DRYING RATES ESTIMATION FOR DIFFERENT SUNFLOWER SEED VARIETIES GROWN IN ARGENTINA

M. C. GELY and E. M. SANTALLA

Departamento de Ingeniería Química. Facultad de Ingeniería UNCPBA
Av. Del Valle 5737. (7400) Olavarría. Argentina
FAX 54 2284 450628. E-mail: cgely@fio.unicen.edu.ar

Abstract

Morphological characteristics and drying time of confectionery type, high oleic and traditional sunflower (Helianthus annuus L.) seeds were studied. Density values between 586-802 kg/m^3, unit mass in a range of 0.033-0.055 g, sphericity from 0.47 to 0.59 and a hull/kernel relation between 0.26-0.53 were obtained from the different genotypes. The time required to reach an adimensional moisture value of 0.5 presented a positive linear correlation with the oil content (r^2=0.86). The diffusion coefficient value ranged between 1.304-2.35 mm^2/hr with a standard deviation of 0.384 for both the traditional and high oleic varieties. Confectionery sunflower seed type presented the highest value (8.01 mm^2/hr). This coefficient was correlated according a positive potential correlation tendency with the equivalent diameter (r^2= 0.98) whereas a negative potential correlation tendency with true density (r^2=0.96) was detected. High oleic sunflower varieties showed no significative differences in the drying kinetic compared to traditional sunflowers. Greater size and lower both weight and oil content of sunflower seeds are factors that increase the moisture transfer rate.

Keywords: *oilseeds, drying, sunflower*

1. INTRODUCTION

Drying process constitutes a fundamental operation highly important in argentine post-harvest chain, as about 60% of oilseeds production (Hajnal, 1999). The energy consumed for drying process represents about 60% of the whole post-harvest production chain (Giner, 1994), thus an increase in this process efficiency may cause important economic profits.

During the last decades there has been a remarkable development of sunflower varieties with a high oleic acid content. Oil from these genotypes contains over 70% of the mentioned fatty acid (Aguirrezábal y Andrade, 1998). This "invertion" in the oil fatty acid composition results into an oil with an excellent nutritional quality, a superior culinary aptitude and a wider industrial utilization since it can be used in the lubricant or detergent manufacturing (de la Taille, 1995).

The drying kinetic is affected by the grain structure, morphology and chemical composition as well as by the air conditions; thus disposable information about the different varieties and genotypes for industrial use is required.

The thin layer drying process is an essential stage in the drying kinetic analysis. Air with constant moisture content, temperature and mass flow passes through a thin layer of wet material. At several intervals of time the material behaviour is observed analysing the loss of moisture content. Later, the data are adjusted to known theoretical expressions (Parry, 1985; Jayas et al., 1991).

In this work, thin layer drying rates for seven traditional sunflower hybrids (widely grown in Argentina due to its genetic characteristics and oil yield), two high oleic hybrids and one confectionery type were experimentally determined. Parameter adjusted to the thin layer equations were analysed and the times required to get the half value of adimensional moisture content were compared in order to associate this parameter with the physical and chemical characteristics and the diffusivity coefficient of each oilseed.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

Thin layer experiments were carried out using an experimental apparatus described in previous works (Gely and Santalla, 1999). The air conditions used for the present work were: dry bulb temperature 75 _ 1°C, relative humidity 35-42%, relative humidity within the drying chamber below 10%, average air speed 0.2925 m/s (Henderson and Pabis, 1962; Hutchinson and Otten, 1983). For the drying rates determinations, fresh sub-samples of 200 grams were conditioned to an average moisture content between 20-27% (dry basis) which were stored in a freezer. Moisture contents were determined by the air-oven procedure described in ASAE Standard S352.1.

Seed sub-samples of 30 grams were placed on the drying-tray and weighed periodically. Each test was concluded when the sample weight remained constant (variations less than 0.1 grs during an over 40 minute intervals) considering that the sample get the equilibrium moisture content (M_e) according to the experimental conditions (Syarief 1984).

3. MATERIALS AND METHODS

Morphological characteristics and drying rates of the following consumption type seeds were evaluated: confectionery type (434 Palaversich), high oleic hybrids (Aromo-Nidera and Trisum 568-Mycoyen), traditional hybrids: Contiflor 9 and Orion (Zéneca), Dekasol 3881 and 4100 (Dekalb), Zenit (Sursem), Rancul (Novartis) and Aca 884 (Qeaca) all from 97/98 harvest.

The seeds were handled, cleaned and stored in a refrigerator until being used. The following properties were determined on original samples at initial moisture content (M_0): characteristic dimensions (length, width, thickness), equivalent diameter (D_{eq}), sphericity, real density (_$_G$), bulk density (_$_B$) and porosity (_) according to Gupta and Das (1997). The hull (pericarp and tegument) and kernel (botanically 'seed', constituted of endosperm and embryo, Merrien, 1998) of three sub-samples were manually separated determining the hull/kernel (H/K) weight relation as the triplicates average.

