

Scientific Electronic Archives

Issue ID: Sci. Elec. Arch. Vol. 15 (5)

May 2022

DOI: <http://dx.doi.org/10.36560/15520221543>

Article link: <https://sea.ufr.edu.br/SEA/article/view/1543>



Water content in *Annona squamosa* seeds under different temperature and relative humidity conditions of storage environment

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Abstract. The conditions of the storage environment, mainly related to temperature and relative humidity, influence the interaction of seeds with the environment and, consequently, the water content of the product. The study aimed to analyze the influence of ambient temperature and relative humidity on the water content of *Annona squamosa* seeds. The experiment was carried out in a completely randomized design with a 5x7 factorial scheme, with five temperatures (15, 20 and 25, 35, 40°C) and seven conditions of relative humidity with nine replications. The equilibrium moisture content of the seeds was analyzed by mass difference. Data were subjected to analysis of variance by the F test and regression analysis. For significant interaction between the sources of variation, multivariate analysis was performed. Through regression analysis, linear models were obtained for the analyzed temperatures. Through multivariate analysis, a mathematical model was obtained to predict the equilibrium humidity of the pinecone considering temperature and relative humidity. The moisture in *A. squamosa* seeds is influenced by the temperature and relative humidity of the environment. Obtaining a mathematical model by multivariate analysis allows an adequate prediction of equilibrium moisture.

Keywords: Hygroscopicity, postharvest, potential specie.

Introduction

Annona squamosa belongs to the Annonaceae family, whose biomass has high potential as a raw material for oil extraction industries, being even a source for obtaining quality biofuel, as an alternative way to obtain it (Silva & Pereira, 2018; Barros et al., 2020).

In the field, upon reaching the point of maturation, the seed exposed to several factors that can favor its deterioration. During post-harvest, seeds have a reduced respiratory process, but

inadequate conditions can increase the consumption of compounds with increased metabolic activity (Lima et al., 2021; Saath et al., 2021). Maintaining storage environment conditions is important to reduce biochemical activity, aiming to reduce losses (Gugé et al., 2019; Sá et al., 2021), with temperature and relative humidity being the main factors related to conservation (Jaques et al., 2019).

Due to their hygroscopic capacity, the seeds maintain a constant dynamic of interaction of gas exchange with the atmosphere, being able to give or

absorb water to the ambient air due to the difference in water vapor pressure, until they reach equilibrium humidity (Amaral et al., 2019; Teixeira et al., 2020; Wenneck et al., 2020; Sá et al., 2021).

Considering the impact of the environment on seed properties, the study aimed to analyze the influence of ambient temperature and relative humidity on the water content of *A. squamosa* seeds.

Materials and Methods

The study was conducted at the Laboratory of Medicinal Plants and Post-harvest Technology belonging to the State University of Maringá (UEM), Maringá-PR. The fruits were collected on a rural property in the municipality of Campo Mourão-PR (23°59'11.63"S, 52°29'52.02"W and altitude of 535 m), and the seeds were removed from fresh fruits, washed in running water and kept in the metal tray in the shade to remove excess water.

The experiment was carried out in a completely randomized design with a 5x7 factorial scheme, with five temperatures (15, 20 and 25, 35, 40°C) and seven conditions of relative humidity (Table 1) with nine replications. The samples were kept in hermetic packages containing salts to simulate different conditions of relative humidity. The packages were kept in Biochemical Oxygen Demand (BOD) with constant temperature.

An analysis of the equilibrium moisture content of the seeds by mass difference was performed. The material, when presenting constant mass, under storage conditions, was weighed on an analytical balance (± 0.001 g) to determine the wet mass. The dry mass was obtained in an oven with forced air circulation (105°C for 24 hours) with subsequent determination of the mass in an analytical balance. Moisture was determined by the difference in mass of wet and dry product, according to equation 1, and the result was expressed in % dry basis (db).

$$\text{Water content (\%db)} = \left(\frac{\text{wet mass (g)} - \text{dry mass (g)}}{\text{dry mass (g)}} \right) \times 100 \text{ (Equation 1)}$$

Data were subjected to analysis of variance by the F test and regression analysis. For significant interaction between the sources of variation (temperature and relative humidity) a multivariate analysis was performed, obtaining a mathematical

model to predict equilibrium humidity and a three-dimensional response surface graph. For data analysis, Microsoft Excell®, Surfer® and Sisvar software were used (Ferreira, 2019).

Table 1. Simulated relative humidity at different temperatures.

Saturated solution	Temperature (°C)					
	15	20	25	35	40	50
Potassium hydroxide	9.0	8.5	8.0	6.9	6.3	6.3
Potassium acetate	23.5	23.0	22.5	20.8	21.0	19.2
Potassium carbonate	33.5	33.0	32.5	32.0	31.7	31.2
Magnesium chloride	44.0	44.0	43.2	43.2	43.0	43.3
Calcium nitrate	58.0	56.0	52.8	52.6	52.3	52.2
Sodium chloride	75.5	75.3	75.2	75.1	74.8	74.6
Potassium chloride	86.0	85.0	84.3	82.2	82.0	80.2
Barium chloride	91.2	90.8	90.4	89.6	89.3	89.2

Adapted from: Wenneck et al. (2020) and Sá et al. (2021).

