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ORIGINAL ARTICLE

Drying behaviour of rapeseed under thin layer conditions

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Abstract Thin layer drying behaviour of rapeseed (*toria*, *Brassica campestris*) varieties like 'TL-15', 'TH-68' and 'Sangam' in the temperature range of 30 to 70°C and at constant air velocity of 2 m/sec was studied. The validity of modified Page's equation for prediction of drying time was assessed by fitting the experimental drying data. The drying air temperature affected drying time significantly. The effect of variety on drying time was not significant. Drying constants of modified Page's model were calculated for each variety and at each drying temperature. Germination percentage and seed vigour index were not affected significantly when dried up to 55°C and reduced drastically to 16 to 20% when dried above 55°C.

Keywords Thin layer drying · *Brassica campestris* · Rapeseed · Drying model

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Introduction

Rapeseed (*Brassica campestris*) is the major rabi oil seed crop in India. The production of rapeseed and mustard in India has been rapidly increasing over the years (Anon 2005). 'TL-15' early; 'TH-68' medium and 'Sangam' late matured are some of the important varieties of rapeseed sown in September and October and harvested in November and December. Seeds are either yellow or brown in colour with a smooth seed coat. The oil content and average yield vary from 40 to 45% and 12 to 15 quintals/ha, respectively (Singh and Rai 1976).

Toria seed contains high moisture content (16–20% wb) at the time of harvest and immediate drying is required after harvest (Crisp and Wood 1999) for safe storage. Sun drying, the most common method used by farmers is not feasible as it is weather dependent, non-uniform and uncontrolled. The weather conditions are also not favorable for sun drying in the month of November and December due to foggy weather in Northern part of India. The germination of toria seed reduces due to fungus formation on moist seed during storage. Little information is available on the drying characteristics of rapeseed (toria) and the effects of drying air temperature on quality of toria seed. The drying process of any biological product can be predicted by empirical, theoretical or semi-theoretical equations (Misra and Brooker 1980, Singh 1994, Correa et al. 1999). Several investigators (Simmonds et al. 1953, Hustrulid and Flinkcl 1959, Allen 1960, Henderson and Pabis 1961, Pathak et al. 1991) have fitted modified Page's model successfully to predict drying behaviour of different biological materials. Woodland and Lawton (1965) observed that drying air temperature and relative humidity significantly affected the germination and vigour of toria. They found that drying air temperature of 60°C or less caused no reduction in germination of rapeseed having 20% moisture content. The present investigation was carried out with the objective to study the drying behaviour of different varieties of toria seed under thin layer conditions. The adequacy of modified Page's model to predict the drying behaviour without affecting the germination and vigour of toria seeds was tested.

Materials and methods

Freshly harvested toria seed (*Brassica campestris* var. *toria*) varieties, 'TL-15', 'TH-68' and 'Sangam' were procured from Department of Plant Breeding, CCS Haryana Agricultural University, Hisar. Equilibrium moisture content of the selected varieties of toria seed was calculated using the modified Henderson equation. The constants of this equation were determined experimentally using static method. Drying behaviour at 30, 40, 55 and 70°C and at constant air velocity of 2 m/sec was studied and laboratory set up thin layer dryer (up to 15 cm depth) was used.

Initial moisture content of all the varieties was determined as per AOAC (1970) and ASAE (1991). The samples were dried to safe storage moisture content of 8–9% (ISTA 1985). The moisture content of the samples during drying was computed using mass balance equation.

The validity of modified Page's equation (1) was tested for predicting the drying rates of all varieties of toria seed.

$$MR = [(M(t) - Me)/ (Mo - Me)] = \exp(-K\, t^{n}) \quad (1)$$

where, MR = moisture ratio, dimensionless; M(t) = moisture content, % at time, t (db); Mo = initial moisture content, % (db); Me = equilibrium moisture content, % (db); t = drying time (min); and K, n = equation constants.

