

Seed quality of crambe (*Crambe abyssinica* Hochst) submitted to different drying methods¹

Qualidade de sementes de crambe (*Crambe abyssinica* Hochst) submetidas a diferentes métodos de secagem

Magnun Antonio Penariol da Silva², Juliana Joice Pereira Lima^{3*}, Marco Antonio Martin Biaggioni², Claudio Cavariani³ and Gisela Ferreira⁴

ABSTRACT - The objective of this research was to evaluate the effects of different drying methods on physiological quality of crambe seeds. Crambe seeds of *FMS Brilhante* cultivar were produced in the Lageado experimental farm (UNESP, Botucatu, Brazil) in 2012. The drying methods were: artificial drying with hot air, artificial drying with fresh air, natural yard drying, natural shade drying and natural field drying. The water content of seeds was monitored before, during and after drying. Germination, first germination count, abnormal seedlings, GSI, germination synchronization, frequency and germination mean time, electrical conductivity, fatty acid index and oil content were evaluated in order to know the physiological quality. The experimental design was randomized and the averages compared by the t-test at 5% significance. Results showed that artificial hot air drying favored with higher germination and vigor of crambe seeds when compared to other drying methods and demanded shorter time to reduce the water content. The natural shade drying method is feasible for crambe seeds despite taking longer.

Key words: Natural drying. Artificial drying. Crambe seeds vigor. Seeds damage.

RESUMO - Objetivou-se nesta pesquisa avaliar o efeito de diferentes métodos de secagem na qualidade fisiológica de sementes de crambe. As sementes de crambe da cultivar FMS Brilhante foram produzidas na Fazenda Experimental Lageado (UNESP - Botucatu) no ano de 2012. As condições de secagem foram: secagem artificial com ar aquecido, secagem artificial com ar natural, secagem natural em terreiro, secagem natural à sombra e secagem na planta. O teor de água foi monitorado antes, durante e após a secagem. Para avaliação da qualidade fisiológica foi realizado o teste de germinação, primeira contagem de germinação, plântulas anormais, IVG, sincronização da germinação, frequência e tempo médio de germinação, teste de condutividade elétrica, índice de acidez graxa e teor de óleo. O delineamento experimental foi inteiramente casualizado e as médias comparadas pelo teste de Tukey a 5% de significância. Pelos resultados obtidos a secagem artificial com alta temperatura favoreceu obtenção de sementes de crambe com alta germinação e vigor em relação aos demais tipos de secagem com um tempo menor para redução do teor de água. A secagem natural na sombra é viável para sementes de crambe apesar de ser longa.

Palavras-chave: Secagem natural. Secagem artificial. Vigor de sementes de crambe. Danos em sementes.

DOI: 10.5935/1806-6690.20160042

*Autor para correspondência

¹Recebido para publicação em 29/11/2013; aprovado em 10/11/2015

Parte da Dissertação de Mestrado do primeiro autor apresentada ao Programa de Pós-Graduação em Energia na Agricultura da Universidade Estadual Paulista "Júlio de Mesquita Filho"

²Departamento de Engenharia Rural, Faculdade de Ciências Agronômicas, Universidade Estadual Paulista Júlio de Mesquita Filho, Botucatu-SP, Brasil, 18.610-307, penariol@gmail.com, biaggioni@fca.unesp.br

³Departamento de Produção e Melhoramento Vegetal, Faculdade de Ciências Agronômicas, Universidade Estadual Paulista Júlio de Mesquita Filho, Rua José Barbosa de Barros, 1780, Caixa Postal 237, Botucatu-SP, Brasil, 18.610-307. julianafoicelima@yahoo.com.br, ccavariani@fca.unesp.br

⁴Instituto de Biociências, Universidade Estadual Paulista Júlio de Mesquita Filho, Botucatu-SP, Brasil, gisela@ibb.unesp.br

INTRODUCTION

Member of the *Brassicaceae* family, crambe (*Crambe abyssinica* Hostch) is an annual cycle plant species and it is tolerant to drought and cold conditions. In the climatic conditions of Brazil it is cultivated in wintertime. The great interest in this specie is due to the high seed oil and protein concentrations plus its agronomic advantages such as reduced demand for crop treatment, satisfactory yield (around 1500 kg/ha) and short cycle (90 days), makes it a potential raw material for biodiesel production (MASETTO *et al.*, 2009; MASETTO *et al.*, 2011; PITOL, 2008; SOUZA *et al.*, 2009).

