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DIMENSION CHARACTERISTICS EVALUATION OF COFFEE BERRIES DURING DRYING

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ABSTRACT Surface and volume measurements are important parameters that affect storage and shipping space, spray and gas applications, respiration rates, water loss or absorption data and heat and mass transfer coefficients. Also, drying models usually neglect the volume and surface alterations of agricultural products during the dehydration process, which leads to machinery and handling inefficiency. That being stated, the objective of the present work was to study the dimension alterations of Coffea Arabic L., cultivar Catuaí Vermelho. Coffee berries were dried at temperatures (T) of 35, 45, 55 and 65 ºC, along with relative humidities (φ) of 25, 35, 45 and 55 %, totalizing 16 different conditions, with initial moisture content of 2.27 dry basis (d.b.), dried until approximately 0.11 d.b. An equation was proposed to describe the relationship among superficial area with weight values of coffee berries. Changes in the product dimensions were measured continuously during drying utilizing a digital caliper. Surface area-to-volume ratio values increased with moisture content decrease. According to statistical parameters, the empirical equation was suitable to predict surface area of coffee berries. With this result, engineers can predict the surface area of coffee through its weight, providing information that can be used to develop adequate machinery to use in harvest and postharvest procedures.

Keywords: Surface area-to-volume ratio, Postharvest, *Coffea arabica L.*, Physical properties.

INTRODUCTION Drying process or dehydration of foods is one of the most common method to assure quality and stability of agricultural products, decreases the water activity of the material, reduces biological activity, and chemical and physical changes are reduced during its storage. Moisture loss leads to cellular structural modifications and consequently alters product shape and dimension, and these changes, according to Yan et al. (2007), influence the products physical properties, modifies final texture and transport properties of the dry foods. This information is particularly important to coffee, once that it presents a high level of moisture content at the beginning of drying process, leading to the pronounced physical modifications observed during the drying of this product.

Volumetric behavior of a grain or fruit during drying process is determinant to estimate tension levels which the product is submitted in function of temperature and humidity gradients, as well when developing equipment, processes and simulation models. Additionally, superficial area, shape and dimensions of an agricultural product are crucial data for mass and heat transfer studies as well as airflow within a granular mass of the product. These parameters and additional information, such as moisture content, are used for predicting storage and drying conditions of grain and cereals and quality losses during the postharvest period.

Agricultural products with high initial moisture content such as coffee ($\approx$ 60 % w.b.) (Resende et al., 2009), easily loses moisture via diffusion to the drying surrounding environment, due to the great water vapor pressure difference among the product and air. Depending upon evaporative demand of drying air, moisture loss rate contributes to a marked reduction of moisture content, material dimensions, and consequently, volume.

Information regarding surface and volume measurements are useful into calculations of storage and shipping space, spray and gas applications, respiration rates, or water loss or absorption data (Eifert et al., 2006). According to these authors, surface area also is important when calculating the amount of coating to be applied to processed food products to extend shelf-life, as well as the transfer of heat, water vapor, gases, pesticides and nutrients moving in and out of food products. Furthermore, heat and mass transfer coefficients depend on the shape and surface area of the object being analyzed, as well volume dependent properties (Goñi et al., 2007).

Several authors studied the influence of different process conditions at materials volume change during dehydration. Ramos et al. (2004) studied microstructural changes in cells of grape during first stage of convective air drying, concluding that even though cell dimensions suffered modifications during drying, their shape remained unchanged. McMinn and Magee (1997) analyzed the temperature effect over potato, Ratti (1994) investigated air velocity and relative humidity (φ) influence over potato, apple and carrot and Afonso Júnior et al. (2003) examined the effect of moisture content variation on reduction of superficial area, volume and equivalent sphere diameter of coffee berries. However, these studies haven't satisfactory concluded the different process conditions influence over the dimension characteristics of the product.

The measurement of the surface area of irregularly shaped fruits and vegetables can be obtained by different methods: products can be peeled and traced their outlines on paper; three-dimensional image analysis can be used; exploit atomic force microscopy; water or oil displacement when the product is submerged; and utilizing linear and non-linear relationships between surface area and easily measured parameters, such as weight, volume and two-dimensional characteristics.

