Drying of Chickpeas (*Cicer arietinum*) and Black eyed Peas (*Vigna unguiculata*)

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Abstract

In this article an attempt has been made to determine the moisture diffusivity of solid food grains in drying operations using which a comprehensive mathematical model is proposed to predict the drying characteristics of any solid food materials. Moisture diffusivity of whole grain, endosperm and husk were evaluated experimentally at different temperatures of 30^0C, 40^0C & 50^0C for chickpeas and black eyed peas in drying operations. The drying characteristics of solid food grains are also studied. The effects of process parameter like temperature on the rate of drying were assessed. Efforts are made to find the diffusivity model for chickpeas and black eyed peas in drying operations.

Keywords- *solid food grains, drying characteristics, moisture diffusivity*

I. INTRODUCTION

Food is consumed to provide nutritional support for the body. It contains essential nutrients, such as fats, proteins, vitamins and minerals which is ingested by an organism and assimilated by the cells to provide energy, maintain life and stimulate growth. Cereals and pulses grain is a staple food that provides more food energy worldwide than any other type of crop. Especially pulses contain rich proteins. Most food has always been obtained through agriculture. Beans and peas are the mature forms of legumes. This category include like black-eyed peas, garbanzo beans (chickpeas). Food preservation involves preventing the growth of bacteria, fungi, or micro-organisms, as well as slowing the oxidation of fats that cause rancidity.It may also include processes that inhibit visual deterioration, such as the enzymatic browning reaction in apples after they are cut during food preparation.The most common techniques of food preservation became available to the home chef from the dawn of agriculture until the industrial revolution is drying. Middle Eastern and Oriental cultures were drying foods using the power of the sun. Vegetables and fruit are naturally dried by the sun and wind, but "still houses" were built in areas that did not have enough sunlight to dry things. The simulation of both heat and mass transfer operation finds extensive applications in food processing to extend the shelf life of food products and agro-products from seasons of glut to gloomy days by reducing the moisture content which in turn reduces the water activity. The Tray Dryer is chosen as equipment for drying of solid food grains. It has low nutrition losses as compared to other dryers like fluidized bed, spray dryer etc. The moisture removal process was studied at different temperatures and a model has been studied to determine the diffusivities for the drying of the solid foods grains.

II. MATERIALS AND METHODS

A. Materials

The food materials play a vital role in moisture diffusivity of solid food grains. Materials considered are pulses, cereals, etc. These food materials are major energy consumption compare with other food material in world level.

The Raw material chosen for study is Chickpeas (Bengal gram) and Black eyed peas for drying operation. The chickpeas contain fiber advantage and weight loss. Like other beans, Chickpeas, are rich in both soluble and insoluble dietary fiber. Soluble fiber forms a gel-like substance in the digestive tract that snares bile (which contains cholesterol) and ferries it out of the body. Studies in this have shown that insoluble fiber not only helps to increase the stool bulk, prevent constipation, and also help to prevent digestive disorders. Protein for vegetarians in chickpeas is a good source of protein. Combined with a whole grain such as whole-wheat protein, they provide good amount of protein compare to that of meat or dairy foods with no calories or saturated fats. Chickpeas are an excellent source of manganese, which is important in energy production and antioxidant defense.. Iron boost in your energy because of their high iron content. This is particularly important for menstruating women, pregnant or lactating women and growing children. Iron is an integral component of hemoglobin, which transports oxygen from the lungs to all body cells, and is part of key enzyme systems for energy production and metabolism. Stabilizing Blood Sugar and Low Glycemic Index (GI) Soluble fiber helps stabilize blood sugar levels. If you have insulin resistance, hypoglycemia or diabetes, beans like garbanzos can help you balance blood sugar levels while providing steady, slow-burning energy. They have low GI value of 28 – 32 means the carbohydrate in them is broken down and digested slowly. This is helpful for weight loss as it controls appetite. Weight Loss is due to high fiber content and low GI, chickpeas are excellent for weight loss diets.