Crambe has been gaining more importance in recent years, however, there is not much information in the literature about seed production with high physiological quality. To obtain the desired seed quality care must be taken at all stages of the production process, particularly in the harvest, processing, and storage.

Seeds with high water content may have their quality affected by mechanical damages suffered during improvement processes, moreover performance and separation efficiency of the machines used also can influence the physiological quality (CARVALHO; NAKAGAWA, 2012). This makes drying a critical process in this production stage.

Drying allows harvesting to near physiological maturity when water content and quality are high. Its goal is to reduce the water content of the seeds to levels adequate to storage, preserving them from physical and chemical changes induced by excess water (RESENDE *et al.*, 2012). However, because the removal of water during seed drying can cause chemical, physical and biological changes, the drying conditions must be monitored so that all possible effects on seed quality have to be considered (JOSÉ *et al.*, 2005; ROSA *et al.*, 2005).

The drying methods are chosen according to the characteristics of species, the quantity of seed and the weather conditions likely to prevail after harvest (FRANKE; TORRES; LOPES, 2008) and can be classified as natural or artificial. Natural drying employs air, without modification of its characteristics, and sun to reduce the water content of the seeds in the field, on a yard or in sheds (GARCIA *et al.*, 2004). Depending on the species, seeds can be attached or not to the plant or even remain inside of the fruits. The artificial drying method is characterized by forced air through seed mass (ZUCHI *et al.*, 2009).

Baker, Paulsen and Van-Zweden (1991) and Donadon *et al.* (2013) mention that decrease of germination is due to damaged cell membranes or disorganization of cell components when drying is on high temperatures. Costa *et al.* (2012a) studied the effect of artificial drying

with air at different temperatures on the physiological quality of crambe seeds and they did not observe effects on germination for the temperature used (35-90 °C). Costa *et al.* (2012b), studying the same species but at drying with temperature from 23 to 70 °C, observed higher germination when the seeds were dried at 30 °C.

Given the importance of drying, the objective of this research was to evaluate the effects of different drying methods on the physiological quality of the crambe seeds.

MATERIAL AND METHODS

Crambe seeds of FMS Brilhante cultivar developed by the Fundação MS were produced in the winter of the crop year 2012 in the Lageado agricultural experimental farm, Faculdade de Ciências Agrônômicas, UNESP - Univ Estadual Paulista, with the following coordinates and geographic characteristics: 22°52'20" S and 48°26'37" W, average altitude of 770 meters, an average slope of 4.5% and a subtropical climate with warm, wet summers and cool dry winter. Fertilization followed Oliva, Biagnoni and Cavariani (2012) and was preceded by soil analysis. Sowing was made in May and harvesting in August 2012. Evaluations were performed in the Agricultural Products Processing Laboratory of the Rural Engineering Department and in the Laboratory of Seed Analysis of the Production and Plant Breeding Department.

Water content of seeds was monitored before, during and after drying, employing the oven at 105±3 °C method (BRASIL, 2009), with three replicates and its results were given as the wet basis percentage. Drying was finished when the seeds reached 8.0 ± 2.0% of water content. Water content of seeds during the drying was estimated based on the weight and water content initial. The following drying methods were used:

Fixed artificial drying with hot air: it was carried out in a research dryer developed at FCA - UNESP made of PVC columns 0.8 m high and 0.15 m in diameter and with a metal screen at its bottom. The height of the seed mass was 0.60 meters and the drying air blown by a fan driven by an electric motor. The air was heated by an electrical resistance up to a maximum temperature of 60 °C at the seed mass and monitored by digital thermometers located at 0.10 m and 0.25 m from the base of the drying column. The average speed of drying air was measured at the exit of the column with a propeller anemometer and used to compute the average flow of drying air. After the drying the seeds were homogenized to start the analysis.