Thus, the aim of this work was to determine the influence of various drying temperatures and relative humidities on the dimension characteristics of coffee berries during drying. These include change in area and volume, which directly affect the visual attributes of the fruit. In addition to mentioned parameters, a new correlation among surface area and weight of coffee berries were investigated.

MATERIALS AND METHODS The present work was conducted in the Laboratory of Physical Properties and Quality Evaluation of Agricultural Products at the National Grain Storage Training Center – CENTREINAR, Federal University of Viçosa, Viçosa, MG, Brazil.

Coffee berries (*Coffea Arabica* L.) from Catuaí Vermelho cultivar were purchased from a local farmer. They were manually harvested at cherry stage with initial moisture content of 2.27 d.b., immature, deteriorated or damaged fruits were eliminated, with the purpose to obtain a material more homogeneous with elevated quality.

Initial moisture content was achieved by the oven method at 105 ± 1 ºC until a constant mass was obtained, in triplicates. Reduction of moisture content along drying time was supervised through weight loss, knowing the product initial moisture content, until a final moisture content of approximately 0.11 d.b. For this monitoring, a digital chronometer and an analytical balance with 0.01 of precision were utilized.

Drying treatment were placed in a factorial scheme 4 x 4, with four temperature levels (35, 45, 55 and 65 ºC) and four levels of relative humidities of drying air (25, 35, 45 and 55 %), in a completely randomized design. They were achieved by a temperature controlled chamber, manufactured by Aminco, model Aminco-Aire 150/300 CFM. Removable perforated trays were placed inside the equipment to allow air to pass through the samples, each containing 50 g of product. Airflow was monitored with an anemometer with rotating blades and kept around 10 m^3 min^{-1} m^{-2}. Temperature and air relative humidity were monitored with a psychrometer installed next to the trays containing the samples.

Product dimension were measured using a digital caliper for the three orthogonal axes of coffee berries after weighting the samples over the moisture content range of 2.27 to 0.11 d.b., with ten repetitions for each condition, in order to obtain the product volume (V).

Surface area-to-volume ratio (SVR) SVR was obtained through Equations 1 and 2. It was considered that coffee berry can be represented by a prolate spheroid shape type (Mohsenin, 1986), as seen in Figure 1.

$$V = \frac{\pi abc}{6} \tag{1}$$

$$S = \frac{\pi b^2}{2} + \frac{\pi ab}{2e}\sin^{-1} e \tag{2}$$

$$e = \left[1 - \left(\frac{b}{a}\right)^2\right]^{1/2} \tag{3}$$

In which,

V: volume, cm^3;

S: surface area, cm^2;

a: longest intercept, mm;

b: longest intercept normal to a, mm;

c: longest intercept normal to a and b, mm;

e: eccentricity, dimensionless.

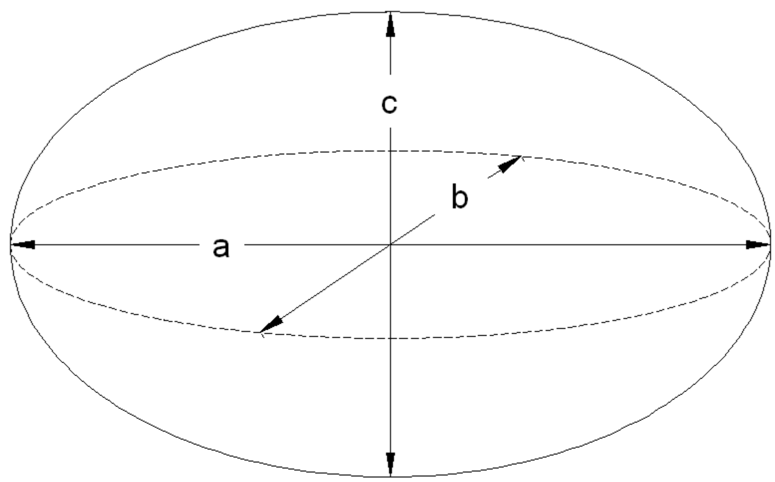

Figure 1. Schematic draw of a coffee berry considered as a prolate spheroid shape type and its characteristics dimensions.

