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Investigation of Moisture Distribution During Soya Bean Seed Drying

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Abstract **-**In this study, diffusion equation and convenient diffusion coefficient depending on temperature is used to model to drying phenomena of spheroidal shape soya bean seed. This model is valid for the air velocity varying from 0.22 m/s to 0.25 m/s. Moisture distribution inside the soya bean seed is investigated for three different conditions. Simulations are obtained for 40^{o}C, 70^{o}C and varying ambient air temperature from 40^{o}C to 70^{o}C. Comsol Multiphysics finite element analysis software was used to obtain results. Simulation results of moisture distribution are presented for 0.5h, 1h, 3h, 5h and 7h for each conditions. Finally it has been shown that drying of soya bean seed exhibits falling rate drying period especially when temperature is constant.

Keywords**:** Drying phenomena, diffusion, soya bean

1. Introduction

One of the preservation method for storage of food stuff without moulding is drying. During drying process product quality and energy usage should be controlled. Not only food engineers but also textile engineers, chemical engineers and many scientists dealing with drying, have investigated mass transfer mechanisms during drying. Sometimes two or more different mass transfer mechanisms could be responsible of drying. On the other hand drying of food stuff is generally modelled by diffusion.

As it absolutely known that drying of hygroscopic materials takes place in two or three different stages. First drying stage is called as constant rate drying stage. It is apparent that removing unbounded moisture from surface requires relatively less energy and takes relatively less time. Second and/or third stages takes longer time relative to the first stage and these drying stages are called as falling drying rate stage. Gely and Giner (2007) studied thin layer drying of Nidera A6381, which is a soya bean cultivar, between 19 and 75^{o}C. They found that the convenient diffusion coefficients discribing the experimental drying curves. They also dried soya beans (Nidera A5409) from moisture contents of 0.15 and 0.30 (d.b.) for drying air temperatures 25^{o}C and 70^{o}C and found activation energy as 27kJ mol^{-1}. In their study air velocity was varying from 0.22m/s to 0.25m/s. Kocabiyik et.al. (2009) determined the properties of thermal conductivity, thermal diffusivity and specific heat for the pumpkin seed. In their study the moisture content (d. b.) was in the range of 5.32-24%. They showed that contrary to specific heat and thermal conductivity, thermal diffusivity decreases as moisture content increases. Hanh et. al. (2000) determined the diffusion coefficient of the drug in the liquid medium by applying a mathematical model based on Fick's second law. Can (2007) made an experimental study on drying of pumpkin seed under the effect of natural and forced convection respectively. In his study he present an analytic method based on diffusion equation. He obtained diffusion coefficients as a function of temperature for natural and forced convection. Kavak Akpınar and Bicer (2008) made an experimental study by drying long gren pepper with forced convection and natural convection. They used 13 different known mathematical models to fit their results.Their results shows that while logarithmic model is the most convenient model for forced convection drying, Midilli and Kucuk model is the best for natural convection drying. Rafiee et. al. (2008) experimentally dried thin layer soybean seed at 30, 40, 50, 60 and 70°C and drying air velocity of 1 m/s.

They used Fick's diffusive model, finite element formulation and as a result they presented vairation of moisture content of soybean seed as a function of time during drying.

2. Material and Method

In this study drying simulations of soya bean seed in the spheroid form, are obtained by using diffusion equation. Dimensions of 20 soya been seed were measured, average of them was taken as the dimension of the seed we examined. An ellipsoid geometry is defined on Comsol Multiphysics finite element analysis software. The values of semiaxis values are entered as 4.76mm, 4.76mm and 3.645mm and spheroid form of the soya been seed is obtained as shown in the Fig.1.

