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Standardisation of drying methods in solar tunnel drier for groundnut (*Arachis hypogea* L.) seeds

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Abstract
Groundnut is an important oilseed crop in which seed drying necessarily required to eliminate the excess moisture and better storage. In the present study, use of solar energy for better elimination of seed moisture has been studied with solar tunnel drier by adopting different temperatures and durations. The results revealed that among varying temperatures (40, 45 and 50 °C) and durations (4, 8, 12, 16 and 20 h), optimum moisture content (8.42%) and higher germination (91%) was attained at 40 °C for 20 h period.

Keywords: Groundnut seed, germination, solar drying, moisture content

Introduction

Groundnut *(Arachis hypogea* L.) is an annual oilseed crop belongs to the family Fabaceae. It is commonly known as peanut, monkey nut, pig nut and also known as 'Wonder legume' or 'King of oilseeds crop'. It is commonly called as 'poor man's nut' because they are highly proteinaceous which helps to fight against the malnutrition. It provides 607 Kcal of energy, 25 g of protein, 14 g of fat, 3.57 mg of sugars, 44-56% oil and 10.7 mg of fibre in 100 g of kernels (USDA, 2019).

Drying is one of the most basic and important post-harvest operation which determines the quality of the seed. Drying eliminates the moisture content present in the product by evaporation using the heat received from the sun's incident solar radiation (Belessiotis and Delyannis, 2011; Di Pretoro and Manenti, 2020) [5, 9]. Removal of moisture from seeds by drying is mainly through evaporation of water present in the inner layers of seeds. Drying is one of the energy intensive and time-consuming processes, especially for large sized granules like groundnut (Sarker *et al.*, 2020) [16]. The water in seeds is held in three different states as bound water, absorbed water and free water, which have been characterized into three phases or zones depending on the way it is held in the seed. Bound water is tightly held in ionic groups such as amino or carboxyl groups and exists as a monolayer around the macromolecules of the seed. Absorbed water is considered to exits in multi layers, loosely held by bonding or hydroxyl group and amide group above the monolayer of bound water. Free water is considered as capillary or solution water held by capillary forces to the seed tissues (Kaveh *et al.*, 2020) [13].

In the process of seed drying, there are two different stages of removal of moisture from the seed. In first stage, the free water presents at the surface of the seed at constant drying rate and similar to the vaporization of water is evaporated into the ambient environment. Second stage involves the removal of absorbed moisture from inner layers of the seeds. As surface drying creates the imbalance in moisture potential which develops a gradient for migration of moisture from the inner organ to the surface. Seed is in equilibrium with the environment when the rate of moisture loss from the seed to the surrounding atmosphere is equal to the rate of moisture gained by the seed from the atmosphere. If the relative humidity of atmosphere is higher, the drying cannot be accomplished at a rapid rate.

Natural drying is the process of drying the seeds in field and threshing yards. However, the major issues in sun drying are uneven drying, risk of weather damage and field losses. Thus, mechanical driers can be preferred for uniform drying and improved seed quality. The mechanical driers are used in commercial units for drying of seeds. The fuel consumption and cost for mechanical driers are high and hence, a common farmer cannot afford to adopt this method of drying. Solar drying is one of the modified drying processes which utilises the solar energy for drying the seeds.

One of the possible solutions is the usage of the solar energy for forced air circulation which offers effective solution for seed drying operations. Thus, the present study was carried out in groundnut seeds using the solar drier on seed moisture elimination and the resultant seed quality.

Materials and Methods

An experiment was conducted on drying of groundnut seed pods using solar tunnel dryer available in the Department of Renewable Energy Engineering and the laboratory experiments for assessing the quality of such solar dried seeds were carried out in the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore during 2021-22.

Solar tunnel dryer works based on the principle of "Natural convection of solar radiation" as the model proposed by Binnisha *et al.* (2021) [21]. The semi-cylindrical tunnel structure was constructed with metal frame. It was covered with ultra violet stabilized low density polyethylene (LDPE) as collector material and the absorber surface were movable metallic trays. The cement concrete floor was coated with black coloured material to increase the absorption efficiency. It results in 15-20 °C increase in temperature inside the solar tunnel dryer over the ambient conditions. The increase in temperature was monitored with the help of sensors. Also, the temperature rise was regulated by exhaust fans which expel the excess heat through duct pipe (Figure 1).

Freshly harvested groundnut pods in the variety VRI 8 were collected with the moisture content (40 - 45%) and used for drying in solar tunnel driers. The experiment was carried out at different temperatures *viz.*, 40 ºC (T_1), 45 ºC (T_2) and 50 ºC (T_3) and drying durations *viz.*, initial (D_1), 4 (D_2), 8 (D_3), 12 (D_4), 16 (D_5) and 20 h (D_6). The seeds dried under sun were served as control (T_0). The samples were collected from the tunnel drier at every 4 h interval upto 20 h for analysis of seed quality parameters.