Fixed artificial drying with natural air: it was carried out in a research dryer developed at FCA - UNESP,

consisting of PVC columns 1.5 m high and 0.15 m in diameter and with a metal screen at its bottom. The height of the seed mass in each column was 1.25 m. Drying air and temperatures of seeds mass were monitored during the drying operations by digital thermometers respectively installed in the inlet air duct and in the drying columns at 0.35 m and 0.75 m from their bases. After the drying the seeds are homogenized to start the analysis.

Natural sun yard drying: the seeds were spread over shade screens in a single layer with 5 cm of height. The seed layer was revolved several times during the day for the better exposure to the sun and by twilight stacked and covered with plastic canvas.

Natural shade drying: the seeds were spread over shade screens in a single layer of one seed of height and kept on a shed with natural ventilation.

Natural field drying: the fruits were naturally dried on the plant until their water contents reaches at $8.0 \pm 2.0\%$.

The evaluation of the physiological quality of seeds was performed using the following tests or evaluations: **Germination test** conducted with four replicates of 50 seeds for each treatment. Seeds were placed on blotting paper moistened with a solution of potassium nitrate (KNO_3) at 0.2% in an amount 2.5 times from mass of the dry substrate and stored in transparent plastic boxes (11 x 11 x 3.5 cm) and then placed into B.O.D. germinators at a constant temperature of 25 °C. Counts of normal seedlings for subsequent expression of results in percentages were performed on the fourth (**first germination count**) and seventh days after the test and included the count of abnormal seedlings according to Brasil (2009). Along the germination test, germinated seeds were counted daily in order to calculate the **germination speed index** (GSI), employing the formula proposed by Maguire (1962).

$$\text{GSI} = E_1/N_1 + E_2/N_2 + \dots + E_m/N_m$$

Where: $E_1, E_2, \dots,$ and E_m = number of seedlings, computed in the first, second, ..., last count and N_1, N_2, \dots, N_m = number of days from sowing at the first, second, ..., last count.

The **Germination Mean Time** (GMT), **Germination Relative Frequency** (RF) and **Germination Synchronization** (U) were computed according to Labouriau (1983) as follows:

$$\text{GMT} = (\sum ni) / \sum ni$$

Where: GMT = germination mean time; ni = number of germinated seeds per day; ti = incubation time (days)

$$\text{RF} = ni / \sum ni$$

Where: RF = relative frequency of germination; ni = number of germinated seeds per day; $\sum ni$ = total number of germinated seeds

$$U = - \sum fi \log_2 fi$$

Where: U = germination synchronization; fi = relative frequency of germination; \log_2 = logarithm base 2.

The **electrical conductivity test** was performed according to Vieira and Krzyzanowski (1999), using four replicates of 50 seeds with mass was determined with a 0.001 g precision scale, moistened in plastic containers with 75 ml of deionized distilled water which were placed in a B.O.D. incubator at 25 °C for 24 hours. Electrical conductivity of the solution was determined by a Digimed DM-31 conductivimeter and the average values per gram of moistened seeds were computed in $\mu\text{S cm}^{-1} \cdot \text{g}^{-1}$. The **oil content** was determined by the chemical solvent extraction method (Soxhlet). The **content of fatty acids** was determined as recommended by AACC (1995) and calculated by the equation:

$$\text{FA} = \text{volume of KOH} / \text{weight of dry sample.}$$

The experimental design was completely randomized. The homogeneity of the data (Shapiro-Wilk test) was verified and then an analysis of variance (F test) was carried out with averages compared by the t-test at 5% significance level.

