American Journal of Food Technology

ISSN 1557-4571

Academic Journals Inc.

www.academicjournals.com

American Journal of Food Technology 6 (10): 945-950, 2011
ISSN 1557-4571 / DOI: 10.3923/ajft.2011.945.950

Sorption Behaviour of Rapeseed (Toria)

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ABSTRACT
Sorption isotherms of rapeseed (Toria) var. viz. TL-15, TH-68 and Sangam were evaluated at 30, 50 and 70°C using the standard static salt solutions method. Sigmoid trends were observed for isotherms sowing a clear effect of temperature. Four mathematical models, i.e., modified Henderson; modified Chung-Pfost; modified Halsey and modified Oswin were fitted for their ability to best fit experimental data on the basis of coefficient of determination. The equilibrium moisture content curves were obtained, both experimentally and by fitting the selected models to the experimental data. Modified Henderson model was found to give the best fit (R^2 = 0.99) for describing the experimental data.

Key words: *Brassica campestris* var. toria, equilibrium moisture content, rapeseed, relative humidity, storage and processing

INTRODUCTION
Oil seed crop plays an important role in Indian economy. Oilseed rapes are the world's third most important source of vegetable oils after palm and soybean throughout the world. Among the rapeseed-mustard group, var-Toria is the early maturing one and it usually matures in 85-110 days. The early maturing genotypes of Toria are also desirable for growing in drought prone and/or dry land areas with scanty rainfall, making their survival possible on the residual moisture of kharif harvest (Kumar *et al*., 2010). Rapeseed contains high level of moisture (about 16-20%, w.b.) at the time of harvesting (November and December), in north India. Therefore, drying and storage conditions are very important to protect the quality of seeds. Seeds should be dried immediately after harvest and thus must be stored under safe storage conditions (Giner and Gely, 2005).

The information on Equilibrium Moisture Content (EMC) of biological materials is important to directly relate the drying and storage conditions (Menkov *et al*., 2003; Vishwakarma *et al*., 2007). The Equilibrium Moisture Content (EMC) determines whether a product would gain or loose moisture under a given set of temperature and relative humidity conditions. The values for the Equilibrium Moisture Content (EMC) of biological products depend mainly on the temperature and relative humidity of the air and the species and/or var. of the product. The physiological maturity and the history of the product, as well as, the way equilibrium obtained, also affect the equilibrium moisture (Sahay and Singh, 2001). So, equilibrium relative humidity and equilibrium moisture content to temperature are necessary conditions for designing post harvest processing and storage system of oilseeds (Santalla and Mascheroni, 2003).

Several investigators have been used to fit EMC/ERH data for predicting Equilibrium Moisture Content (EMC) of biological materials using modified Henderson, modified Chung Pfost, modified Halsey, modified Oswin and Guggenheim-Anderson-de Boer (GAB) models (Basunia and Abe, 2005; Jha and Singh, 2006). Modified Halsey and Oswin models were also studied as the EMC/ERH isotherm equations for rapeseed (Correa *et al*., 1999). Vishwakarma *et al*. (2007) determined the sorption isotherms of Pigeonpea grain and dhal at various temperature and relative humidities. They predicted the modified Chung-Pfost equation was most suitable model for grain and modified Henderson equation for dhal for representation the of the EMC data up to 80% ERH. Swami *et al*. (2005) studied the moisture sorption isotherm of black gram nuggets at different temperature and relative humidity conditions and fitted to GAB model. Kumar *et al*. (2010) also reported that, drying of totia seeds from 30 to 70°C and found up to 55°C drying temperature has best for Toria seeds and found maximum germination percentage and it deceased drastically when dried above 55 to 70°C. So, this study is useful for drying and storage of toria seeds as well as oil seeds. The objectives of this study has determined the experimental equilibrium data of rapeseed (*Brassica campestris* var. toria), var. viz. TL-15; TH-68 and Sangam at 30, 50 and 70°C and found the suitable model predicting the isotherms.

MATERIALS AND METHODS

Freshly harvested Toria Seeds (*Brassica campestris* var. toria) viz., TL-15, TH-68 and Sangam var. were procured dated 20.08.2004 from Oilseed Section, Department of Plant Breeding, CCS Haryana Agricultural University, Hisar (India) and completed study in the year of 2004-05. The seeds were cleaned manually and broken, foreign matter, split and deformed seeds were discarded before the samples were prepared for the experiment.

