

Drying process: effects of temperature on the oil of different sunflower genotypes

Proceso de secado: efecto de la temperatura en la calidad del aceite de girasol

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ABSTRACT

Drying is a critical stage in postharvest grain processing and alters its structural and physiological characteristics, affecting the quality of the final product. This study aimed to assess the effect of drying sunflower achenes on oil content. A randomized block design was used, in a 5 x 4 factorial scheme consisting of four drying treatments (35, 40, 50 and 70 °C) in a forced-air dryer and one under uncontrolled conditions (drying terrace), with four repetitions. Oil content and acid value were analyzed in oil extracted from the achenes of 13 sunflower genotypes grown under the same conditions, whose moisture content declined from 30 to 8 % (dry basic) under different drying temperatures. Data were analyzed using the Scott-Knott test ($p < 0.05$). Drying under controlled conditions at high temperatures (50 and 70 °C) reduced the achene oil content for all the genotypes assessed, with an acid value close to (50 °C) or above (70 °C) the maximum legal limit. Uncontrolled drying and controlled low temperatures (35 and 40 °C) showed no significant variations in oil content or acid value.

Key words: Heat stress, *Helianthus annuus* L., postharvest, quality, yield.

RESUMEN

El secado es una etapa crítica en el procesamiento pos cosecha de granos y altera sus características estructurales y fisiológicas, afectando la calidad del producto final. Este estudio tuvo como objetivo evaluar el efecto del secado de los achenes de girasol sobre el contenido de aceite. Se utilizó un diseño de bloques aleatorio, en un esquema factorial de 5 x 4 que consta de cuatro tratamientos de secado (35, 40, 50 y 70 °C) en un secador de aire forzado y uno en condiciones no controladas (terrazza de secado), con cuatro repeticiones. El contenido de aceite y acidez se analizó en aceite extraído de los achenes de 13 genotipos de girasol cultivados en las mismas condiciones, cuyo contenido de humedad disminuyó del 30 al 8% (base seca) bajo diferentes temperaturas de secado. Los datos se analizaron utilizando la prueba de Scott-Knott ($p < 0,05$). El secado bajo condiciones controladas a altas temperaturas (50 y 70 °C) redujo el contenido de aceite de achenes para todos los genotipos evaluados, con un valor de acidez cercano (50 °C) o superior (70 °C) al límite legal máximo. El secado no controlado y las bajas temperaturas controladas (35 y 40 °C) no mostraron variaciones significativas en el contenido de aceite o el índice de acidez.

Palabras clave: estrés térmico, *Helianthus annuus* L., pos cosecha, calidad, rendimiento.

Introduction

Sunflower (*Helianthus annuus* L), a high-quality oil (Bahia *Et*, 2018) used in biodiesel as well as animal and human food, is ranked third in terms of global oilseed production, with 51.51 metric tons produced in the 2018/2019 growing season (USDA, 2019).

The physical and chemical properties of agricultural products generally vary in accordance

with crop management practices, which influence drying speed (Botelho *et al.*, 2018) and other postharvest processes. As such, the final quality of the product is associated with a combination of factors, from the seed to processing.

Grain quality is related to product characteristics at harvesting and changes that occur during postharvest processing. The repercussions on seed/achene integrity expose flaws in the sector, with deterioration linked to the physical and chemical

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factors of grain weight (Bischoff *et al.*, 2016). Drying is a vital stage of postharvest processing, ensuring grain stability by reducing the moisture content of the plant material (Botelho *et al.*, 2015a; Botelho *et al.*, 2018).

Both natural and artificial drying involve interaction between the product and the environment via heat and mass transfer. Transfer intensity and gradient formation can qualitatively alter the final product, depending on the drying conditions used (Nádvořníková *et al.*, 2018; Defendi *et al.*, 2016; Khatchatourian *et al.*, 2013).

Reduced grain quality as a function of drying temperature has been reported in peanut (Araújo *et al.*, 2017), sunflower (Oliveira *et al.*, 2012; Smaniotto *et al.*, 2017), soybean (Botelho *et al.*, 2015a), and sorghum (Botelho *et al.*, 2015b), with immediate and latent consequences (Botelho *et al.*, 2015a; Goneli *et al.*, 2011).

