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PHYSICAL CHARACTERISTICS OF PSEUDOCEREALS SEEDS

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ABSTRACT: Looking for alternatives to supply the world's food demand, and the numerous benefits of new crops as the pseudocereals. It becomes increasingly necessary studies on this subject, for production, management and consequently its commercialization. Then, aimed to evaluate the physical properties of amaranth and quinoa seeds. The length, width and thickness were 0.825 mm, 1.287 mm and 1.389 mm for amaranth seeds and 2.025 mm, 2.04 mm, 1.06 mm for quinoa. The specific mass and weight of one thousand amaranth seeds were 804.7 kg m^{-3} and 0.78 g and for quinoa seeds of 720.7 kg m^{-3} and 3.01 g. Water content in amaranth and quinoa seeds close to 13% provides 25º in the angle of inclination. The dimensions and sphericities of the quinoa and amaranth seeds are decisive for the selection of the set of sieves and processing.

Keywords: *Amaranthus cruentus, Chenopodium quinoa*, sphericity, porosity.

CARACTERÍSTICAS FÍSICAS DAS SEMENTES DE PSEUDO CEREAIS

RESUMO: Com o aumento da população mundial, busca-se alternativas para suprir a demanda mundial de alimentos. Em vista disso, e dos inúmeros benefícios da exploração de novas culturas, como ocorre com os pseudo-cereais, torna-se cada vez mais necessário estudos sobre esse assunto, portanto, resultados que permitem a implantação dessas culturas no setor produtivo são de extrema relevância, com o objetivo de facilitar sua produção, gerenciamento e consequentemente sua comercialização. O objetivo deste estudo foi avaliar as propriedades físicas de sementes de amaranto e quinoa. O comprimento, largura e espessura foram de 0,825 mm, 1,287 mm e 1,389 mm para sementes de amaranto e 2,025 mm, 2,04 mm, 1,06 mm para quinoa. A massa específica e o peso de mil sementes de amaranto foram 804,7 kg m-³ e 0,78 g e para sementes de quinoa de 720,7 kg m-³ e 3,01 g. Teores de água nas sementes de amaranto e quinoa próximos a 13% proporcionam 25º no ângulo de inclinação. As dimensionalidades e esfericidades das sementes de quinoa e amaranto são determinantes para a seleção do conjunto de peneiras e beneficiamento.

Palavras-chave: Amaranthus cruentus, Chenopodium quinoa, esfericidade, porosidade.

INTRODUCTION

The diversification of crops adds numerous benefits, among them the reduction of risks and uncertainties of a single crop. Although widely known and exploited by the indigenous peoples of South America, mainly Mayans and Aztecs, pseudocereals have lost space as a source of food over time (CASINI; ROCCA, 2014). Among the species that make up the group of pseudocereals are the quinoa (*Chenopodium quinoa* Willd.), buckwheat (*Fagopyrum esculentum* Moench.) and amaranth (*Amaranthus* sp.), all of which have been gaining prominence due to their nutritional composition. The pseudocereals can be understood to have characteristics similar to cereals. They are crops that have been studied in recent years due to their versatility and adaptation to the most varied environments in their places of origin, as well as their proven contribution to complementing human and animal food and its high market value (SPEHAR, 2007).

The amaranth and quinoa crops stand out particularly as a source of good quality protein, which is comparable to milk casein and is present in the grain, leaves, as well as in the inflorescences of plants. Also, its in human food is the absence of gluten, perfectly adapting to the diet of celiac people (FERREIRA, et al., 2004). The nutritional quality of quinoa, for example, is characterized by having lysine, an amino acid absent in cereals, as well as having a better distribution of essential amino acids, as well as high amounts of vitamins such as riboflavin, niacin, thiamine, B6, and minerals such as magnesium, zinc, copper, iron, manganese and potassium (BORGES et al., 2003). Amaranth is a carbohydrate source grain, has about 15% protein, containing all the amino acids essential to the body. It also has fibers, calcium, phosphorus and selenium (COSTA, 2007).

In addition to the innumerable benefits of these crops, in human and animal feeding, pseudocereals can be alternative cultivation, which can add value to the product and promote the productive development of a region. In Brazil, crop losses occur for a variety of reasons, many of them related to processes, for example losses during storage are frequent. Considering that pseudocereals are becoming alternative crops and being widely exploited, the knowledge of physical properties becomes fundamental. The size, weight, shape, color, volume serves as a basis in the design of conveyors, cleaning and separation equipment.

The knowledge of the dielectric properties of grains and seeds is vital in many areas of science and engineering, both in basic and applied research (BARTTLEY; NELSON, 2002). In agriculture, the dielectric properties of grains have been widely used to determine the water content due to the rapid detection of moisture. The degree of detection moisture is based on the correlation between the dielectric properties of the grains and the amount of water present. Most agricultural and food products are hygroscopic, and there is a large difference in the dielectric properties of dry matter and water (NELSON; BARTTLEY, 2000; SZARESKI et al.,2018).