Oil seed content and oleic acid percentage were determined according American Oil Chemists's Society (Ai 3-75 and Ce 2-66 respectively, 1997) as described in Gely and Santalla, 1999.

4. RESULTS

4.1. Physical and Chemical Properties

Properties evaluated are presented in Table 1. No significant differences were detected in relation to size and density between high oleic and traditional varieties except a greater H/K relation (T568) for the former and high grain density (Aca 884) between the latter. Sphericity varied between 0.47-0.59. Oleic acid percentage resulted superior to comercialization base (USDA) in both hybrids and for the traditional ones it was at the rank of 18-24%. Little variability was detected in oil seed content between the traditionals and high oleic genotypes (standard deviation=3.03% at the rank of 43.60-51.02). The lowest oil content was presented by the confectionery variety. This grain, of lower real density, greater hull/kernel relation and greater porosity, presented in its structure a great part of its weight occupied by the hull and the tegument that surrounds the endosperm. It has been noted that in general, greater oil seed content corresponds with lower both H/K relation and real density values.

Table I. Physical and Chemical Properties of oilseeds evaluated at initial moisture

Grain	M_0 [% d.b.]	H/K [w/w]	_ real [kg/m^3]	_	D_{eq} [mm]	Oleic acid [%]	Oil [%]
Contiflor 9	9.74	0.316	749.7	48.32	5.562	18.54	51.02
Dekasol 3881	7.83	0.35	697.6	38.92	6.351	24.40	49.44
Dekasol 4100	8.24	0.32	693.1	37.85	6.000	21.50	49.31
Orion	8.05	0.255	798.6	36.20	5.295	23.40	51.77
Zenit	8.17	0.335	777.2	44.58	5.882	16.14	46.76
Rancul	9.52	0.333	772.4	35.92	6.159	18.38	52.53
Aca 884	8.27	0.456	802.4	35.78	5.768	22.00	47.45
Aromo	9.02	0.385	744.4	40.46	5.411	79.33	45.22
Trisum 568	9.76	0.531	661.8	38.12	5.392	80.25	43.60
434	11.26	0.819	586.7	52.25	8.433	-------	33.02

4.2 Thin Layer Drying Models

Lewis and Page (Parti 1993) semiempirical equations were used to study moisture loss rate. Lewis equation (Ecn 1) is a particular case of the second diffusion Fick's law (Nellist and Bruce, 1995):

$$M_{ad} = \frac{M - M_e}{M_0 - M_e} = \exp(-k.t) \qquad (1)$$

where k is an empiric coefficient, t is the drying time (seconds), M moisture content (decimal, dry base), M_{ad} adimensional moisture, M_0 moisture content initial (decimal, dry base) and M_e equilibrium moisture content (decimal, dry base). Adjustments results are presented in Table II.

Table II. Constants of adjustments of Page and Lewis equations.

Genotype	k_{Lewis}	r^2_{Lewis}	k_{Page}	n_{Page}	r^2_{Page}
Contiflor 9	0.00119	0.9739	0.0134	0.6359	0.995
Dekasol 3881	0.00113	0.9900	0.0065	0.7453	0.999
Dekasol 4100	0.00114	0.9786	0.0132	0.6440	0.999
Orion	0.00092	0.9915	0.0050	0.7629	0.999
Zenit	0.00113	0.9849	0.0095	0.6927	0.999
Rancul	0.00103	0.9798	0.0111	0.6602	0.999
Aca884	0.00086	0.9906	0.0049	0.7552	0.999
434	0.00203	0.9801	0.0229	0.6271	0.999
Aromo	0.00128	0.9864	0.0098	0.7032	0.999
Trisum 568	0.00138	0.9852	0.0117	0.6851	0.999

Later experimental data were adjusted to Page Equation (Ecn. 2) which is an empirical modification to Lewis equation (Parti, 1993) that involves and additional empirical coefficient (n) to try to make up for the defects of the previous expression.

$$M_{ad} = \exp(-k.t^n) \quad (2)$$

This equation has been broadly used to characterize thin layer drying models for oilseeds (Jayas et al., 1991). The results obtained are presented in Table II showing a more precise fitting for all studied varieties, even though to those that presented significant differences in their morphological and chemical characteristics.

The necessary time to reduce to its half the adimentional moisture ($t_{1/2}$) was evaluated from Page equation so as to compare drying rates (Giner et al., 1994). Fig. 1 shows variation of half times obtained at 75°C. 434 variety, which presents the lowest oil content and true density values showed the lowest half time value. High oleic hybrids showed lower half time values respect traditional ones which varied between 7.8 –11.6 minutes.

