indicated that the drying efficiency of the dryer can be achieved above 80% by maintaining the drying air temperature above 49°C. The cost of drying one kg of groundnut was estimated as Rs 1.45 (1.7 US cents), which was very reasonable for the groundnut growers.

Key Words: Groundnut; Drying; Flat-bed Dryer; Drying Efficiency; Cost – Effective; Pakistan.

INTRODUCTION

Groundnut or peanut (*Arachis hypogaea* L.), originated in South America and is now grown throughout the tropical and warm temperate region of the world. It is an important food and oil crop being grown on about 17 mha worldwide (FAO, 2005). It is the third major oilseed of the world next to soybean and cotton. China, India, and the United States have been the leading producers for over 25 years and grow about 70% of the world production. In Pakistan, groundnut is primarily grown on *barani* (rainfed) lands and is an important cash crop for farmers in these areas during *kharif* (summer) season. It is grown on 105.8 thousand ha with an annual production of 76.4 thousand tonnes. Eighty five percent of the groundnut area lies in Punjab, 10% in Khyber Pakhtunkhwa and 5% in Sindh (Anonymous, 2009-10). Groundnut's kernels are rich in edible oil (42-52%), and protein (25-32%). Therefore, the groundnut has the potential to become a significant contributor to edible oil production in Pakistan.

At the time of digging, the groundnut pods contain about 40-50% moisture which should be reduced to safe storage moisture content (8-10%) as rapidly as possible. If groundnut is not dried quickly to this moisture content, then it may be infested by two closely related fungal species *Aspergillus flavus* and *A. parasiticus*. Both

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species produce highly toxic mycotoxins known as aflatoxins. Aflatoxins are carcinogens that can cause liver cancer, these are synergistic with hepatitis B and C viruses, and hazardous to the health of human beings, cattle, sheep and poultry (Batan, 1986).

Artificial drying of wet or semi dry peanut should start immediately after combining to prevent mold growth and aflatoxin formation (Putnam et al., 2000). Presence of aflatoxin is a concern in peanut producing areas with warm climates. However, cool October and November temperatures minimize this problem when proper drying and storage practices are followed during the harvesting/ digging of groundnuts. At the time of digging, groundnuts normally contain 40% to 50% moisture content, which must be reduced promptly to prevent quality losses from possible proliferation of *A. flavus* and *A. parasiticus* resulting in aflatoxin production (Chinnan et al., 1992). Normally the groundnut is dried at air temperature of 45°C, with a minimum air flow rate of 10 m^3 per minute per m^3 of groundnuts (Young et al., 1982).

Butts and Sanders (2002) conducted two years study in which a single pass continuous flow dryer and a re-circulating batch dryer were compared with conventional wagon drying systems. The rate of change of peanut kernel moisture content (% w.b.h^{-1}) was considerably higher in single pass continuous flow dryer (2.1% h^{-1}) and the re-circulating batch (1.0%h-1) than that observed in conventionally cured peanut (0.41%h^{-1}). Peanuts cured using the single pass continuous flow dryer had unacceptably higher level of split and bald kernels when compared to those cured in wagons. The re-circulating batch dryer results in significantly higher percent split kernels and skin slippage. However, the reduction in peanut milling quality was acceptable to achieve the faster drying rate.

In storage, peanut samples with average moisture content greater than 13.5% were more likely to have molds and aflatoxin than samples with lower average moisture (Dowell et al., 1993). Peanuts were dried in the shell, an operation specific characteristics because the peanut pod is a heterogeneous system where shell and grain present different composition and hygroscopicity. The hulls initially dry rapidly to moisture content near equilibrium for the drying air condition. The moisture content of the hulls then gradually decreases as moisture moves through the hulls from the kernels and transfer to the environment. The moisture content of the kernels initially change very slowly and then begin to decrease more rapidly as the hulls reach lower moisture contents (Palacios et al., 2004).

In Pakistan, the groundnut is harvested in October-November, when the weather is cold, and it is not possible to dry it to a safe storage moisture level by sun drying. Hence, heated air drying is required to reduce its moisture to a safe level before storage to avoid risk of afflatoxin. A mobile flat-bed dryer was developed and evaluated for sunflower drying (Ahmad and Mirani, 2007). The experimental results indicated that the dryer was capable of drying 1.25t sunflower in 3h, from 30% moisture content down to 10%, which is usually considered a safe moisture content for storage. This preliminary study was undertaken to evaluate the performance of already developed mobile flat-bed dryer for drying of groundnut, and to predict the cost of drying groundnut operation.