The initial moisture contents (replicated thrice) were determined using standard hot air oven method at 100±3°C until the constant weight was achieved (AOAC, 1970; ASAE, 1991). Initially the seeds were stored at room temperature (25°C) for 1 to 2 weeks (Correa *et al*., 1999).

Different saturated salt solutions (AR grade) of LiCl, $MgCl_2.6H_2O$, NaBr, NaCl and KNO_3 (AOAC, 1970) were prepared to obtain constant relative humidity environment. A set of five controlled humidity environment desiccators were used to obtain the desired relative humidities in the range of 11 to 90.70%. Table 1 lists the five salts used and characteristics relative humidities

Table 1: Relative humidities above salt solutions

Sr. No.	Temperature (°C)	Relative humidity (%)	Name of the salt
1	30	11.8	LiCl (Lithium chloride)
	30	32.8	$MgCl_2$. $6H_2O$ (Magnesium chloride)
	30	56.3	NaBr (Sodium bromide)
	30	75.6	NaCl (Sodium chloride)
	30	90.7	KNo_3 (Potassium nitrate)
2	50	11.4	LiCl (Lithium chloride)
	50	31.4	$MgCl_2$. $6H_2O$ (Magnesium chloride)
	50	51.1	NaBr (Sodium bromide)
	50	74.7	NaCl (Sodium chloride)
	50	85.0	KNo_3 (Potassium nitrate)
3	70	11.0	LiCl (Lithium chloride)
	70	26.7	$MgCl_2$. $6H_2O$ (Magnesium chloride)
	70	47.5	NaBr (Sodium bromide)
	70	73.3	NaCl (Sodium chloride)
	70	79.1	KNo_3 (Potassium nitrate)

produced above the solutions at the specified temperatures. Values of relative humidities given in Table 1 were determined from data given by Perry and Chilton (1973) and Rockland (1960). A total of three such sets were prepared and each set of five desiccators was kept in three different temperature controlled chambers 30, 50 and 70°C. Ten gram samples (replicated thrice) of freshly harvested Toria Seeds of each var. viz, TL-15; TH-68 and Sangam with initial moisture contents of 19.05±0.11, 17.65±0.33 and 16.30±0.22% (d.b.), respectively were kept in container made from wire mesh in 15 different desiccators maintaining five different relative humidities. The samples kept in the desiccators were then placed in three different controlled temperature chambers (Wink, 1946; Henderson, 1952).

Toria seeds having high moisture content and which were exposed to higher relative humidities, so thirum was mixed with seeds and treated in order to avoid fungus growth. Samples were equilibrated for approximately 21 days and the samples were weighed (±0.001 g) at intervals of 24 h till constant weight was achieved. The Equilibrium Moisture Content (EMC) was computed using standard techniques.

ASAE Standards (1997) Standards (ASABE, D245.5) provides isotherm equations and equation constants for the moisture relationship of agricultural products. Therefore, the following EMC/ERH equations were chosen for the current study.

- Modified Henderson Equation (MHEE):

$$1\text{-}R_H = \exp\text{-}[A\ (T+C)\ M_e^{-B}] \tag{1}$$

- Modified Chung Pfost Equation (MCPE):

$$R_H = \exp-\left[\frac{A}{T+C}\left(\exp\frac{B\times M_e}{100}\right)\right] \tag{2}$$

- Modified Halsey equation (MHAE):

$$R_H = \exp\text{-}[\exp\ (A+B\times T)\ M_e^{-B}] \tag{3}$$

- Modified Oswin Equation (MOSE):

$$R_H = \frac{1}{\left[\frac{A+B\times T}{M_e}\right]^c + 1} \tag{4}$$

where, from Eq. 1-4, R_H is the relative humidity in decimal, A, B and C are the model constant and M_e is the equilibrium moisture contents (%) (d.b.).

Statistical analysis: In order to select the most appropriate equation, the statistical package, SPSS (2004) (version, 13.0) and MS-Excel 2003 were used to fit the equations of the EMC/ERH for combined experimental data of rapeseed (Toria) and decided the best fitting equation on the basis of coefficient of determination (R^2).