RESULTS AND DISCUSSION

Table 1 is a summary of the analysis of variance for the variables analyzed. According to the F test at 5% probability, significant differences were found among treatments for all response variables evaluated.

Table 2 shows the mean percentage of seeds water content before and after drying and the time in hours to reduce them from 20.0 ± 1.0 to 8.0 ± 2.0 (% wb). As expected, the shortest time required to reduce the water content of crambe seeds (7.4 hours) was observed when employing artificial drying with hot air. The fact is due to the drying air temperature (55.6 °C) which combined with low relative humidity and air flow determined the efficiency of the process (GARCIA *et al.*, 2004).

On the other hand, removing seed water content through natural drying by air and sun weather dependent actions are a slow methods. Depending on the type of natural drying, it took 92, 90 or 74 hours to reduce the water content of the seeds to levels comparable to the seeds storage respectively undergoing shade, field and yard.

Thus, artificial air drying was more than 12 times faster than other drying methods and highlights the relevance of temperature rise and consequent reduction in relative humidity to decrease the drying time with forced air. Zonta *et al.* (2011) compared various drying methods and Sirisomboon and Kitchaiya (2009), Ahrens *et al.* (1995) and Ullmann *et al.* (2010) evaluating the artificial drying in the temperature range from 40 to 80 °C obtained similar results with jatropha seeds.

The average values of the air temperature in the inlet duct, the relative humidity and air flow recorded with artificial drying with hot and natural air are presented in

Table 3. In the drying with hot air, the average temperature of the drying air duct inlet was 55.6 °C, while the temperature of seed mass was 47 °C and the air flow 17.6 m³ m⁻².min. Although the air flow was similar in both methods, temperature combined with low humidity made the hot air method the most effective in reducing the humidity of the seed mass.

In the Table 4 is the average results observed in germination and vigor tests. Natural drying of seeds in the field was harmful for crambe seeds germination and germination speed which is related to the seed vigor tests given by the first germination count and GSI.

Table 1 - Summary of analysis of variance for Germination, First germination count, Abnormal seedlings, Germination synchronization, Germination speed index, Electrical conductivity, Fatty acids and Oil content

Variables analyzed	Mean squares	Coefficient of variation (%)
Germination	216.20*	5.29
First germination count	1601.3*	5.81
Abnormal seedlings	62.50*	16.60
Germination synchronization	0.016*	8.14
Germination speed index	16.41*	4.67
Electrical conductivity	6561.2*	5.00
Fatty acids	4.17*	17.86
Oil content	39.13*	6.13

*Significant at 5% probability by F test

Table 2 - Initial and final mean values of water content (% wb) and drying time (DT) in crambe seeds in different drying conditions

Treatment	Water content (% wb)		DT (hours)
	Initial	Final	
Hot air drying	21.2	9.49	7.4
Natural air drying	21.0	6.12	88
Natural yard drying	21.4	6.01	74
Natural shade drying	21.3	6.85	92
Natural field drying	21.5	7.43	90

Table 3 - Mean values of the temperatures of the drying air and the seed mass, relative humidity (RH) and air flow when drying crambe seeds with hot air and natural air

Treatment	-----Temperature (°C)-----		RH (%)	Airflow (m ³ min•m ²)
	Drying air	Seed mass		
Hot air drying	55.6	47.4	10.11	17.6
Natural air drying	27.0	24.0	50.2	15.55

Table 4 - Mean values of germination percentage (G), first germination count (FC), abnormal seedlings (A), germination synchronization (U) and germination speed index (GSI) of crambe seeds submitted to different drying conditions

Treatment	G	FC	A	U	GSI
	----- % -----				
Hot air drying	80 a	72 a	07 a	1.63 a	12.84 a
Natural air drying	73 b	53 c	13 b	2.03 bc	11.05 c
Natural yard drying	78 ab	53 c	16 e	2.01 c	11.91 b
Natural shade drying	84 a	64 b	11 b	1.83 ab	12.57 ab
Natural field drying	65 c	19 d	07 a	1.89 bc	7.83 d