Moisture content (%)

Moisture content of the seed was estimated using low constant oven method at 103 ± 1 ºC for 16 ± 1 h. After drying, the seed samples were placed in desiccators containing calcium chloride for 30 min (ISTA, 2015) [11]. The percentage moisture content was calculated using the following formula

$$\text{Moisture content \%} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M_1- Weight of empty moisture bottle along with lid (g)

M_2- Weight of moisture bottle along with sample before drying (g)

M_3- Weight of moisture bottle along with sample after drying (g)

Germination (%)

The germination test was performed in four replicates comprising of 100 seeds each in sand medium and kept in germination room maintained at 25 ± 2 °C and 95 ± 3% relative humidity. After 10 days, the seedlings were evaluated and the number of normal seedlings produced was counted and germination was calculated. The mean data was calculated and expressed in percentage (ISTA, 2019) [12].

Statistical design

The experiment was carried out using a Factorial Completely Randomized Design (FCRD) with four replications. ANOVA was carried out on the data statistically by the 'F' test of significance following the methods given by Gomez and Gomez (1984) [10]. The critical differences (CD) were calculated at five percent probability level.

Results and Discussion

In the present study, significant differences were observed between the different temperatures and durations and their interaction. The freshly harvested groundnut seeds contained the moisture content of 45.3%. When these seed pods were dried in the solar tunnel drier, the moisture content was reduced with the increase in drying duration. In which, the optimum moisture content of 8.4 and 9.2% was observed at 40 °C (T_1) for 20 h (D_6) and 16h (D_5) of drying. While drying at 45 °C (T_2), the optimum moisture content of 8.4% was recorded at 16 h (D_5). Whereas, no optimum moisture content (8 to 9%) was obtained under both 50 °C (T_3) and control (T_0) (Table 1).

Also, the seeds dried at 40 °C for 20 h have recorded the highest germination (91%) followed by drying at 45 °C for 12 h (89%). Also, the pods dried at 40 °C for 16 h have showed better germination (88%) of seeds. Moreover, drying of pods at 50 °C for 12 h resulted with reduction in germination (87%). In case of open sun drying, only 80% germination was recorded at 20 h drying with the moisture content of 12.4% which is above the required level (Table 2 and Figure 2). Therefore, the groundnut pods requires more time duration for drying to safe moisture content under open sun drying.

Similarly, Dickens (1973) opined that the groundnut pods should be dried to a moisture level of 10% or less to ensure safe storage. Also, it was reported that the drying groundnut pods at the temperatures of 49 °C or higher has a detrimental effect on seed viability (Bailey *et al*., 1954) [4]. observed comparable results for shelled corn that the grain moisture content decreased from 27.23 to 14.12% at 38.23 °C, 28.09 °C at 20 and 38 h, with drying rates of 0.699 and 0.427 kg/h for solar drying and natural sun drying, respectively. Utilizing the solar driers, higher temperatures can be generated with lower relative humidity in the drier compartment which facilitated easy reduction in moisture and reduced spoilage of seeds compared with sun drying (Umogbai *et al.*, 2013) [18]. In addition, the high temperatures recorded in the dryer might be due to the transparent cover material used to construct the solar tunnel drier. Also, an increase in drying temperature from the bottom to the upper drying shelves (L1 - L4) resulted in decreases in germination of maize seeds (Akowuah *et al.*, 2018) [1]. In which, maize seeds dried at the upper tray (L4) of the SBHD where the highest mean temperature (52.8) and highest stress crack index (160) were recorded and had the lowest kernel germination (44%). Similar observation was observed in sweet sorghum seeds in which a reduction in germination was recorded, especially at temperatures above 40 °C. The low germination rate observed at L4 could be attributed to the high drying temperature, which resulted in the formation of stress cracks in the seed coat and micro fissures in the cotyledons. The moisture content of the seeds inside the shells was reduced from 17.4 to 7.3% in 14 h and 11 min with a moisture removal rate of 0.71% per hour (Krzyzanowski *et al.,* 2006) [14]. Observed that the germination was 85% in rice seeds dried in the drier when compared with 70% under sun drying. Also, the temperature range of 40.5 to 43.3 °C is the maximum tolerated level by the seeds without causing physical and chemical damage to the seeds (Brooker *et al*., 1974) [7].

The initial moisture content had the least impact on groundnut seed germination at low drying air temperatures, but had a significant impact at higher temperatures (Sivaprasad and Sarma, 1987) [17]. This might be the reason for increased abnormalities and decline in germination of groundnut seeds. In addition, drying at elevated levels of temperature resulted in anaerobic respiration of seeds which caused the accumulation of lactate ultimately leading to cytoplasmic acidosis and cell death (Roberts *et al*., 1984, Chung *et al*., 1997) [15, 8]. The mechanical damage such as cracked seed coats and stress cracks in the seeds dried under solar drier were less compared to open sun-dried seeds. Roy *et al*. (2020) reported that BRRI Dhan 50 rice variety harvested in *boro* season was dried at 43 ºC with different initial moisture contents of 25.7, 19.0 and 22.5% to achieve the final moisture content of 14% required 21.0, 13.5 and 13.5 h, respectively with germination percentage of 96, 92 and 93%.