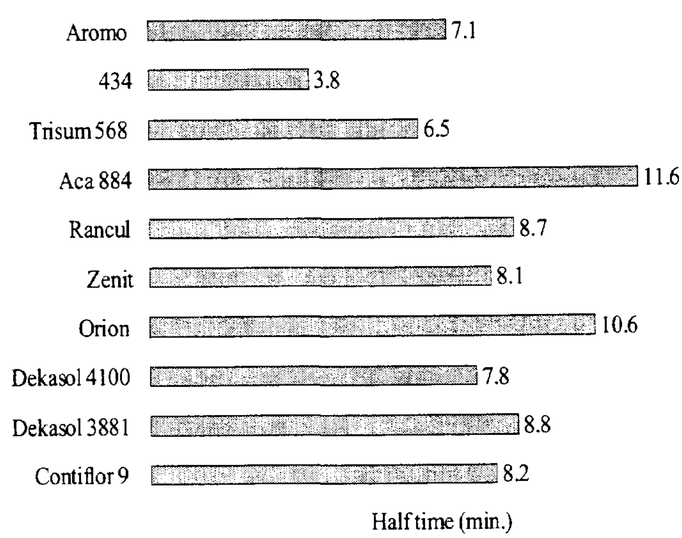

Fig. 1: Drying time to get a 0.5 value for adimensional moisture content (M_{ad}) for sunflower seeds evaluated.

Oil/starch proportion in an oilseed affects moisture transfer from the middle of the grain to its surface because fatty matter, due to its hydrophobic characteristics, makes moisture migrate through oil free matter. This mechanism makes that grain isotherms with a greater oil content are in equilibrium with air conditions at lower moisture levels than grains with less fatty matter content. This is why grain isotherms with high oil content are below to those with high oil content (Brooker et al., 1992). Influence of oil content over half times was studied. Figure 2 shows a positive lineal relationship between these parameters with a correlation coefficient of 0.8653. Aca 884 genotype is not included in this correlation, as it has a high grain density value and it does not show higher oil seed content as it is seen in Orion (798 kg/m^3 , 52% oil) but it delays moisture transfer. Morphological characteristics of hull (greater thickness or thicker tegument) should be a responsible factor in the relative increase in half time response detected in this genotype.

Drying theoretical equation defined for spheres of R radium (Rovedo *et al.*,1993) was used to adjust drying curves and to evaluate the diffusion coefficient a 75 °C:

$$M_{ad} = \frac{M - Me}{Mo - Me} = \frac{6}{\pi^2} \sum_{n=1}^{n=\infty} \frac{1}{n^2} \exp[-n^2 \pi^2 \frac{D.t}{R^2}] \quad (3)$$

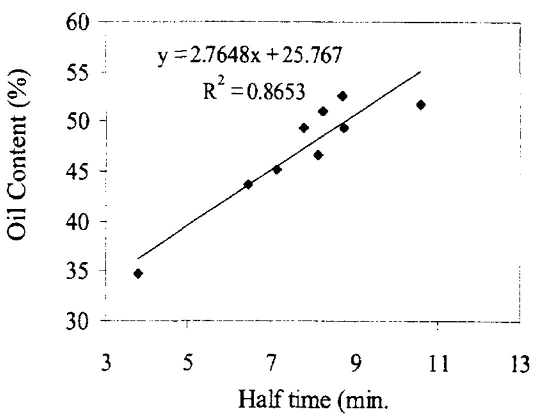

Fig. 2. Oil Content and half time relatioship for oilseeds studied.

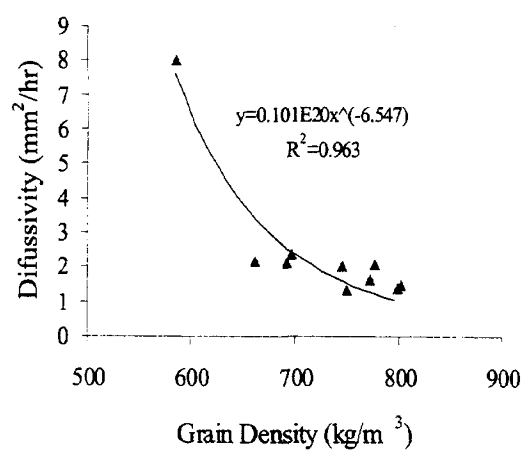

Fig. 3. Difussivity of water in grain according true density of grains.