*Means followed by the same letter do not differ at 5% level of significance by the t-test

Despite both being natural methods, leaving seeds to dry in the plant resulted in germination approximately 20% below that obtained with natural shade drying which might be explained by the longer time that seed remains in the field which promotes deterioration and consequent reduction in seed germination. This was also observed in other species such as beans (AHRENS; LOLLATO, 1995), soybean (MIRANDA; SILVA; CAVARIANI, 1999); ryegrass (EICHELBERGER *et al.*, 2003) and jatropha (ZONTA *et al.*, 2011).

Higher values of germination and germination speed index (Table 4) were observed when in the artificial drying with hot air and the natural shade drying methods. Also, a high percentage of normal seedlings in the first germination count and better germination synchronization were seen when crambe seeds were dried on hot air drying. Drying air temperature was approximately 55 °C and it did not immediately affect seed quality, agreeing with Costa *et al.* (2012a) but contradicting results found by Costa *et al.* (2012b), who reported that temperatures close to 60 °C is detrimental to the germination of crambe seeds. Zonta *et al.* (2011) and Ullmann *et al.* (2010) found no effect of drying temperatures respectively of 43 °C and 60 °C on the germination of Jatropha seeds.

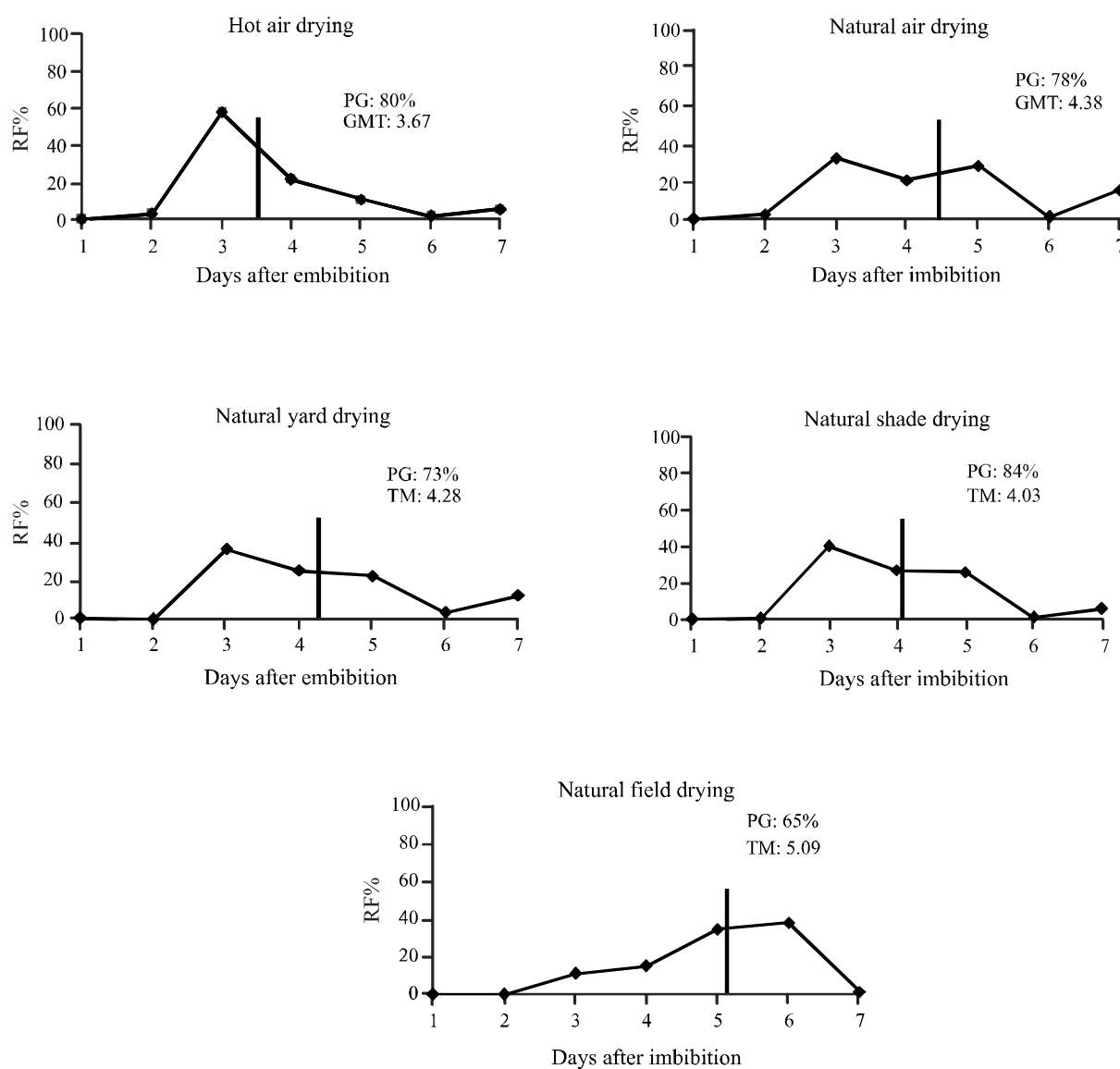
Artificial drying with natural air and natural yard drying (Table 4) provided an intermediate level of seed germination and vigor. However, the germination synchronization - which measures the organization of a system and whose value varies inversely with organization and synchrony (NASSIF; PEREZ, 2000) - for natural yard drying showed greater disorganization of the system although it is not statistically different from artificial drying with natural air and natural field drying. Carvalho and Carvalho (2009) report that the germination synchronization is correlated to germination and germination speed index, similarly to what was observed in this study.