MATERIALS AND METHOD

Low Cost Mobile Flat-bed Dryer

A low cost mobile flat-bed dryer was developed at Agricultural and Biological Engineering Institute, National Agricultural Research Centre, Islamabad (Ahmad and Mirani, 2007). The grain container of the dryer holds the grain above the plenum chamber on a false floor through which the air is forced. A 65cm diameter axial flow fan forced the drying air through drying bed. It is powered with a 7.4 kW diesel engine through V-belts and pulleys arrangements. A direct fired diesel burning system has been incorporated in this dryer. This consists of a diesel tank, a pump for pressurizing the diesel, a filter, a nozzle for vaporizing the diesel, and a diesel burning chamber. This heating system is capable to heat the ambient air up to 58°C, depending upon the ambient weather conditions (Figure 1).

Figure 1. A typical view of the groundnut drying trial

Performance Evaluation of Dryer

The performance of the mobile flat-bed dryer was evaluated by drying groundnut in October 2009 in Chakwal District of Pothowar, Punjab, Pakistan. Eight experiments (drying tests) were conducted, and the relevant data were collected. First the dryer's grain tank was loaded with the un-shelled groundnut, and the weight of the one batch was estimated by measuring the density of the groundnut. Then the diesel fired system was started and the hot air was forced through the groundnut pods via plenum. The data regarding air flow rate, moisture content, temperature and relative humidity of ambient air, drying air, and exit air were taken from the start of the test, with after half hour intervals till the end of each test. The loading and unloading time was also recorded to predict man-hours needed for this task.

The air velocity in the inlet duct to the plenum chamber was measured using Velometer, and then the air flow rate was predicted by multiplying the air velocity with the cross sectional area of the inlet duct, which was 0.13 m^2. A T-type digital thermometer was used to measure ambient air temperature, plenum air temperature, and the temperature of the escaped air from the groundnut. The moisture content of the groundnut was measured using the Dicky John moisture meter. The samples for measuring the moisture meter were taken at two locations (front and rear of the dryer). At each location two samples were taken, one from the bottom of groundnut layer, and other from the top of the groundnut layer. The depth of bed was 0.80 m, and samples were taken from 0.2 m, and 0.6 m depth. Plenum pressure was measured using VELOCICALC Plus Multi Parameters. The relative humidity of the ambient air, and escaped air from the groundnut was measured with "MANNIX" digital thermohygrometer.

Prediction of Drying Efficiency of the Dryer

The thermal efficiency of the heated air batch drying system can be expressed by the ratio of the temperature drop of the heated air in passing through a bed of grain to the temperature rise of the entering air. This disregards any losses in sensible heat from the dryer not utilized in removing moisture from the grain. According to Johnson and Lamp (1966), when the temperature rise of the entering air is equal to the wet-bulb depression of the heated air, the thermal efficiency can be expressed as the drying efficiency. This is the thermal efficiency for adiabatic drying because any sensible heat which is in the drying air below the wet bulb temperature is not available for removing moisture from the grain. This method was used to predict the drying efficiency of the dryer from the measured data. In equation form, it can be written as:

Drying Efficiency (%): (Temp. drop of heated air (°C) / Wet-bulb depression of heated air (°C) *100

RESULTS AND DISCUSSION

The initial and final moisture content of un-shelled groundnut, air flow rate, the quantity of groundnut loaded in the dryer, and the drying time during the different tests conducted for groundnut drying revealed that the average amount of groundnut loaded in the dryer was 1818 kg, and the average air flow rate was 4.22 m^3s^{-1}(Table 1). The average plenum pressure during these tests was 5.6 mm of H_2O. The average drying time for the one batch of groundnut was 2.4 hours. The average initial moisture content of groundnut during these tests was 23.31%, whereas the average final moisture content of the groundnut

Table 1. Groundnut loaded, air flow rate, drying time, initial and final moisture content for different tests conducted for groundnut drying