Given the limited information available on dependence and interaction between achene composition and drying temperature in selecting sunflower genotypes, this study aimed to assess oil content variation in sunflower achenes submitted to different drying conditions and, based on the results, adapt drying processes and help researchers select the most promising genetic material for achene production.

Material and methods

The experiment was carried out at the Medicinal Plants and Postharvest Technology Laboratory of the State University of Maringá (UEM) Agronomy Department, in the municipality of Maringá, Paraná state (PR), Brazil (23°25' S, 51°57' W and 542 m.a.s.l.). The achenes used were from a crop grown at the Technical Irrigation Center (CTI/UEM), whose capitula (sunflower heads) were manually harvested after reaching physiological maturity. After threshing to ensure uniform raw material, damaged or defective plant material was removed and 500 g samples of achenes with a dry basis (db) moisture content of $0.30 \pm 1\%$ were submitted to the pre-established conditions.

For each condition, with samples in triplicate, achenes of thirteen sunflower genotypes were exposed to controlled (35, 40, 50 and 70 °C) and uncontrolled drying (drying terrace). In forced-air drying, the achenes were placed on steel mesh trays and temperature and relative humidity monitored

by a psychrometer inside the dryer, while for uncontrolled drying, the trays were placed on an asphalt drying terrace. Under both drying conditions, moisture content reduction to 0.08 ± 1 (db) was monitored based on weight variation, with weighing performed every 30 minutes.

Achene oil content was determined using the nondestructive pulsed nuclear magnetic resonance (NMR) technique (Ungaro *et al.*, 1992) and the acid value based on the methodology of the Adolfo Lutz Institute (2005), for unrefined cold pressed oil. The experimental data on achene oil content were analyzed using the Scott-Knott test ($p < 0.05$) for comparison of means.

Results and discussion

Increased achene oil content is one of the characteristics targeted by breeding programs (Lustri, *et al.*, 2017). The degree of oil content variation range observed between genotypes at a same temperature is associated with the selection of genetic material. Although the genetic origin of the sunflowers did not affect drying time, heat tolerance differed between genotypes, with a significant difference in oil yield for achenes with a moisture content of $8 \pm 0.5\%$ (db) in response to air drying temperatures (Table 1).

Separate analysis of the sunflower genotypes (Table 1) revealed that the lowest air drying temperatures were associated with the highest oil content after drying, indicating interaction between drying and achene composition regardless of genotype. Temperatures of 35-40 °C maintained stable oil indices, with an average 2.8% decline in oil yield at 50 °C and between 4.83 and 20.09% at 70 °C.

Oil content analysis under the different drying conditions made it possible to identify the genotypes with the highest oil yield, a key parameter in breeding programs and financial returns for crops. Genotype 8 exhibited the highest oil content under all drying conditions, with 46.40% at 40 °C and 38.21% at 70 °C. Based on oil contents for terrace drying and controlled drying at 50 °C, genotypes 3, 4, 5, 8, 9, 11 and 12 showed the highest yields. In addition to genetic factors, oil yield may be related to planting time, water availability and solar radiation during flowering (Thomaz *et al.*, 2012).

Interaction between exposure time and temperature during drying can alter grain

Table 1. Oil content (%) of achenes from thirteen sunflower genotypes as a function of drying conditions.