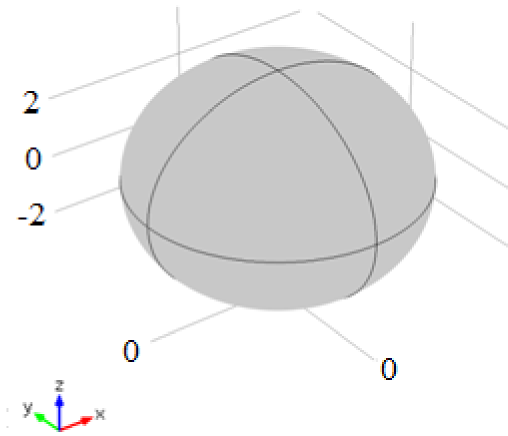

Fig. 1. Soya bean seed

Arrhenius type diffusion equation, which is valid for the air temperatures between 41.5 and 70.8 ^{o}C, is used from the study of Gely and Giner (2007). In equation (1) the universal gas constant is 8.314J/ K^{-1} mol^{-1}. The governing equation is diffusion equation.

$$D_{eff} = 3.39 \cdot 10^{-5} \exp\left(\frac{-36400}{R_g(T_y + 273.16)}\right) \quad (1)$$

$$\vec{\nabla} \cdot \left(D_{eff} \vec{\nabla} X\right) = \frac{\partial X}{\partial t} \quad (2)$$

Initial and equilibrium moisture content of the soya bean seed is taken from the study of Gely and Giner (2007) and given as follows.

$$X_o = 0.2615 \quad (3)$$

Table. 1. Experimental conditions for thin layer drying of soya bean

Air temperature T(^{o}C)	Relative humidity of air	X_e (d.b.)
40	0.23	0.037
70	0.05	0.009

When defining boundary conditions it is assumed that surface of the soya been seed is in equilibrium moisture content. Finally initial and boundary conditions are defined as followings.

$$X|_s = X_e \quad (4)$$

$$X|_{t=0} = X_o \quad (5)$$

Regarding that the given differential equation is valid for the air temperatures between 41.5 and 70.8 ^{o}C, three different cases are investigated. For the first and second cases drying occurs under the constant air temperature at 40 and 70^{o}C respectively. Finally it is assumed that drying air temperature linearly varies from 40^{o}C to 70^{o}C and moisture distribution inside the seeds are investigated for each cases. For the case of varying air temperature equilibrium moisture content is same as the equilibrium moisture content for drying at 70^{o}C. On the other hand, linear function of drying air temperature is arranged as it reaches 70^{o}C when 500 min. elapses.

$$T_y=40+ 0.001t \quad (6)$$

3. Conclusion

Accurate determination of drying rate is important because drying conditions affect the quality of the food stuff. Simulations of moisture distributions inside the soya been seed during drying are obtained for each cases as shown in Fig. 2. , 3 and 4 respectively.