Results and discussion

Equilibrium humidity is variable in relation to product properties and environmental conditions, mainly related to temperature and relative humidity. The answers are different in relation to temperature, and linear models are obtained for temperatures ranging from 15 to 40°C (Table 2).

Knowledge of isothermal sorption models allows obtaining important information for handling, associating preventive measures with product quality maintenance (Aghazadeh et al., 2021; Wenneck et al., 2020). The water content influences the thermodynamic properties (Campos et al., 2019) and in conditions of relative humidity above 70% it can cause physical and chemical changes with

potential for deterioration (Yang et al., 2012; Veronezi & Jorge, 2012; Severino et al., 2019; Saath et al., 2019).

Studies developed by Sá et al. (2021) analyzing the water content in peanut seeds also obtained a linear increase as a function of the relative humidity of the environment. This factor may be associated with the chemical compositions of the species, with peanuts being an oilseed and the *A. Squamosa* seed presenting approximately 30.41% oil (Abdualrahman et al., 2019). Still, other factors considered since the exchange of water vapor between the environment and the product influenced by the physical characteristics of the grain.

Considering the interaction of the factors temperature and relative humidity for the water content in *A. Squamosa* seeds, a multivariate analysis was performed to determine a mathematical model for the prediction of equilibrium humidity (Equation 2). This analysis technique used in several studies, as it considers the factors simultaneously (Kemsley & Marini, 2019).

$$WC = 12.406 + 0.04425 \cdot RH - 0.18742 \cdot T \quad R^2 = 0.96$$

(Equation 2)

Where,
WC= Water content (%db);

RH= Relative humidity (%);
T= Temperature (°C).

The multivariate mathematical model allows the prediction of equilibrium humidity at unanalyzed temperatures (Table 2), according to the interval adopted in obtaining the data. Based on the multivariate equation, a graph with a three-dimensional response surface was constructed (Figure 1).

Table 2. Equilibrium moisture equations in *A. squamosa* seeds.

Temperature (°C)	Equation	R ²
15	$y = 0.033x + 10.495$	0.93
20	$y = 0.0389x + 8.6721$	0.96
25	$y = 0.0444x + 7.5319$	0.97
35	$y = 0.0552x + 5.6694$	0.99
40	$y = 0.0509x + 4.3114$	0.99

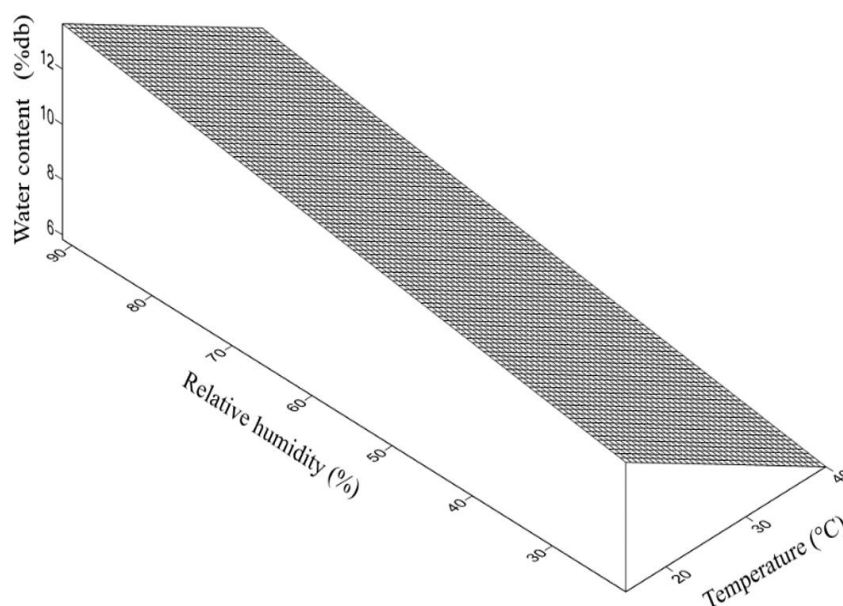


Figure 1. Response surface for equilibrium moisture in *A. Squamosa* seeds.

The storage of grains with low humidity allows quality maintenance, with a reduction of biochemical and microorganism activities (Saath et al., 2021). However, changing the characteristics of the air (temperature and relative humidity) in the storage environment can generate costs, and information on seed exchanges with the environment is important to make the process more efficient.

Although there are few studies analyzing the storage of *A. Squamosa* seeds, promising results from the use of compounds extracted from the seed are reported in medicine, such as cytotoxicity in

cancer cells, and in the industry in the production of biodiesel (Vikas et al., 2019; Barros et al., 2020), characterizing it as a product with economic potential.

The results obtained allow us to understand the influence of temperature and relative humidity in the environment on the water content of the seeds, and further studies needed to analyze the changes caused by storage in the composition and quality of the extracted compounds.

Conclusion

The moisture in *A. Squamosa* seeds is influenced by the temperature and relative humidity of the environment.

Obtaining a mathematical model by multivariate analysis allows an adequate prediction of equilibrium moisture.

Acknowledgment

The Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Fundação Araucária.

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