Genotype	Drying process				
	Drying terrace	35 °C	40 °C	50 °C	70 °C
1	36.75 aA	36.79 aA	36.80 aA	35.59 aB	35.02 fC
2	38.62 bA	38.77 dA	38.78 dA	37.58 dB	35.98 hC
3	42.02 dA	42.07 gA	42.08 gA	40.83 gB	35.66 gC
4	40.50 cA	40.47 fA	40.48 fA	39.28 fB	36.72 iC
5	40.50 cA	40.09 eA	40.12 eA	38.91 eB	32.07 bC
6	38.25 bA	38.44 cA	38.44 cA	37.58 cB	34.73 eC
7	37.07 aA	37.11 bA	37.14 bA	35.90 bB	33.29 dC
8	46.37 eA	46.38 iA	46.40 iA	45.47 iB	38.21 jC
9	42.55 dA	42.51 h A	42.52 h A	41.37 hB	34.48 eC
10	37.20 aA	37.28 bA	37.32 bA	36.17 bB	29.82 aC
11	40.27 cA	40.34 fA	40.39 fA	39.23 fB	32.99 cC
12	40.50 cA	40.55 fA	40.57 fA	39.42 fB	33.44 dC
13	39.90 cA	39.97 eA	40.00 eA	38.77 eB	32.99 cC
C.V. (%)	0.98	0.54	0.54	0.53	0.54

Means followed by the same lower case letter in the column for genotypes, and upper case in the row for drying conditions, do not differ ($p < 0.05$).

characteristics (Teixeira *et al.*, 2018; Ziegler *et al.*, 2017), since substantial variations in moisture content may damage seed structure and viability (Botelho *et al.*, 2015a; Oliveira *et al.*, 2012; Goneli *et al.*, 2011).

The use of different temperatures influenced/ altered the oil content of achenes, whose heat tolerance is related to genetic capacity. Low oil content variation ($< 1\%$) was observed in achenes dried on a drying terrace and at 35 °C in a dryer (Table 1); however, while there are no energy costs involved in terrace drying, this technique may not be operationally viable for large amounts of achenes.

For drying at 50 to 70 °C, the oil content variation of genotypes 1 and 2 was less than 4%, but greater than 15% for genotypes 5, 8, 9, 10, 11 and 12 (Table 1). With respect to the effect of drying at 70 °C on sunflower genotypes, the high oil concentrations obtained in 1, 2, 3, 4, 6, 8, and 9 express heat tolerance. The results of drying-genotype interaction can contribute to the selection of physiological and morphological characteristics in sunflower genotypes, whose diversity indicates heat tolerance, making high temperature drying a viable option.

Nevertheless, high grain drying temperatures accelerate the migration of water vapor to the external atmosphere (Botelho *et al.*, 2018), which, despite initially suggesting lower energy costs,

damages grain structure (Saath, *et al.*, 2010). Moisture diffusivity in the grain is directly related to the energy required to transform free water into vapor, which are both inversely proportional; in other words, the greater the diffusivity, the less energy is needed (Silva *et al.*, 2018; Teixeira *et al.*, 2018).

The high oil acidity indices recorded in high temperature drying (Table 2) indicate changes in oil structure due to high drying rates (70 °C), one of the factors responsible for accelerated glyceride decomposition and free fatty acid formation (Thode Filho *et al.*, 2014). In association with the conservation conditions of the raw material, the oil acid value demonstrates that drying at 70 °C accelerated glyceride decomposition, altering oil quality and shortening the shelf life of the final product.

In regard to oil quality, this study revealed changes in the physical and chemical stability of sunflower genotypes when the achenes of a same genotype were exposed to high-temperature drying. The higher the drying temperature, the greater the increase in acid value, which may be associated with the concentrations of unstable compounds, whose vulnerability is attributed to the double bonds present in their carbon chains (Thode Filho *et al.*, 2014).

Resolution RDC 270 of the Ministry of Health (2005) stipulates a maximum acid value of 4.0

mg KOH g⁻¹ for unrefined and cold pressed oil; in this study, the acid values of oil from achenes dried at 50 °C were close to the upper limit, but exceeded it at 70 °C (Table 2).

Since achene oil content was not influenced by water availability to the plants (Simões *et al.*, 2016), based on the results obtained, the stable physiological quality (Table 3) and minor oil

content variations observed in achenes dried at 35-40 °C (Table 1) are related to genetic factors. From a breeding perspective, this is an important criterion in selecting high-yield genotypes.

Differences in achene variable values (Table 3) were attributed to the genetic traits of the genotypes; however, susceptibility to injury due to drying varied among genotypes. For achenes dried at 50-70 °C,

Table 2. Acid value (mg KOH g sample⁻¹) of the oil from thirteen sunflower genotypes as a function of drying.