The Black eyed peas contain digestion-friendly fiber: Eat black-eyed peas and you get soluble fiber, which keeps blood sugar balanced and helps prevent type 2 diabetes. Soluble fiber also binds to cholesterol and carries it out of the body. It protects you from several intestinal disorders as well.. This contains Vitamin A: This vitamin, as we know, is essential for eye health. It also strengthens skin and skeletal tissue. In a cup of cooked black-eyed peas, you get nearly 70 milligrams of Vitamin A. Addition to this some broccoli, carrot or spinach, and you gift yourself a meal that's not only delicious, but also rich in vision-boosting nutrients.

B. Method

This category refers to the nature of the production schedule. For large scale production the appropriate dryer is of the continuous type with continuous flow of material in and out of the dryer. Conversely, for small production.

1) Physical Properties of Material

The physical state of the feed is probably the most important factor in the selection of the dryer type. The wet feed may vary from a liquid solution, a slurry, a paste, or filter cake to free-flowing powders, granulations, and fibrous and non-fibrous solids. The design of the dryer is greatly influenced by the properties of the feed; thus dryers handling similar feeds have many design characteristics in common. A comprehensive classification of commercial dryers based on properties of materials handled, is given in Perry's Chemical Engineering Handbook

2) Conveyance

In many cases, the physical state of the feed dictates the method of conveyance of the material through the dryer; however, when the feed is capable of being performed, the handling characteristics of the feed may be modified so that the method of conveyance can be selected with greater flexibility. Generally, the mode of conveyance correlates with the physical properties of the feed

3) Method of Energy Supply

Where the energy is supplied to the material by convective heat transfer from a hot gas flowing past the material, the dryer is classified as a Conduction-type dryers are those in which the heat is transferred to the by the direct contact of the latter with a hot metal surface.

4) Cost

Cost effect of dryer selection influence the classification of industrial drying. When capacity is large enough, continuous dryers are less expensive than batch units. Those operating at atmospheric pressure cost about 1/3 as much as those at vacuum. Once through air dryers are one-half as expensive as reciprocating gas equipment. Dielectric and freeze dryers are the most expensive and are justifiable only for sensitive and specialty products. In large scale drying, rotary, fluidized bed and pneumatic conveying dryers cost about the same.

5) Special process features

Special characteristics of the drying material together with particular features of product are carefully considered in classifying of dryer and selection of dryer type. Hazardous, heat sensitive, quality sensitive products and cost effects can clearly dictate process consideration in classification.

III. EXPERIMENTAL SETUP

A. Wet Solid Preparation

Chickpeas soaked in water bath. After soaking wrap with cloth and take the initial weight of chickpeas before drying. The value of the born dry weight is calculated. Drying studies of chickpeas are evaluated (solid food) into three categories like Whole Grain, Endosperm, and Husk etc. similarly for black eyed peas has been done.

B. Drying Process

Food materials are dried in tray dryer using stream of air at different temperatures. Depend upon the relative humidity of air, the diffusion of moisture from food grains to air take place. Since drying is a simultaneous heat and mass transfer operation. The moisture migration in the falling rate zone of solid foods is essentially due to diffusion. Similarly, drying is an unsteady state process. Therefore this experimental setup follows the Fick's second law for transient movement condition.

C. Procedure for Drying

- The Tray Dryer is chosen as equipment for drying of solid food grains.
- It has low nutrition losses as compared to other dryers like fluidized bed, spray dryer etc.
- Hot air circulated through the tray at a square meter of tray area.
- Fresh air enters the tray is drawn by the fan through the heater coils.
- Then blown across the food trays to exhaust.
- The air is being heated by the indirect method.
- Screens filter out any dust that may be in the air.
- The air is exhausted to the atmosphere after one pass rather being recirculated within the system.
- In recirculating designs, the moisture laden air, after evaporating water from food.
- The weights of the drying solids were weighed at an interval of 15 minutes for the grain and endosperm and an interval of 5 minutes for the husk.