Test No.	Quantity of groundnut loaded (kg)	Air flow rate (m^3s^{-1})	Drying time (h)	Initial moisture content (%)	Final moisture content (%)
1	1500	4.55	2.5	25.0	17.0
2	1608	3.25	3.0	21.0	17.0
3	1434	3.25	3.0	25.0	18.0
4	2000	4.60	2.0	24.0	12.0
5	2000	4.16	2.0	23.7	11.9
6	2000	5.20	2.0	23.7	12.6
7	2000	4.16	2.0	24.5	12.0
8	2000	4.60	2.5	19.6	12.0
Avg	1818	4.22	2.4	23.31	14.0

was 14%. During the first three tests the final moisture content of the groundnut was 17.5% mainly because of the relatively low drying air temperature, whereas during the last five tests the final moisture content of the groundnut was 12.1%. It should be noted that during the first three tests the average drying air temperature was 45.3°C, whereas during the last five tests the average drying air temperature was 49.4°C (Table 2). On average the moisture removal rate was 3.9% $hour^{-1}$ during these eight tests.

On average ambient air, drying air, and exit air temperatures during these tests were 29.6°C, 47.8°C and 31.5°C, respectively, whereas the average relative humidity of ambient air, drying air and exit air during these tests were 29.2%, 16.4%, and 49.2%, respectively (Table 2). The average moisture take-off for the different tests during the groundnut drying trial revealed that on average the moisture take-off was 199.48 kg during the eight tests (Table 3). However, the moisture take-off was low (114.82 kg) during the first three tests as compared to the moisture take-off (250.26 kg) during the last

Table 2. Ambient air, drying air, exit air temperatures and relative humidity during the tests conducted for groundnut drying

Test No.	Ambient air temp. (°C)	Drying air temp. (°C)	Exit air temp. (°C)	Ambient air humidity (%)	Drying air humidity (%)	Exit air humidity (%)
1	32.8	48.2	35.5	17.0	11.1	31.2
2	31.7	47.3	34.1	19.0	14.2	41.2
3	30.7	40.4	30.3	18.4	14.7	32.8
4	30.9	50.4	30.1	26.6	18.0	55.5
5	28.0	52.2	30.0	38.2	16.6	58.6
6	23.8	46.2	30.0	49.0	22.2	59.0
7	29.3	51.4	31.6	31.4	16.8	56.8
8	29.8	46.5	30.1	33.8	17.6	58.7
Avg	29.6	47.8	31.5	29.2	16.4	49.2

Table 3. Moisture take-off for the different tests during groundnut drying trial

Test No.	Quantity of groundnut loaded (kg)	Air flow rate ($m^3 s^{-1} kg^{-1}$)	Initial (%)	Final (%)	**Moisture take off (kg)
1	1500	4.55 (5.28)	25.0	17.0	144.57
2	1608	3.25 (3.77)	21.0	17.0	77.49
3	1434	3.25 (3.77)	25.0	18.0	122.41
4	2000	4.60 (5.34)	24.0	12.0	272.72
5	2000	4.16 (4.82)	23.7	11.9	267.87
6	2000	5.20 (6.00)	23.7	12.6	254.00
7	2000	4.16 (4.82)	24.5	12.0	284.09
8	2000	4.60 (5.34)	19.6	12.0	172.72
Avg	1818	4.22 (4.89)	23.31	14.0	199.48

***Dry matter before drying (DM1) = Dry matter after drying (DM2)*
Sample calculation for test 1: (1-0.25) 1500 = (1-0.17) (1500-w)*
Therefore, Moisture take-off, (kg), w = 1500 (0.83-0.75)/ 0.83 = 144.57 kg

five tests. This was mainly due to the low dry-bulb temperature of the drying air (45.3°C) during the first three tests as compared to the drying air temperature (49.4°C) during the last five tests.

The wet bulb depression is the difference between the dry-bulb temperature and wet bulb temperature of the drying air, whereas the temperature drop of the drying air is the difference between dry-bulb temperature of the drying air, and dry-bulb temperature of the exit air. It was revealed that the drying efficiency has a strong correlation with the drying air temperature (Table 4). The higher was the drying air temperature, the higher was the drying efficiency of the dryer. It can also be seen from this table that drying efficiency varies from 50% to 92% during the different tests conducted. This variation in the drying efficiency of the dryer was because of different drying air humidity, and drying air temperatures during these tests. On average the drying efficiency of the mobile flat-bed dryer for drying groundnut was 69%. However, for the 4th, 5th, and 7th tests, the drying efficiency was 83.2%, 92.5%, and 81.1%, respectively. This indicated that by maintaining the drying air temperature above 49°C, one may achieve the drying efficiency of the dryer above 80%.