Genotype	Drying process				
	Drying terrace	35 °C	40 °C	50 °C	70 °C
1	1.68 aA	1.98 bA	1.92 aA	3.89 aB	4.52 aC
2	1.85 bA	1.89 bA	1.86 aA	3.92 aB	4.61 aC
3	1.72 aA	1.96 bA	1.93 aA	3.89 aB	4.76 aC
4	1.65 aA	1.71 aA	1.88 aA	3.85 aB	4.69 aC
5	1.81 bA	1.86 bA	1.91 aA	3.88 aB	4.74 aC
6	1.96 bA	1.94 bA	1.91 aA	3.93 aB	4.72 aC
7	1.71 aA	1.98 bA	1.85 aA	3.85 aB	4.68 aC
8	1.67 aA	1.71 aA	1.83 aA	3.88 aB	4.79 aC
9	1.91 bA	1.88 bA	1.89 aA	3.92 aB	4.87 aC
10	1.83 bA	1.99 bA	1.88 aA	3.91 aB	4.81 aC
11	1.89 bA	1.91 bA	1.82 aA	3.86 aB	4.74 aC
12	1.88 bA	1.85 bA	1.86 aA	3.82 aB	4.68 aC
13	1.92 bA	1.89 bA	1.87 aA	3.84 aB	4.81 aC
C.V. (%)	5	4.83	5.33	6.12	8.89

Means followed by the same lower case letter in the column for genotypes, and upper case in the row for drying conditions, do not differ ($p < 0.05$).

Table 3. Achene yield (AY), oil content (OC), oil yield (OY), germination (G), test weight (TW) and 1000 achene weight (1000AW) of sunflower genotypes grown in the CTI/UEM experimental field, Maringá - PR, 2017/2018 growing season.

Genotype	AY (kg ha ⁻¹)	OC (%)	OY (kg ha ⁻¹)	G (%)	TW (kg 100 L ⁻¹)	1000AW (g)
1	19.64 a	36.75 c	721.77 b	92.50 a	46.17 a	43.46 b
2	20.45 a	38.63 c	789.98 b	94.50 a	46.47 a	40.70 b
3	21.54 a	42.03 b	905.33 a	88.50 c	46.27 a	51.26 a
4	19.82 a	40.50 b	802.71 a	90.00 b	46.42 a	43.33 b
5	15.99 b	40.50 b	647.60 c	91.50 b	45.07 b	52.46 a
6	13.60 b	38.25 c	520.20 c	89.50 b	46.11 a	41.13 b
7	12.74 c	37.08 c	472.40 d	88.50 c	46.57 a	40.00 b
8	11.38 c	46.38 a	527.80 c	87.50 c	44.31 b	42.50 b
9	20.66 a	42.55 b	879.08 a	92.50 a	46.67 a	43.56 b
10	10.44 c	37.20 c	388.37 d	88.50 c	44.15 b	42.16 b
11	19.28 a	40.28 b	776.60 b	89.50 b	46.77 a	42.60 b
12	20.89 a	40.50 b	846.05 a	87.50 c	47.14 a	51.23 a
13	21.86 a	39.99 b	872.21 a	87.50 c	46.44 a	52.68 a

Means followed by the same letter in the column for genotypes do not differ ($p < 0.05$).

null germination, low oil content (Table 1) and high acid values (Table 2) indicate cell membrane rupture due to high drying temperatures and/or the moisture gradient during moisture loss. Defendi *et al.* (2016); Khatchaturian *et al.* (2013) and Nádvořníková *et al.* (2018) attributed reduced grain quality to the drying conditions and moisture gradient in the grain.

Conclusion

Drying temperature affected the quantity and quality of the oil extracted, with an increase in acid

value for achenes dried at 50 °C and 70 °C and a decline of up to 18.92% in oil content.

Achene oil content, unique to each genotype, was influenced by the drying process, with the degree of changes observed attributed to the genetic traits of sunflowers.

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