Germination relative frequency (Fr) of crambe seeds versus drying methods shows that the germination mean time (TM) required to reach 60% of seed germination under hot air drying was 3.67 days (Figure 1), which demonstrates the superior vigor of these method. In a similar manner, the artificial drying with natural air and the natural yard drying methods demanded longer periods before most seeds germinated (4.28 and 4.38 days). However, seed damaged was most noticed for the natural field drying method.

Reductions in seed physiological quality are generally accompanied by increased electrolyte and sugar liberation by water soaked seeds as a result of loss of selective permeability of the cell membranes (VIEIRA, 1994). The damage causes by drying to the membrane system can be estimated by measuring electrical conductivity. Table 5 shows a lower electrical conductivity of the soaking solution when the seeds were dried naturally in the field which, however, it was the drying method most damaging to seed germination and vigor. There were no significant differences in the electrical conductivity of crambe seed leachate subjected to the other drying methods.

Sensitivity is the main advantage of the fatty acid test method for assessing the deterioration of stored seeds. Formation of free fatty acids in the seed results from the hydrolysis of lipids and the lipids acidity test can detect the onset of the deterioration process (BIAGGIONI; BARROS, 2006). The results for the lipids acidity index (Table 5) shows the superiority of artificial hot air drying when compared to the other methods evaluated regarding the production of crambe seeds of better quality. However, the test was not sensitive enough to distinguish the other treatments regarding vigor levels.

Assessing the oil quality obtained from these seeds from each drying method, the highest seed oil

Figure 1 - Germination Relative Frequency (RF) of crambe seeds submitted to different drying methods. PG: average percentage of germinated seeds and GMT: Germination Mean Time (days). Arrows indicate the Germination Mean Time**Table 5** - Average values of electrical conductivity (EC), fatty acids (FA) and oil content (OC) in crambe seeds submitted to different drying conditions