IV. RESULT AND DISCUSSION

A. Determination of Moisture

*1) **Grain***

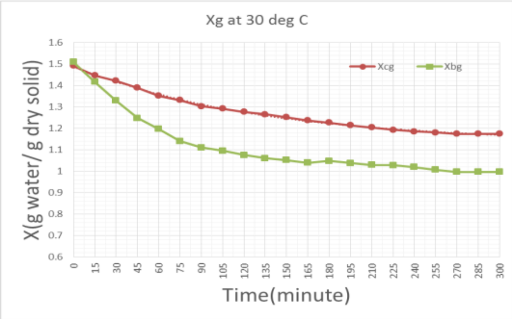


Fig. 1: Determination of Moisture Content of Grain at 30^{0}C

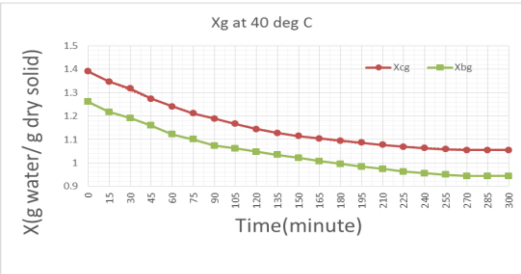


Fig. 2: Determination of Moisture Content of Grain at 40^{0}C

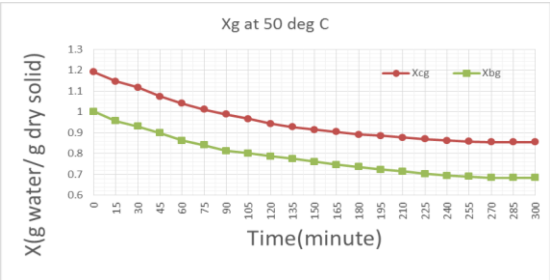


Fig. 3: Determination of Moisture Content of Grain at 50^{0}C

From the above graph it was observed that the moisture diffusivity of grain is higher at lower temperature lower at higher temperature. Moreover the equilibrium moisture content is inversely proportional to temperature

*2) **Endosperm***

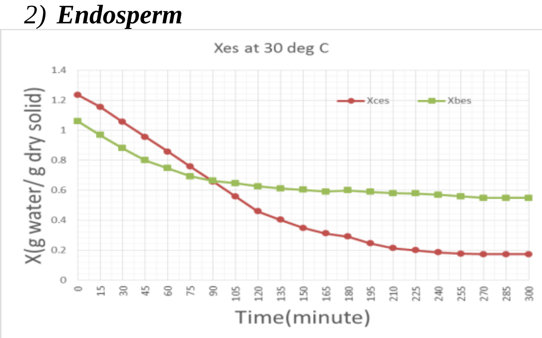


Fig. 4: Determination of Moisture Content of Endosperm at 30^{0}C

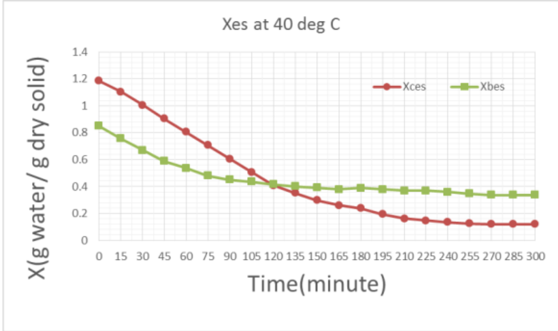


Fig. 5: Determination of Moisture Content of endosperm at 40^{0}C

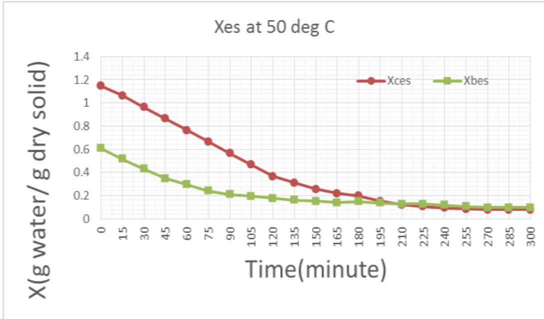


Fig 6: Determination of Moisture Content of endosperm at 50^{0}C

From the above graph it was observed that the moisture diffusivity of endosperm is higher at lower temperature lower at higher temperature. Moreover the equilibrium moisture content is inversely proportional to temperature