Surface area (S) and weight (W) relationship Mohsenin (1986) states a relationship between weight and surface area for spheroid products (Equation 4):

$$S = \xi W^d \qquad (4)$$

In which,

S: surface area, cm^2;

d, ξ: constant, dimensionless;

W: weight, g;

Quantifying superficial area of agricultural products is a difficult process due to these foodstuffs doesn’t have a uniform and homogeneous form, and also requires a great amount of time and replicates, giving a large range of errors. On the other hand, weight measurement is easy to obtain with a simple weighing scale, and therefore this equation provides a simple approach to acquire values of superficial area by means of product weight. This information is essential to develop and improve drying equipments and help studies over mass and heat transfer.

The equation best fitting was evaluated through calculation of the mean relative percent deviation (P), Equation 5, in %, standard error (SE), Equation 6, decimal, along with analysis of the determination coefficient (R^2).

$$P = \frac{100}{n} \sum_{i=1}^{n} \left(\frac{\left| X_{\exp} - X_{pre} \right|}{X_{\exp}} \right) \quad (5)$$

$$SE = \sqrt{\frac{\sum_{i=1}^{n} \left(X_{\exp} - X_{pre} \right)^2}{DF}} \quad (6)$$

In which,

n: number of observations, dimensionless;

X_{exp}: experimental values of the equilibrium moisture content, d.b.;

X_{pre}: predicted values of the equilibrium moisture content through the model, d.b.;

DF: degrees of freedom of the model.

Values below 10% of the mean relative error indicate a good fitting for practical purposes (Mohapatra & Rao, 2005).

RESULTS AND DISCUSSION

Surface area-to-volume ratio (SVR) Figure 2 demonstrates the changes in the dimension characteristics of coffee berries at the beginning and the end of drying process.

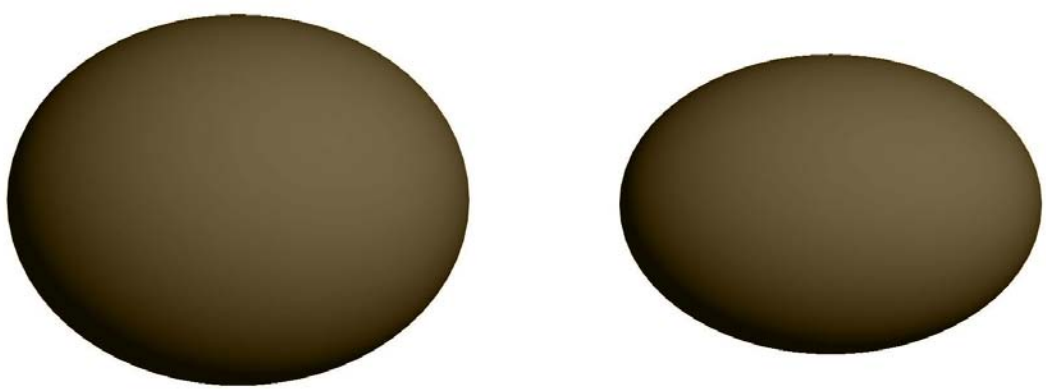

Figure 2. Representation of the changes in the dimension characteristics of coffee berries.

Ten repetitions were made for each berry continuously during drying, and an average of a, b and c values were attained in order to obtain the product volume. Volume values ranged from 10.59 x 10^{-7} to 6.43 x 10^{-7} m at the beginning and end of drying, respectively. The product dimensions varied 1.22, 2.23 and 2.18 mm for a, b and c, respectively. Through these results, it can be concluded that coffee grains presents irregular decrease of its dimension characteristics during drying process, such as several agricultural products. Fortes and Okos (1980), which analyzed the alterations of corn during drying, Kaleemullah and Gunasekar (2002) researching the physical properties of arecanut kernels, Resende et al. (2005) for beans and Goneli (2008) working with castor beans, also observed this trend.

Alterations in the product dimension characteristics are more relevant at the initial stages. As the drying process occurs, the product tends to an equilibrium state, and that way variations in volume and surface starts to become more difficult to take place, leading to a stability condition of the product dimension characteristics.