The germination of the dried seeds was determined using standard top of paper method (ISTA 1985) and vigour index was calculated as per method described by Abdul Baki and Anderson (1973).

Least square regression analysis was performed using statistical package for Social Sciences (SPSS 2004) to evaluate the constants 'K' and 'n' for each experimental run. The statistical analysis was also done to see the effect of drying air temperature on germination and vigour index of each variety of toria seed.

Results and discussion

All the 3 varieties took 16 to 190 min for drying when dried at 30–70°C (Fig. 1). Drying curves of 3 varieties of *toria* seeds fully exposed to the air stream at different drying air temperatures were obtained by plotting moisture content *versus* time duration. Prediction of drying rate of biological material is more complicated during falling rate period. A modified drying equation described by Page was fitted to predict the drying rate of seeds.

The observed and predicted moisture ratio curves were obtained by plotting MR *versus* drying duration (Fig. 1). The modified Page's model represents the data closely, R^2 ranging from 0.981 to 0.999 (Table 1). Effect of drying air temperature on drying time was significant ($p \leq 0.01$) and

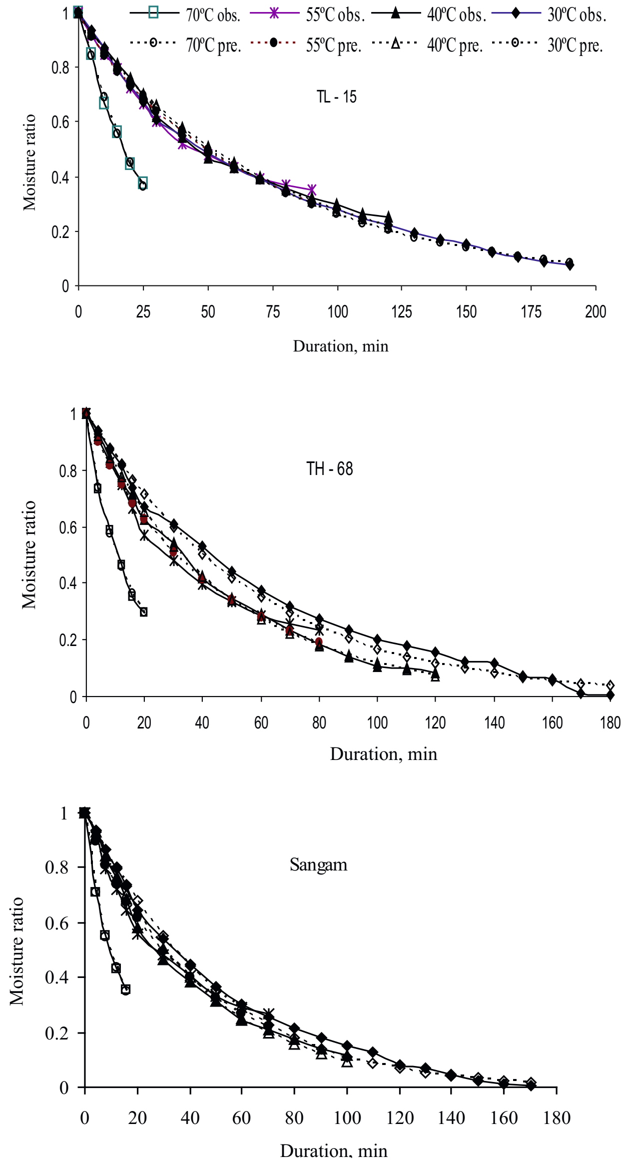

Fig. 1 Variation of moisture ratio with temperature of *toria* variety seeds, obs: observed, pre: predicted

the effect of variety on drying time was not significant. The effect of variety on constants 'K' and 'n' was not significant at 1% level.