3) HUSK

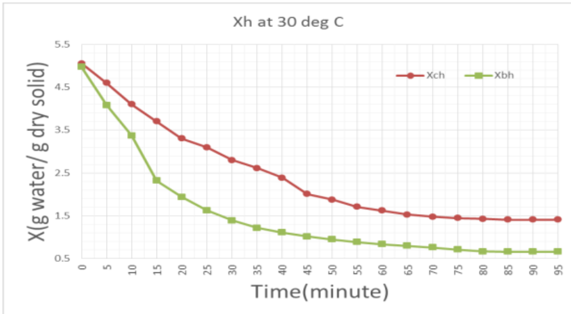


Fig 7: Determination of Moisture Content of husk at 30^{0}C

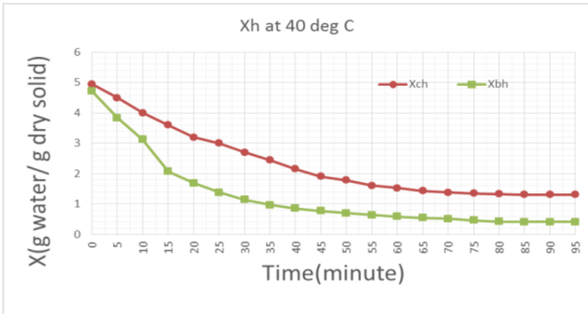


Fig 8: Determination of Moisture Content of husk at 40^{0}C

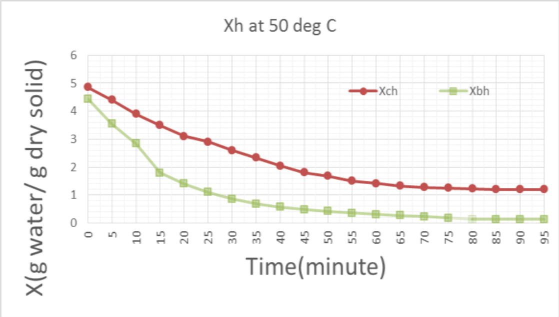


Fig 9: Determination of Moisture Content of husk at 50^{0}C

For safe storage of grains, removal of husk is required because the relative moisture content is higher in the husk than the grain.

B. Determination of Drying Rate

1) Rate of Drying for Grain

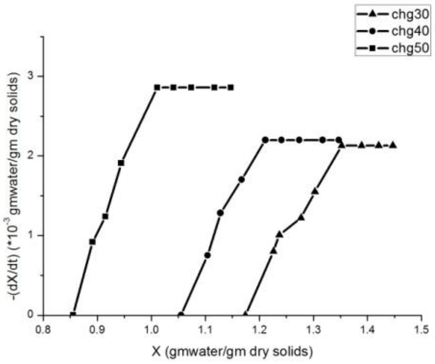


Fig 10: Determination of Drying Rate for Chickpeas Grains at 30^{0}C, 40^{0}C, 50^{0}C

Table 1: Drying Rate of Grain (Chickpeas)

30^{0}C		40^{0}C		50^{0}C	
X	-(dX/dt) x 10^{-3}	X	-(dX/dt) x 10^{-3}	X	-(dX/dt) x 10^{-3}
1.447	2.13	1.347	2.2	1.147	2.86
1.421	2.13	1.317	2.2	1.117	2.86
1.389	2.13	1.274	2.2	1.074	2.86
1.352	2.13	1.241	2.2	1.041	2.86
1.303	1.553	1.211	2.2	1.011	2.86
1.277	1.223	1.167	1.703	0.944	1.91
1.237	1.01	1.128	1.283	0.915	1.24
1.226	0.8015	1.104	0.75	0.891	0.92
1.174	0	1.055	0	0.855	0
1.174	0	1.055	0	0.855	0
1.174	0	1.055	0	0.855	0

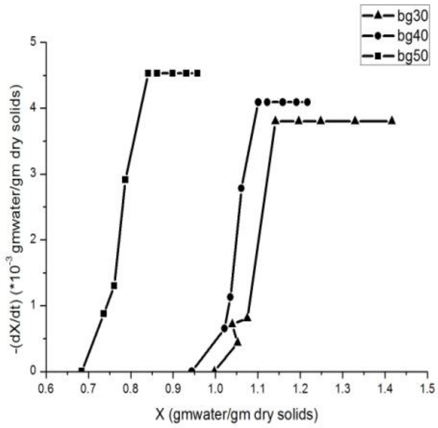


Fig 11: Determination of Drying Rate for Black Eyed Peas Grains at 30^{0}C, 40^{0}C, 50^{0}C.