Genotype 434 presented a diffusion coefficient of 8.010 mm^2/hr and it was the maximun value found for all the varieties. The rest of sunflower seeds (traditional and high oleic) were at the rank of 1.304-2.35 mm^2/hr with a standard deviation value of 0.384. The diffusion coefficients (D) obtained were correlated with the equivalent diameter (Deq.) of grain, and a positive potential functionality ($D = 1.86E\text{-}3.Deq^{3.92}$, $r^2 = 0.98$) was found. This relationship is of the same form that obtained by Gely et al, 1999 when adjusted these parameters from different oilseeds. As regards the relation between diffusion coefficient and true density of grain, a negative potential correlation tendency was obtained (Fig. 3). The diffusion coefficient shows a fast variation for grain densities between 600 and 700 kg/m^3 which afterwards keeps itself in relatively low values (2.5-1.5 mm^2/hr) for grain densities superior to 700 kg/m^3, independently of oil seed content. This would be showing that fatty matter proportion is not a decisive factor in moisture transfer delay from the inner part of the grain but true grain mass/volume relation should be also a factor that influence on this behavior. Genotypes of high H/K relation together low grain density or seeds that present an important air chamber in its structure between the endosperm and the pericarp (as it happens with 434 sample) showed greatest moisture transfer rate.

5. CONCLUSIONS

Oil seed percentage was positively correlated with half time value according true density of grains for a range of oil content between 33 and 52%.

Diffusivity was positively correlated with the equivalent diameter and negatively with true density independently of the fatty matter. This response should be showing that greater size and low weight (high hull/kernel relation) of sunflower seeds help moisture transfer to the external part of the grain.

High oleic sunflower varieties showed no significative differences in the drying kinetic compared to traditional sunflowers.

The confectionery sunflower presented morphological characteristics quite different from the rest of the sunflower varieties. Lower drying times and higher diffusivity coefficients were detected for this variety.

REFERENCES

Aguirrezábal L.A.N., and F.H.Andrade, 1998, *Calidad de Productos Agrícolas, Bases Ecofisiológicas, genéticas y de manejo agronómico,* Unidad Integrada Balcarce, 315 p..

Brooker D.B., F.W. Bakker-Arkema and C.W. Hall, 1992, *Drying and Storage of grains and Oilseeds*, Ed. AVI Book, 450 p .

De la Taille, G., 1995, "Produire du tournesol oléique, à quelles fins? " *Oleoscope*, **30**, 12-14.

Gely M.C. and Santalla E., "Comparación de Modelos de secado en Capa Delgada para Oleaginosos Tradicionales y no Tradicionales", Enpromer'99,II Congreso de Ingeniería de Procesos del Mercosur, 30 de Agosto al 2 de Septiemgre de 1999, pág. 395-396

Giner S.A., 1994, "Temas de post-cosecha de granos oleaginosos: Parte I". *A&G*,**17**, 71-83 .

Giner S.A., Borrás, J.L. and Añón M.C.,1994, "Drying Rates of 25 Varieties of Soybean: A Comparative Study",*Lebensm.-Wiss.u.-Technol.*,**27**,308-313.

Gupta R.K. and S.K.Das, 1997, "Physical Properties of Sunflower Seeds", *J. agric. Engng. Res.*, **66**,1-8 .

Hajnal R.D., 1999, "Grain Handling in Argentina", *World Grain*, 26-33.

Henderson, S.M. and Pabis S., 1962, Grain drying theory IV, The effect of airflow rate on the drying index, *J. agric. Engng Res.*,7 pp. 85-89.

Hutchinson, D. and Otten L.,1983, Thin-layer air drying of soybeans and white beans, *J. of Food Technology*, **18**, 507-522.

Jayas D.S., S. Cenkowski, S. Pabis and W.E. Muir, 1991,"Review of Thin-Layer Drying and Wetting Equations", *Drying Technology*, **9** (3), 551-558 .

Merrien A. , 1998"Conociendo el Girasol", *A&G*, **30**, 76-80.

Nellist m.E. and Bruce D.M., 1995, Heated-Air Grain Drying, in: Stored-Grain Ecosystems, edited by Jayas D.S., White N.D.G. and Muir W.E..

Official Methods and Recommended Practices of the AOCS, 5th edn., Chem's Soc., Champaign, Illinois (1997)

Parry J.L.,1985, "Mathematical Modelling and Computer Simulation of Heat and Mass Transfer in Agricultural Grain: a Review", *J. agric. Engng. Res.*, **32**, 1-29.

Parti M., 1993, "Selection of Mathematical Models for Drying Grain in Thin –Layers", *J. agric. Engng Res.*, **54**, 339-352.

Rovedo C.A., R.J.Aguerre and C. Suárez, 1993, "Moisture diffusivities of sunflower seed components", *International Journal of Food Science and Technology*, **28**, 159-168.

Syarief A.M., R.V. Morey and R.J. Gustafson, 1984, "Thin-Layer Drying Rates of Sunflower Seeds", *Trans. of the ASAE*, 195-200 .