Treatment	EC	FA	OC
	($\mu\text{S cm}^{-1} \text{g}^{-1}$)	(ml KOH 0.1N 100g ⁻¹ DM)	(%)
Hot air drying	479.55 b	6,735 a	22,12 c
Natural air drying	482.85 b	8,115 b	28.92 a
Natural yard drying	476.74 b	9,112 b	24.43 cb
Natural shade drying	473.76 b	8,930 b	26,39 b
Natural field drying	387.96 a	9,100 b	29.68 a

*Means followed by the same letter do not differ at the 5% level of significance by the t-test.

contents were obtained with the methods of plant drying and natural air drying (Table 5), while the lowest levels were obtained with artificial drying with hot air. According Donadon *et al.* (2013) temperatures above 45 °C cause a change of the oil drops in the cytoplasm of the cotyledons cells in crambe seeds.

CONCLUSIONS

1. Artificial drying with hot air is the preferred method for reducing water contents of crambe seed. Furthermore maintains the seed physiological quality;
2. Despite taking a long time, natural shade drying is feasible for crambe seeds.

REFERENCES

- AHRENS, D. C.; LOLLATO, M. A. Qualidade de semente de feijão e velocidade de secagem ao sol e em secador de fluxo contínuo. **Informativo ABRATES**, v. 5, n. 2, p. 52, 1995.
- AMERICAN ASSOCIATION OF CEREAL CHEMISTS. **Approved methods of the AACC**. 8 th ed. Saint Paul: AACC, 1995. Paginação irregular.
- BAKER, K. D.; PAULSEN, M. R.; VAN-ZWEDEN, J. Hybrid and drying rate effects on seed corn viability. **Transactions of the ASAE**, v. 34, n. 2, p. 499-506, 1991.
- BIAGGIONI, M. A. M.; BARROS, R. E. Teste de acidez graxa como índice de qualidade em arroz. **Ciência e Agrotecnologia**, v. 30, n. 4, p. 679-684, 2006.
- BRASIL. Ministério da Agricultura e da Reforma Agrária. **Regras para análise de sementes**. Brasília, DF: SNDA: DNDV: CLAV, 2009. 398 p.
- CARVALHO, D. B.; CARVALHO, R. I. N. Qualidade fisiológica de sementes de guanxuma em influência do envelhecimento acelerado e da luz. **Acta Scientiarum. Agronomy**, v. 31, n. 3, p. 489-494, 2009.
- CARVALHO, N. M.; NAKAGAWA, J. **Sementes: ciência, tecnologia e produção**. 5. ed. Jaboticabal: Funep, 2012. 590 p.
- COSTA, L. M. *et al.* Storage of crambe fruit subjected to different drying conditions. **African Journal of Agricultural Research**, v. 47, n.7, p. 6274-6280, 2012a.
- COSTA, L. M. *et al.* The influence of drying on the physiological quality of crambe fruits. **Acta Scientiarum. Agronomy**, v. 34, n. 2, p. 213-218, 2012b.
- DONADON, J. R. *et al.* Effect of hot air drying on ultrastructure of crambe seeds. **Drying Technology**, v. 31, p. 269-276, 2013.
- EICHELBERGER, L. *et al.* Efeito do retardamento da secagem na qualidade fisiológica de sementes armazenadas de azevém anual. **Pesquisa Agropecuária Brasileira**, v. 38, n. 5, p. 643-650, 2003.
- FRANKE, L. B.; TORRES, M. A. P.; LOPES, R. R. Performance of different drying methods and their effects on the physiological quality of grain sorghum seeds (*S. bicolor* (L.) Moench). **Revista Brasileira de Sementes**, v. 30, n. 3, p. 177-184, 2008.
- GARCIA, D. C. *et al.* A secagem de sementes. **Ciência Rural**, v. 34, n. 2, p. 603-608, 2004.
- JOSÉ, S. C. B. R. *et al.* Características físicas do pericarpo de sementes de milho associadas com tolerância à alta temperatura de secagem. **Revista Brasileira de Sementes**, v. 27, p. 125-131, 2005.
- LABOURIAU, L. G. **A germinação das sementes**. Washington: Secretaria Geral da Organização dos Estados Americanos, 1983. 174 p.
- MAGUIRE, J. D. Speeds of germination-aid selection and evaluation for seedling emergence and vigor. **Crop Science**, v. 2, p. 176-177, 1962.
- MASETTO, T. E. *et al.* Qualidade fisiológica e sanitária de sementes de crambe produzidas no estado de mato grosso do sul. **Revista Brasileira de Oleaginosas e Fibrosas**, v. 13, n. 3, p. 107-111, 2009.
- MASETTO, T. L. *et al.* Potencial hídrico do substrato e teor de água das sementes na germinação do crambe. **Revista Brasileira de Sementes**, v. 33, n. 3, p. 511-519, 2011.
- MIRANDA, L. C.; SILVA, W. R. da; CAVARIANI, C. Secagem de sementes de soja em silo com distribuição radial do fluxo de ar. I. Monitoramento físico. **Pesquisa Agropecuária Brasileira**, v. 34, n. 11, p. 2097-2108, 1999.
- NASSIF, S. M. L.; PEREZ, S. C. J. G. Efeito da temperatura na germinação de sementes de amendoim do campo (*Pterogynenitens*Tul.). **Revista Brasileira de Sementes**, v. 22, n. 1, p.1-6, 2000.
- OLIVA, A. C. E.; BIAGNONI, M. A. M.; CAVARIANI, C. Efeito imediato do método de secagem na qualidade de sementes de crambe. **Energia na Agricultura**, v. 27, n. 3, p. 16-30, 2012.
- PITOL, C. Cultura do crambe. In: FUNDAÇÃO MS. **Tecnologia e produção: milho safrinha e culturas de inverno**. Maracaju, MS, 2008. p. 85-88.
- RESENDE, O. *et al.* Adzuki beans (*Vigna angularis*) seed quality under several drying conditions. **Ciência e Tecnologia dos Alimentos**, v. 32, n. 1, p. 151-155, 2012
- ROSA, S. D. V. F. *et al.* Enzimas removedoras de radicais livres e proteínas LEA associadas à tolerância de sementes de milho à alta temperatura de secagem. **Revista Brasileira de Sementes**, v. 27, n. 2, p. 91-101, 2005.
- SIRISOMBOON, P.; KITCHAIYA, P. Physical properties of *Jatropha curcas* L. kernels after heat treatments. **Biosystems Engineering**, v. 102, n. 2, p. 244-250, 2009.