Figure 3 demonstrates the SVR tendency to decrease with moisture content (d.b.) increase. As moisture content increases, both surface area and volume raises; however, volume increase proportion is higher than surface area, leading to lower SVR values.

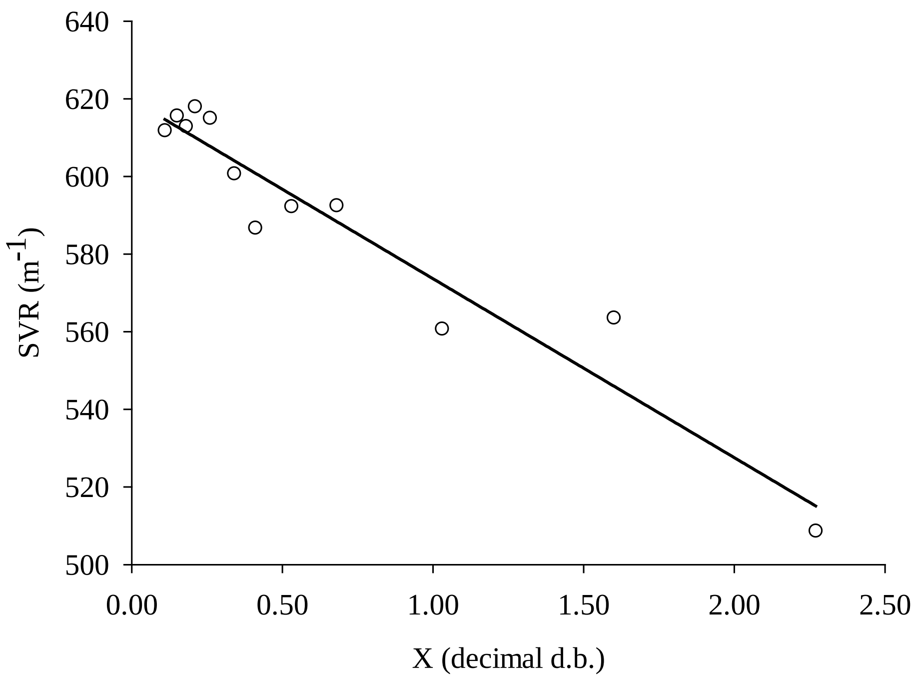

Figure 3. Surface area-to-volume ratio (SVR) as a function of moisture content (X).

Surface area (S) and weight (W) relationship Different relationships between surface area and some easily measured attributes such as weight, volume and two-dimensional measures have been reported throughout the specialized literature (Baten and Marshall, 1943; Frechette and Zahradnik, 1966; Banks, 1985; Humeida and Hobani, 1993; Clayton et al., 1995; Maw et al., 1996).

Recently some new techniques of image analysis have been developed to obtain volume and surface area of several products. However, these procedures require trained staff and equipments that lead to a higher cost when compared to surface area relationships with weight of agricultural products. Eifert et al. (2006) reported linear equations to predict the surface area of apples, cantaloupe, strawberry and tomato from weight measurement, and Goñi et al. (2007) also stated equations that correlate weight and surface area for apple and meat. However, before the present work, no studies between surface area and weight of coffee berries have been published in the specialized literature.

The ξ and d parameters were obtained through software STATISTICA 7.0® and provided *P*, *SE* and R^2 values of 2.077, 0.1392 and 0.9134 respectively, which indicates the good fitting data to the empiric equation, allowing the use of Equation 7 to predict surface area through the coffee berry weight at the moisture content range of 0.11 to 2.27 d.b.

$$S = 3.982756W^{0.278892} \tag{7}$$

CONCLUSION Volume decreased during drying process, with a total decrease of 39.28 %, while dimension characteristics also diminished, with a total variation of (8.62, 17.74 and 19.19) % respectively for a, b and c dimensions. Surface area-to-volume ratio had the tendency to decrease as moisture content increased. This trend can be explained by the fact that the proportion of volume increase is greater than surface area with the increment of moisture content. Prediction of surface area throughout coffee berry weight was satisfactory by the empirical equation formulated at the moisture content range of this study.

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