RESULTS AND DISCUSSION

The experimental values of Equilibrium Moisture Content (EMC) at different temperatures and relative humidities of TL-15, TH-68 and Sangam were varied from 2.19 to 17.20, 3.61 to 18.58 and 4.20 to 19.90% (d.b.), respectively at 30 to 70°C temperature and 11 to 90.7% relative humidity (Table 2). The Effect of temperature and relative humidity on equilibrium moisture content was also examined (Table 2) using Analysis of Variance (ANOVA). Statistical analysis revealed that temperature had significant effect on equilibrium moisture content of Toria Seeds for all the selected var. at all relative humidities at 5% level of significance and the Critical Difference (CD) range of 1.62 to 6.57 (Table 2). The effect of relative humidity on equilibrium moisture content was also found significant of the same CD range (Table 2). But the varietal difference on equilibrium moisture content had non-significant (Table 2). The coefficient of determination values were determined using nonlinear regression analysis and varied from 0.9840, 0.9897 and 0.9865, 0.9840, 0.9774 and 0.9767, 0.9499, 0.9549 and 0.9529, 0.9368, 0.9605 and 0.9605, respectively for modified Henderson, Chung-Pfost, Halsey and Oswin equations of TL-15, TH-68 and Sangam varieties of toria (Table 3). The constants of modified Henderson equation was $A = 1.96\times10^{-4}$, B = 1.8260 and C = 21.4079 for TL-15, $A = 1.70\times10^{-5}$, B = 2.6298 and C = 23.8930 for TH-68 and $A = 2.90\times10^{-5}$, B = 2.5098 and C = 9.5608 for Sangam (Table 4). The shape of the isotherm curves for seeds held at different storage temperature is important since it describes the EMC-RH

Table 2: Effect of temperature (T) and equilibrium relative humidity (H) on equilibrium moisture content (EMC%, db) of selected var. of rapeseed (Toria)

	Equilibrium relative humidity (%)				
Temperature	11.1	33.3	51.63	74.53	90.70
30°C					
TL-15	3.95	7.98	11.23	15.25	17.20
TH-68	5.90	10.40	13.25	16.75	18.58
Sangam	5.16	10.80	13.10	17.20	19.90
50°C					
TL-1'	2.80	6.40	8.60	13.20	14.80
TH-68	4.60	8.88	11.00	14.50	15.58
Sangam	4.80	9.20	11.72	14.38	16.90
70°C					
TL-15	2.19	4.82	7.20	9.42	12.61
TH-68	3.61	7.76	9.82	12.80	13.60
Sangam	4.20	7.08	9.24	12.08	13.10

CD @ 5% T: 2.62, 1.90 and 1.62. H: 3.38, 2.45 and 2.09. T×H: 4.57, 5.27 and 6.57

Table 3: R^2 values of selected equilibrium moisture content equations for rapeseed (Toria)

Variety	Temperature (°C)	Modified Henderson Eq.	Modified Chung Pfost Eq.	Modified Halsey Eq.	Modified Oswin Eq.
TL-15	30-70	0.9840	0.9840	0.9499	0.9368
TH-68	30-70	0.9897	0.9774	0.9549	0.9605
Sangam	30-70	0.9865	0.9767	0.9529	0.9605

Table 4: Values of modified henderson equation constants A, B and C of selected var. of rapeseed (Toria)

Variety	A	B	C
TL-15	1.96×10^{-4}	1.8260	21.4079
TH-68	1.70×10^{-5}	2.6298	23.8930
Sangam	2.90×10^{-5}	2.5098	9.5608

relationship during storage (Li *et al.*, 2011). Similar results were reported by Menkov and Durakova (2005) for pumpkin seed flour; Jha and Singh (2006) for rice; Vishwakarma *et al.* (2007) for dhal; Santalla and Mascheroni (2003) for sunflower seeds and kernels. The sorption isotherms have a typical S-shaped profile. The sigmoidal shape of curve was observed for most of the biological products, Chung and Pfost (1967) for cereal grains and their products; Pixton and Warburton (1971) for oilseeds; Sun and Byrne (1998) for rapeseed and Osborn *et al.* (1989) for soybean seeds; Giner and Gely (2005) for sunflower seeds and Vishwakarma *et al.* (2007) for pigeonpea. For TL-15, TH-68 and Sangam var. of toria seed, modified Henderson equation based on coefficient of determination value represent the experimental data best fitted over the entire experimental range of temperatures and relative humidities.

CONCLUSIONS

Equilibrium moisture content of selected verities of rapeseed (Toria) was performed at different relative humidities and temperatures. The non linear regression analysis indicates that out of four selected empirical models, the modified Henderson equation was identified as the most appropriate equation for describing the variation of the hygroscopic equilibrium moisture content for selected var. of rapeseed. Present study will help in the determination of suitable drying process, level of drying and storage design.

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