A systematic trend in the variation of modified Page's model constants 'K' and 'n' with drying air temperature for all 3 varieties of toria seed was observed. The following equations to predict the value of 'K' and 'n' at different drying air temperature (T) for 3 varieties were developed by regression analysis.

'TL-15'

$K = 1.57 \times 10^{-3} (T)^{0.67014} \qquad R^2 = 0.884$

$n = 1.5572 - 0.02888 (T) + 3.14 \times 10^{-4} (T)^2 \qquad R^2 = 0.855$

'TH-68'

$K = 1.53 \times 10^{-5} (T)^{1.9779} \qquad R^2 = 0.859$

$n = 1.1134 - 1.41 \times 10^{-3} (T) - 3.19 \times 10^{-5}(T)^2 \qquad R^2 = 0.919$

Table 1 Constants of modified Page's model of selected varieties of *toria* seeds at different drying temperatures

Temp, °C	'K' min^{-1}	'n'	R^2
'TL-15'			
30	0.01705	0.9485	0.996
40	0.01703	0.9394	0.993
55	0.02168	0.8909	0.991
70	0.03001	1.0955	0.994
'TH-68'			
30	0.01537	1.03065	0.981
40	0.02051	1.01079	0.996
55	0.02975	0.91815	0.988
70	0.09179	0.86446	0.996
'Sangam'			
30	0.01500	1.08279	0.989
40	0.02037	1.03126	0.992
55	0.03243	0.90427	0.981
70	0.11455	0.79810	0.999

Table 2 Germination (%) and seedling vigour index of selected varieties (V) of toria seeds at different drying temperatures (T)

Temp, °C	Germination, %			Seedling vigour index		
	'TL-15'	'TH-68'	'Sangam'	'TL-15'	'TH-68'	'Sangam'
30	97	97	95	2158	2175	2113
40	92	94	91	2011	2031	1961
55	90	88	87	1809	1689	1687
70	20	16	18	376	282	310
Control	96 (average of each variety)			2160 (average of each variety)		
CD @ 1%	T	8.102		324.996		
	V	N. S.		N. S.		
	T × V	5.832		N. S.		

'Sangam'

$K = 5.46 \times 10^{-6} (T)^{2.2643}$ $R^2 = 0.862$

$n = 1.2039 - 1.92 \times 10^{-3} (T) - 5.69 \times 10^{-5}(T)^2$ $R^2 = 0.955$

The following regression equation (2) was predicted using the lumped data of all drying runs and R^2 value of 0.855.

$$MR = \exp(-0.03434 \times t^{0.8508}) \quad (2)$$

Germination and seedling vigour index varied from 18 to 97% and 282 to 2175, respectively for all the 3 varieties and were highly influenced ($p \leq 0.01$) by drying air temperature but the variety has no significant effect on germination and vigour index (Table 2). Drying at 30°C air temperature and at constant air velocity of 2 m/sec proved best for all varieties.

It is evident that the germination and seedling vigour index of the selected varieties of toria seeds were not affected significantly when they were dried up to 55°C. Only 16 to 20% germination was observed at 70°C drying air temperature. Germination of 95 to 97% and seedling vigour index of 2113 to 2175 were observed while drying at 30°C for all the selected varieties whereas the germination and seedling vigour index of control seeds were 96% and 2160, respectively (Table 2).

The germination and seedling vigour index were not affected significantly when dried up to 55°C. Drying at 30°C and air velocity of 2 m/sec yielded maximum germination for each variety.

Conclusions

Modified Page's equation with individual model constants for each variety and drying air temperature predicted the drying behaviour accurately with in the experimental range (30 to 70°C). The effect of drying air temperature on drying time was significant and the effect of variety was not significant. The model constants 'K' and 'n' varied significantly with temperature and the effect of varieties on model constants was not significant. The drying time of all the varieties can be approximately determined by using following equation:

$$MR = \{-0.03434 (t)^{0.8508}\}$$

where, MR = moisture ratio and t = drying time in min

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