Table 2: Drying Rate of Grain (Blackpeas)

30^{0}C		40^{0}C		50^{0}C	
X	-(dX/dt) x 10-3	X	-(dX/dt) x 10-3	X	-(dX/dt) x 10-3
1.416	3.8	1.217	4.09	0.957	4.53
1.329	3.8	1.191	4.09	0.931	4.53
1.248	3.8	1.159	4.09	0.899	4.53
1.196	3.8	1.122	4.09	0.862	4.53
1.141	1	1.101	4.09	0.841	4.53
1.075	0.81	1.061	2.783	0.787	2.912
1.039	0.72	1.035	1.128	0.761	1.304
1.052	0.4365	1.021	0.654	0.736	0.875
0.997	0	0.944	0	0.684	0
0.997	0	0.944	0	0.684	0
0.997	0	0.944	0	0.684	0

2) Rate Of Drying For Endosperm

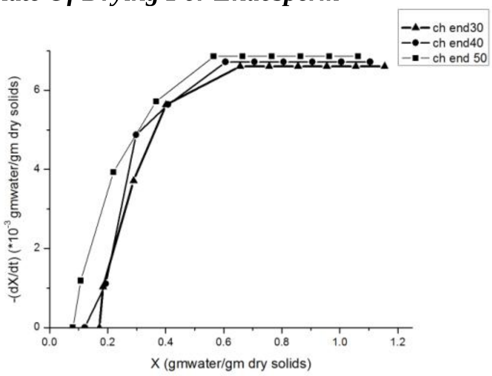


Fig 12: Determination Of Drying Rate For Chickpeas Endosperm At 30^{0}C, 40^{0}C, 50^{0}C

Table 3: Drying Rate of Endosperm(Chickpeas)

30^{0}C		40^{0}C		50^{0}C	
X	-(dX/dt) x 10^{-3}	X	-(dX/dt) x 10^{-3}	X	-(dX/dt) x 10^{-3}
1.154	6.61	1.104	6.72	1.063	6.86
1.055	6.61	1.005	6.72	0.964	6.86

0.955	6.61	0.905	6.72	0.864	6.86
0.876	6.61	0.806	6.72	0.765	6.86
0.756	6.61	0.706	6.72	0.665	6.86
0.656	6.61	0.606	6.72	0.565	6.86
0.401	5.638	0.408	5.6418	0.367	5.7198
0.289	3.7198	0.298	4.8758	0.22	3.9338
0.184	1.0318	0.194	1.1098	0.107	1.1878
0171	0	0.121	0	0.08	0
0.171	0	0.121	0	0.08	0
0.171	0	0.121	0	0.08	0

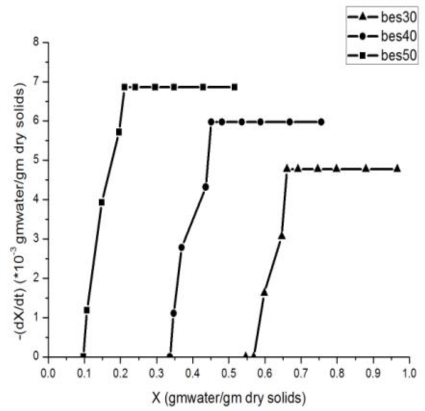


Fig 13: Determination of Drying Rate for Black eyed peas Endosperm at 30^0C, 40^0C, 50^0C

Table 4: Drying Rate of Endosperm(Black Eyed Peas)

30⁰C		40⁰C		50⁰C	
X	**-(dX/dt) x 10^{-3}**	**X**	**-(dX/dt) x 10^{-3}**	**X**	**-(dX/dt) x 10^{-3}**
0.966	4.78	0.756	5.978	0.516	6.86
0.879	4.78	0.669	5.978	0.429	6.86
0.798	4.78	0.588	5.978	0.348	6.86
0.746	4.78	0.536	5.978	0.296	6.86
0.691	4.78	0.481	5.978	0.241	6.86
0.661	4.78	0.451	5.978	0.211	6.86
0.646	3.065	0.436	4.3214	0.196	5.7198
0.598	1.625	0.369	2.7841	0.148	3.9338
0.569	0	0.347	1.1098	0.107	1.1878
0.547	0	0.337	0	0.097	0
0.547	0	0.337	0	0.097	0
0.547	0	0.337	0	0.097	0