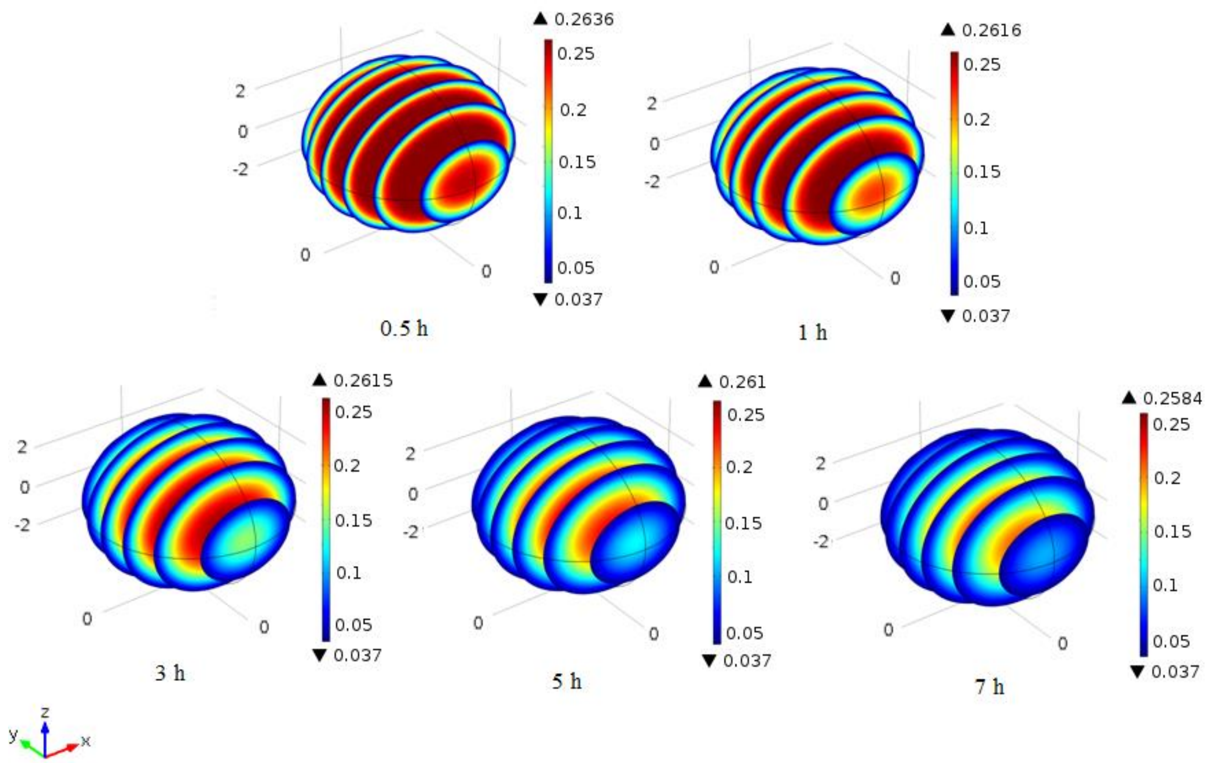

Fig. 2. Moisture distribution for 40^{o}C drying air temperature

As it can be seen from the figures, showing moisture distribution inside the seed, one can conclude that moisture more rapidly decreases as temperature increases. This fact can also be observed from Fig. 5. Moisture transfer starts from the surface. Before the seed reach to the equilibrium moisture content, there always be seen moisture gradient inside the seed. At the begining of the drying, moisture gradient is relatively bigger and this causes drying to be fast at that stage. This explains the reason of the falling rate period when drying is modelled by diffusion.