Cost Analysis of Groundnut Drying

The cost of groundnut drying is the combination of the fixed cost and variable costs. Fixed cost includes depreciation, interest on average investment, and repair and maintenance cost, whereas the variable cost includes labour cost, fuel cost and lubricant cost (Kepner et al., 1982). A complete cost analysis of a low cost dryer for groundnut drying revealed that total annual fixed cost per ton of drying groundnut was Rs 544 (US$ 6.4), whereas the variable cost per ton of drying groundnut was Rs 910.4 (US$ 10.7) (Table 5). It should be noted that the fixed cost per ton of groundnut drying was estimated by assuming the drying capacity of the dryer about 100t year^{-1}. By combining fixed and variable

Table 4. Temperature drop of drying air, wet-bulb temperature, and the wet bulb depression of the drying air, and the drying efficiency of the dryer during various tests

Test No.	Drying air temp. (°C) (a)	Temperature drop of drying air (°C) (b)	Wet-bulb temp. of drying air (°C) (c)	Wet-bulb depression of the drying air (°C) d = a – c	Drying efficiency (%) b/d *100
1	48.2	12.7	22.8	25.4	50.0
2	47.3	13.2	24.0	23.3	56.6
3	40.4	10.1	20.5	19.9	50.7
4	50.4	20.3	26.5	24.4	83.2
5	52.2	22.2	26.0	24.0	92.5
6	46.2	16.2	26.0	26.2	61.8
7	51.4	19.8	27.0	24.4	81.1
8	46.5	16.5	25.0	21.5	76.7
Avg	47.8	16.4	24.7	23.5	69.0

cost, the total cost of drying one ton of groundnut was predicted as Rs 1454 (US$ 17.1). This leads to the cost of drying one kg of groundnut to about Rs 1.45 (1.7 US cents). This cost of mechanical drying of groundnut was very reasonable and growers may save their crop from developing aflatoxin by immediately drying it using this low cost technology.

It is therefore concluded that groundnut can be dried effectively using the low cost mobile flat-bed dryer. The results of the field evaluation indicated that the dryer is capable of drying about 1800 kg un-shelled groundnut from 23.3% moisture content to 14% within 2.4h. The drying temperature played the key role, the higher it was, faster was the rate of drying of groundnut. On average the moisture removal rate was 3.9% per hour, and the average drying efficiency of the dryer was 69%. However, one may achieve above 80% drying efficiency by maintaining the drying air temperature above 49°C. The cost of drying per kg of groundnut was estimated about Rs 1.45 (1.7 US cents), which seems reasonable for the growers to afford.

Efforts are required to popularize this low cost drying technology among the groundnut growers. This technology will help them to reduce the moisture content of the freshly harvested groundnut within a short time, and consequently it helps to save groundnut crop from developing aflatoxins.

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Table 5. Cost analysis of a mobile flat-bed dryer for groundnut drying

Cost parameter	Values Rs. (US$)
Purchasing cost of the dryer (Rs)	400000 ($ 4705)
Useful life (years)	15
Salvage value (10% of purchase price, Rs)	40000 (470)
Annual Fixed Charges	
Depreciation	24000 (282.3)
Interest on average investment (12%)	26400 (310.6)
Repair and maintenance cost (1% of purchase price per annum)	4000 (47.0)
Total annual fixed cost (Rs)	54400 (640)
Annual groundnut drying capacity of the dryer ($year^{-1}$)	100
Fixed cost of drying of groundnut (Rs^{-1})	544 (6.4)
Variable costs (Rs t^{-1})	
Labour cost for loading and unloading (4 man-hrs t^{-1})	160 (1.9)
Diesel cost (Rs), 19L/batch or 10.5 lt^{-1}	735 (8.6)
Lubricant cost (Rs. t^{-1}), 10% of engine fuel consumption (2.2 l^{-1},Rs 154)	15.40
Total variable cost (Rs t^{-1})	910.4 (10.7)
Total (fixed + variable) cost of groundnut drying (Rst^{-1})	1454.4 (17.1)
Cost of drying of groundnut (Rs kg^{-1})	1.45 (0.017)

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