3) Rate Of Drying For Husk

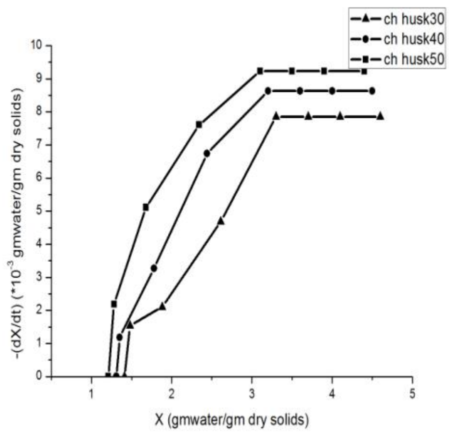


Fig 14: Determination of Drying Rate of chickpeas husk at 30^0C, 40^0C, 50^0C

Table 5: Drying Rate of Husk (Chickpeas)

30⁰C		40⁰C		50⁰C	
X	**-(dX/dt) x 10^{-3}**	**X**	**-(dX/dt) x 10^{-3}**	**X**	**-(dX/dt) x 10^{-3}**
4.6	7.85	4.5	8.63	4.4	9.23
4.1	7.85	4	8.63	3.9	9.23
3.7	7.85	3.6	8.63	3.5	9.23
3.3	7.85	3.2	8.63	3.1	9.23
2.61	4.686	2.44	6.7381	2.34	7.605
1.88	2.1006	1.78	3.2701	1.68	5.1117
1.48	1.532	1.35	1.1802	1.28	2.1885
1.41	0	1.31	0	1.21	0
1.41	0	1.31	0	1.21	0
1.41	0	1.31	0	1.21	0

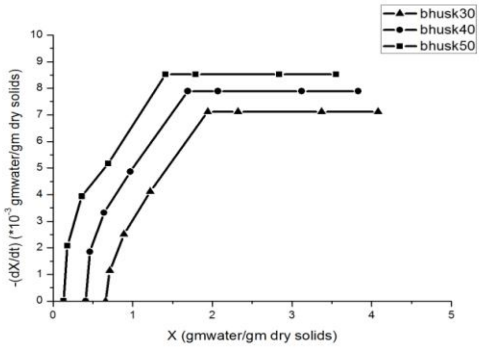


Fig 15: Determination of Drying Rate of Black Eyed Peas Husk At 30^0C, 40^0C, 50^0C

Table 6: Drying Rate of Husk (Black Eyed Peas)

30⁰C		40⁰C		50⁰C	
X	**-(dX/dt) x 10^{-3}**	**X**	**-(dX/dt) x 10^{-3}**	**X**	**-(dX/dt) x 10^{-3}**
4.08	7.12	3.83	7.89	3.55	8.53
3.37	7.12	3.12	7.89	2.84	8.53
2.32	7.12	2.07	7.89	1.79	8.53
1.94	7.12	1.69	7.89	1.41	8.53

1.22	4.123	0.97	4.8621	0.69	5.1685
0.89	2.5143	0.64	3.3175	0.36	3.9415
0.71	1.1432	0.46	1.8549	0.18	2.0845
0.66	0	0.41	0	0.13	0
0.66	0	0.41	0	0.13	0
0.66	0	0.41	0	0.13	0

C. Diffusion In Drying

The moisture migration in the falling rate zone of solid food is essentially due to diffusion. When the foods are dried slowly, moisture transfer is by diffusion from solid foods into the surrounding air will take place. Since drying is an unsteady state process, we can apply Fick's second law for transient movement.

$$\frac{\partial C}{\partial \theta} = D_v \frac{\partial^2 C}{\partial x^2}$$

This is applicable for long slabs. The same on modification to spherical particles can be written as

$$\frac{\partial C}{\partial t} = D_v \left(\frac{\partial^2 C}{\partial r^2} + \frac{2}{r} \frac{\partial C}{\partial r} \right)$$

We experimentally measure time (t) to bring down the moisture content from Xo to X in the falling rate period, and calculate D_v by applying Equation.

$$\frac{X - X^*}{X_0 - X^*} = 0.608 \exp\left(-9.87 \frac{D_v t}{r^2} \right)$$

Where, X* is equilibrium moisture content

Xo is initial moisture content

t is the time taken to bring down the moisture content from Xo to X in the falling rate zone .By using the rate of drying graphs initial, final, equilibrium moisture content were found for whole grains, endosperm, husk.