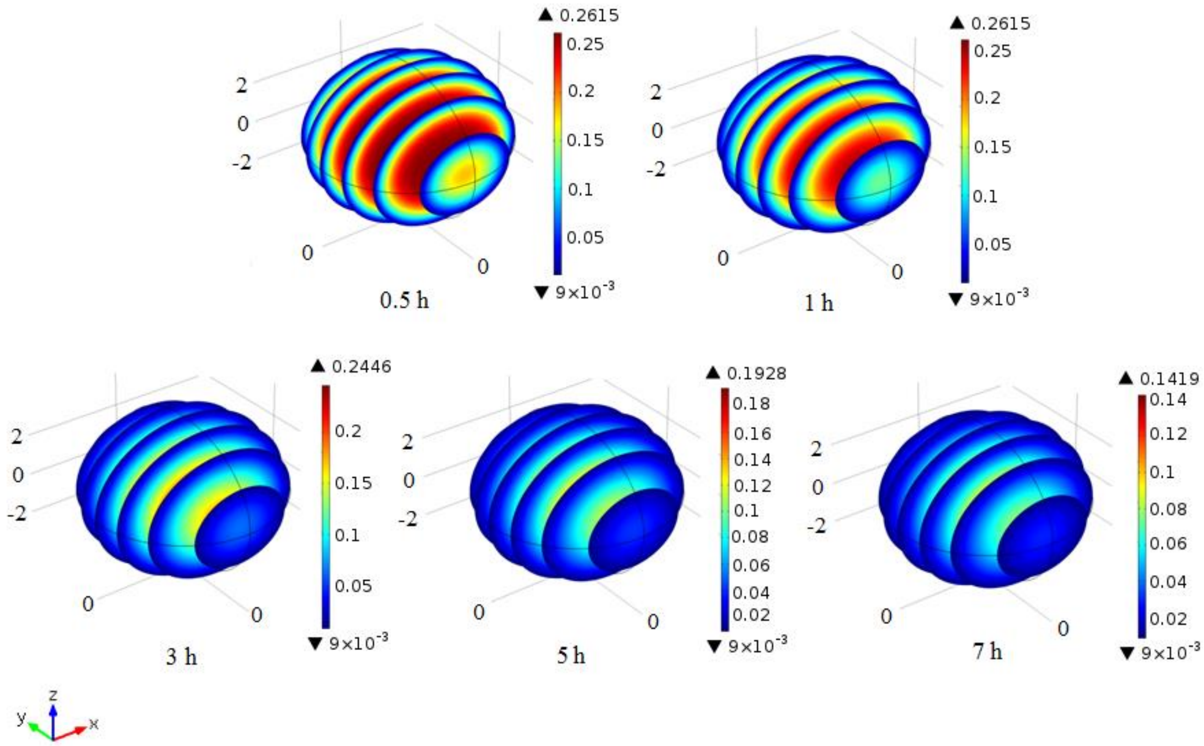

Fig. 3. Moisture distribution for 70°C drying air temperature

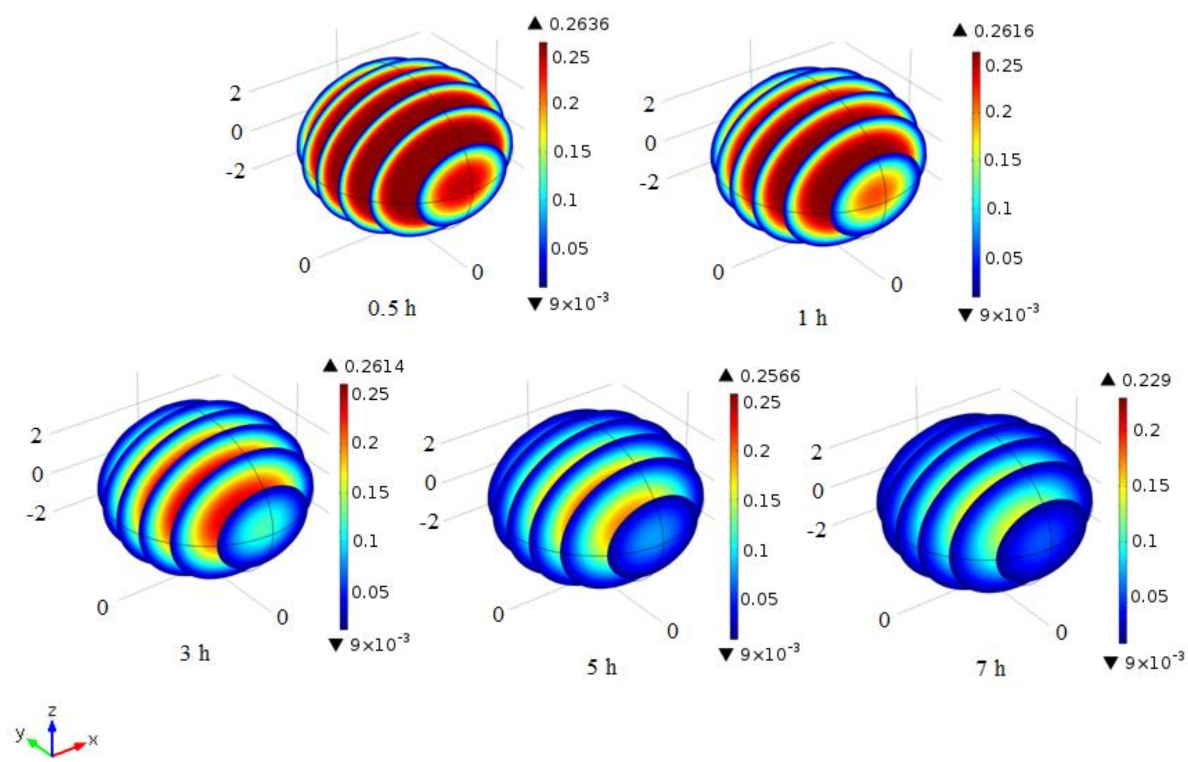

Fig. 4. Moisture distribution for varying drying air temperature

The obtained results of average moisture content shows good agreement with the study made by Gely and Giner (2007). When temperature is constant drying curves shows similar behaviour and exactly suits to falling rate period. It has been concluded that if drying air temperature linearly increases, drying occurs at constant rate period except the beginning of the drying.