Table 1: Effect of drying temperature and duration in solar tunnel dryer on moisture content (%) of groundnut seeds

Moisture content (%)					
Duration (D)	**Temperature (T)**				
	Control (Sun drying)	**T_1 (40ºC)**	**T_2 (45ºC)**	**T_3 (50ºC)**	**Mean**
D_1 - 0 h drying	45.3 (42.29)	45.3 (42.29)	45.3 (42.29)	45.3 (42.29)	45.3 (42.29)
D_2 - 4 h drying)	32.7 (34.87)	28.6 (32.34)	26.7 (31.10)	25.8 (30.49)	28.45 (32.20)
D_3 - 8 h drying	22.3 (28.20)	18.1 (25.22)	16.4 (23.91)	15.4 (23.08)	18.0 (25.10)
D_4 - 12 h drying	15.8 (23.45)	11.9 (20.21)	11.4 (19.73)	10.1 (18.53)	12.3 (20.48)
D_5 - 16 h drying	13.3 (21.36)	9.2 (17.69)	8.4 (16.81)	7.3 (15.63)	9.5 (17.87)
D_6 - 20 h drying	12.4 (20.65)	8.4 (16.88)	6.9 (15.23)	6.0 (14.22)	8.4 (16.74)
Mean	22.7 (28.47)	18.9 (25.77)	17.6 (24.84)	16.6 (24.04)	

	T	D	T×D
S.Ed	0.23	0.29	0.58
CD (P = 0.05)	0.48**	0.58**	1.17**

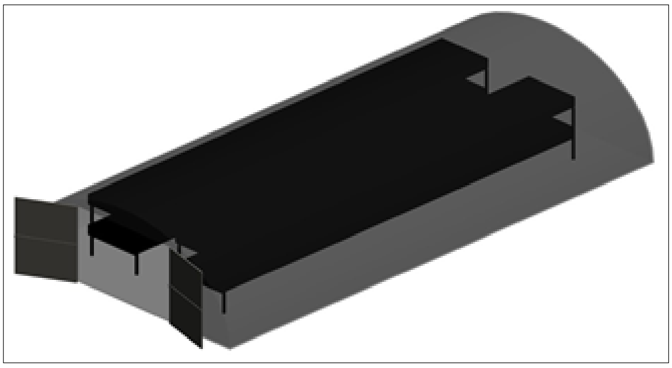
(Figures in parenthesis indicate arcsine transformed values; T - Temperature, D - Drying duration)

Table 2: Effect of drying temperature and duration in solar tunnel dryer on germination of groundnut seeds

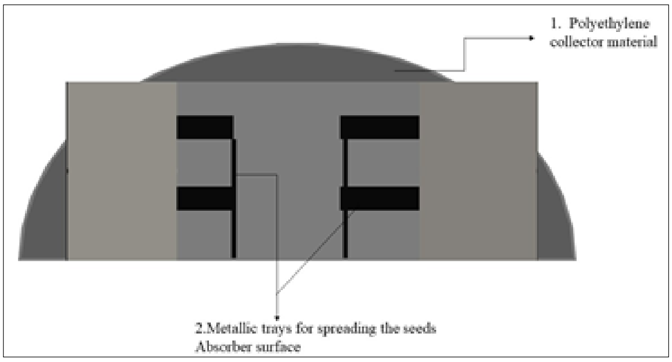
Germination (%)					
Duration (D)	**Temperature (T)**				
	Control (Sun drying)	**T_1 (40ºC)**	**T_2 (45ºC)**	**T_3 (50ºC)**	**Mean**
D_1 - 0 h drying	52 (46.15)	52 (46.15)	51 (45.38)	49 (44.62)	51 (45.58)
D_2 - 4 h drying)	60 (50.78)	72 (58.09)	69 (56.39)	73 (58.93)	69 (56.05)
D_3 - 8 h drying	70 (57.22)	80.0 (63.50)	83 (65.43)	81 (64.43)	79 (62.65)
D_4 - 12 h drying	76 (60.72)	84 (66.53)	89 (71.01)	87 (68.63)	84 (66.72)
D_5 - 16 h drying	76 (60.72)	88 (69.91)	88 (69.91)	85 (67.53)	84 (67.02)
D_6 - 20 h drying	80 (63.51)	91 (72.29)	87 (68.63)	83 (65.43)	65 (67.47)
Mean	69 (56.52)	79 (62.75)	79 (62.79)	77 (61.59)	

	T	D	T×D
S.Ed	0.77	0.94	1.89
CD (P = 0.05)	1.55**	1.90**	3.80*

(Figures in parenthesis indicate arcsine transformed values; T - Temperature, D - Drying duration)



Isometric view of solar tunnel drier



Front view of solar tunnel drier

Fig 1: Diagramatic representation of solar tunnel dryer

Fig 2: Effect of solar drying on germination of groundnut seeds

Conclusion

The study concluded that the groundnut pods dried in the solar tunnel drier at 40 °C at 20 h have recorded significantly higher germination (91%) with optimum moisture content (8.4%) and thus, it can be used for early drying of seeds.

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