The following values of moisture content were used to determine the diffusivity (D_v) respectively.

Table 7: Values of Moisture Content

chickpeas

System	Temperature, ^{0}C	X_0	X	X^*
Grain	30	1.303	1.226	1.174
	40	1.167	1.104	1.055
	50	0.944	0.891	0.855
Endosperm	30	0.401	0.184	0.171
	40	0.408	0.194	0.121
	50	0.367	0.107	0.080
Husk	30	2.61	1.48	1.41
	40	2.44	1.35	1.31
	50	2.34	1.28	1.21

Black Eyed Peas

System	Temperature, ^{0}C	X_0	X	X^*
Grain	30	1.141	1.052	0.997
	40	1.101	1.021	0.944
	50	0.841	0.736	0.684
Endosperm	30	0.646	0.569	0.547
	40	0.436	0.347	0.337
	50	0.196	0.107	0.097
Husk	30	1.22	0.71	0.66
	40	0.97	0.71	0.41
	50	0.69	0.18	0.13

The values of D_v as follows:

Table 8: Diffusivity Values

Chickpeas

System	D_v @ 30^{0}C (x 10^{-10} m^2/s)	D_v @ 40^{0}C (x 10^{-10} m^2/s)	D_v @ 50^{0}C (x 10^{-10} m^2/s)
Grain	**1.2337**	**1.4819**	**1.8351**
Endosperm	**1.9592**	**2.9966**	**3.8148**
Husk	**0.8094**	**0.8456**	**0.8917**

Black Eyed Peas

System	D_v @ 30^{0}C (x 10^{-10} m^2/s)	D_v @ 40^{0}C (x 10^{-10} m^2/s)	D_v @ 50^{0}C (x 10^{-10} m^2/s)
Grain	**1.3906**	**1.6834**	**2.0197**
Endosperm	**2.0833**	**3.1207**	**3.9389**
Husk	**0.8214**	**0.8576**	**0.9037**

D. Effect of Temperature on Diffusivity

The effect of temperature on diffusivity can be represented by Arrhenius type equation as follows

$$D_v = D_0 e^{-E/RT}$$

Where Do is constant, E is the activation energy in J/mole, T is temperature in degrees Kelvin, and R is universal gas constant =8.3144 J/mole k.

To evaluate the constant D_o and (E/R), we measure D_v at different temperature and then we can find out D_o and (E/R) by linearizing equation, and plotting on a graph.

By taking logarithms on both sides of equation.

$$\ln(D_v) = \ln(D_0) - \left(\frac{E}{R}\right)\left(\frac{1}{T}\right)$$

We draw a graph taking ln (D_v) on y-axis and (1/T) on x-axis, we measure the slope and intercept

Slope = - (E/R)

And intercept = ln (D_o)

From which D_o = exp (intercept)

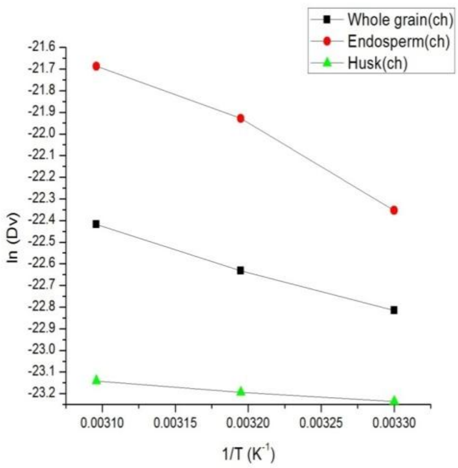
Table 6: Diffusivity Vs Temperature

Chickpeas

System	Temperature, K	D_v x 10^{-10} m^2/s	1/T K^{-1}	ln (D_v)
Grain	303	1.2337	0.0033	-22.8158
	313	1.4819	0.00319	-22.6325
	323	1.8351	0.0031	-22.4188
Endosperm	303	1.9592	0.0033	-22.3533
	313	2.9966	0.00319	-21.9284
	323	3.8148	0.0031	-21.687
Husk	303	0.8094	0.0033	-23.2371
	313	0.8456	0.00319	-23.1936
	323	0.8917	0.0031	-23.1405