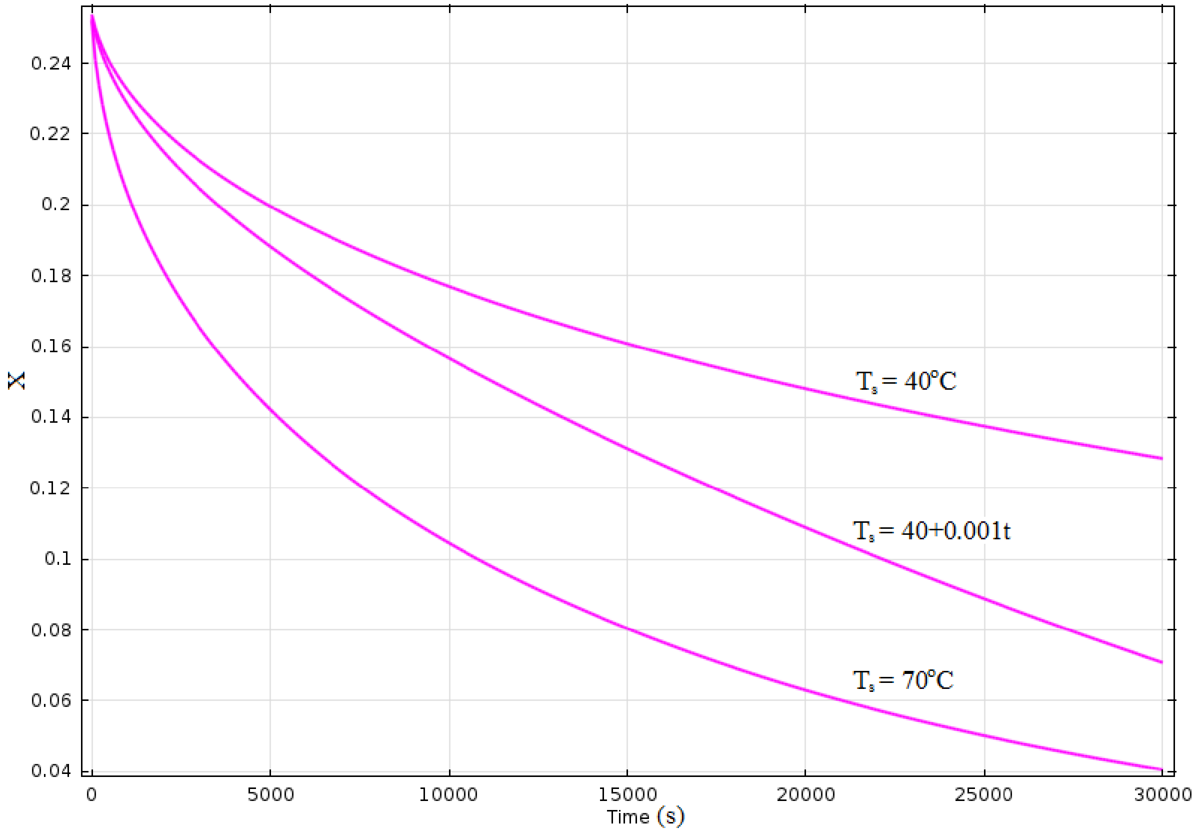

Fig. 5. Average moisture content as a function of time for each examined cases

Nomenclature

D_{eff}: Efffective diffusion coefficient (m^2/s)

R_g: Universal gas constant (J K^{-1} mol^{-1})

T_y: Drying air temperature (^oC)

t: Time (s)

X_e (d.b.): Equilibrium moisture content

X_o (d.b.): Initial moisture content

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