SOUZA, A. V. D. *et al.* Caracterização química de sementes e tortas de pinhao-manso, nabo-forrageiro e crambe. **Pesquisa Agropecuária Brasileira**, v. 44, n. 10, p. 1328-1335. 2009.

ULLMANN, R. *et al.* Qualidade das sementes de pinhão manso submetidas à secagem artificial. **Revista Ciência Agronômica**, v. 41, n. 3, p. 442-447, 2010.

VIEIRA, R. D. Teste de condutividade elétrica. In: VIEIRA, R. D.; CARVALHO, N. M. (Coord.) **Testes de vigor em sementes**. Jaboticabal: Funep, 1994. p. 103-132.

VIEIRA, R. D.; KRZYZANOWSKI, F. C. Teste de condutividade elétrica. In: KRZYZANOWSKI, F. C.; VIEIRA, R. D.; FRANÇA NETO, J. B. (Ed.). **Vigor desementes: conceitos e testes**. Londrina: Abrates, 1999. p. 1-26.

ZONTA, J. B. *et al.* Diferentes tipos de secagem: efeitos na qualidade fisiológica de sementes de pinhão manso. **Revista Brasileira de Sementes**, v. 33, n. 4, p. 721-731, 2011.

ZUCHI, J. *et al.* Retardamento de colheita, método de secagem e qualidade de sementes de mamona. **Revista Brasileira de Sementes**, v. 31, p. 9-15, 2009.