Black Eyed Peas

System	Temperature, K	D_v x 10^{-10} m^2/s	1/T K^{-1}	ln (D_v)
Grain	303	1.3906	0.0033	-22.6961
	313	1.6834	0.00319	-22.5051
	323	2.0197	0.0031	-22.3229
Endosperm	303	2.0833	0.0033	-22.2919
	313	3.1207	0.00319	-21.8878
	323	3.9389	0.0031	-21.6551
Husk	303	0.8214	0.0033	-23.2261
	313	0.8576	0.00319	-23.1795
	323	0.9037	0.0031	-23.1201



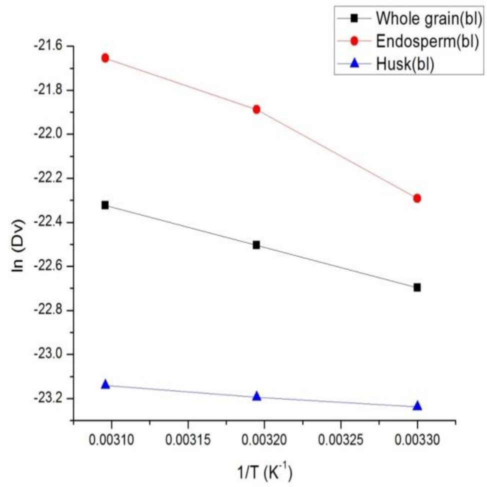


Fig16: Effect of Temperature n Diffusivity

From the graph of Chickpeas ln (D_v) vs (1/T), we get,

Slope of grain = - (E/R) = -1940.4552

Intercept of grain = ln (D_o) = -16.4186

D_o of grain = exp (-16.21) = 9.1219x 10^{-8} m^2/s

Similarly, D_o for endosperm is given by, D_o = 12.434 x 10^{-6} m^2/s

And D_o for husk is given by, D_o = 3.599 x 10^{-10} m^2/s

From the plot of Black eyed peas ln (D_v) vs (1/T), we get,

Slope of grain = - (E/R) = -1826.08325

Intercept of grain = ln (D_o) = -16.66989

D_o of grain = exp (-16.586) = 6.2691 x 10^{-8} m^2/s

Similarly, D_o for endosperm is given by, D_o = 8.048 x 10^{-6} m^2/s

And D_o for husk is given by, D_o = 2.1556 x $10^{-10}$$m^2/s$

The Diffusivity equation as follows:

System	Diffusivity equation for Chickpeas	Diffusivity equation for Black eyed peas
Grain	$9.12x10^{-8}e^{-(2000/T)}$	$6.269x10^{-8}e^{-(1850/T)}$
Endosperm	$12.43x10^{-6}e^{-(3350/T)}$	$8.048x10^{-6}e^{-(3200/T)}$
Husk	$3.59x10^{-10}e^{-(450/T)}$	$2.155x10^{-10}e\text{-}^{(465/T)}$

Thus, the drying process can be made faster by removing the husk. This is evident from the values of diffusivity obtained before and after removal of husk

V. CONCLUSION

- For the safe storage of grains, the moisture present in them has to be removed. the moisture characteristics of food grains using tray drier is studied. The diffusivity of food grains in drying across different temperatures are presented and experimental results are found to be valid with a proposed Arrhenius type of diffusivity equation.

- The diffusivity values of Chickpeas and Black eyed peas at 30, 40 and 50^{0}C are calculated using one dimensional Fick's second law of diffusion and verified with same experimental data.
- It is observed that removal of moisture content in Black eyed peas is high compare with Chickpeas.
- It is concluded from the observation Diffusivity of the whole grain is not a simple summation of the individual diffusivities of husk and endosperm.
- The diffusivity relationship across the different temperatures is found to be affected due to the presence of gum material in food materials.

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