Considering the great importance of the exploitation of these crops and variability in the physical properties of agricultural products, the present work aimed to evaluate the physical properties of pseudocereal seeds (quinoa and amaranth).

MATERIAL AND METHODS

The work was developed in the Seed Didactic Laboratory of the Plant Science Department in conjunction with the Post Harvest Laboratory of the Engineering Center, both of the Federal University of Pelotas. Seeds of quinoa (cultivar BRS Piabiru) and amaranth (cultivar BRS Alegria) were used.

Physical characteristics analyzed:

Porosity: for the evaluation of granular mass porosity was determined by the average of seven replicates, through the soybean oil method, for which two 50 mL measuring cylinders were used, where the volume of added liquid was known (GUIMARÃES et al., 2015). The liquid was added to the measuring cylinder where the grains were (quinoa and amaranth) for determination. The results were obtained in %.

$$\boldsymbol{P}(\%) = \frac{V_{Empty}}{V_{Total}} \quad \text{(Equation 1)}$$

Angle of repose: for the determination of the angle of repose, a device was used with suspended funnel, through which the mass of grains was poured on a flat surface. After, it was calculated by the arc-tangent of the quotient of the height by the radius of the grain mass (GUIMARÃES et al., 2015).

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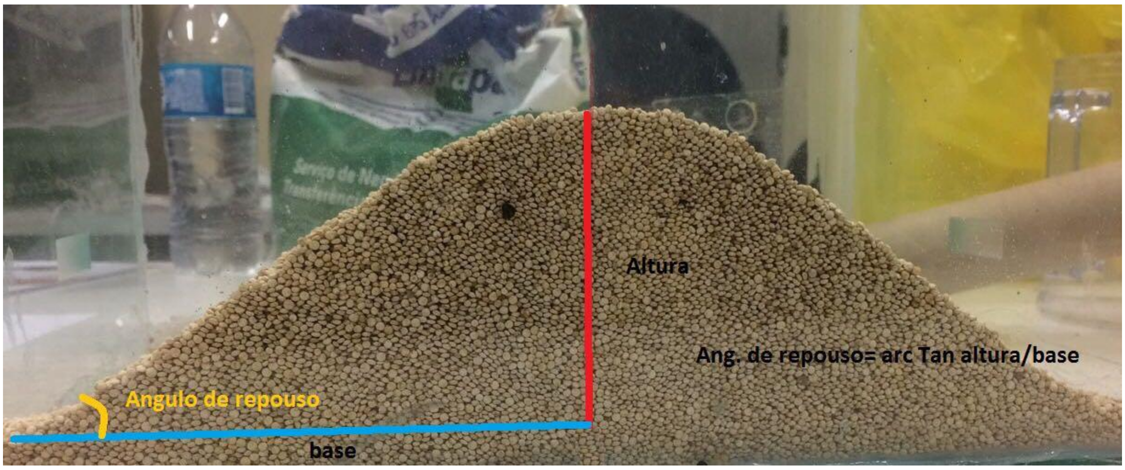

Figure 1. Determination of the quinoa angle of repose.
Figura 1. Determinação do ângulo de repouso de quinoa.

Figure 2. Schematic representation of the angle of repose.
Figura 2. Representação esquemática do ângulo de repouso.

$$\theta_{repose} = \tan^{-1}\left(\frac{2h}{d}\right) \quad \text{(Equation 2)}$$

Where,

h: height of the cone formed by the seed mass at repose

d: diameter of the cone formed by the seed mass

Three-dimensional dimension: the length, width and thickness of amaranth and quinoa grains were evaluated through an analog caliper. Ten seeds randomly taken from the mass were used and the mean of the measurements was calculated, and the reading in millimeters. The sphericity of the seeds was also determined.

Dielectric property: a cylindrical capacitive sensor was used to determine the dielectric property of the seeds (Figure 3). The sensor is composed of two concentric metal cylinders with different diameters, where the seed is stored between the two cylinders (Figure 4) connected to a capacitance meter (Figure 5) where capacitance means are performed. Where the relation between the capacitance of the seed-fed sensor and the capacitance of the empty sensor (Equation 3) is directly the value of the dielectric property. The measurements of dielectric properties were repeated three times, obtaining the mean value of the measurements, according to Araújo (2017), the expressed results are dimensionless.

$$\frac{C_{full} = \varepsilon_0 . \varepsilon_r . L . \ln\left(\frac{D_B}{D_a}\right)}{C_{empty} = \varepsilon_0 . L . \ln\left(\frac{D_B}{D_A}\right)} = \varepsilon_r \qquad \text{(Equation 3)}$$

Where,

C_{full} – Sensorcapacitancewithseedsinside

C_{empty} – Emptysensorcapacitance

ε_r –Relative permissibility of the study material

ε_0 – Permissivenessofthevacuum $\sim 8,54 \times 10^{-12} F.m^{-1}$

L – Heightofcylinders

D_A – Externaldiameterofinnercylinder (A)

D_B – Internaldiameterofinnercylinder (B)

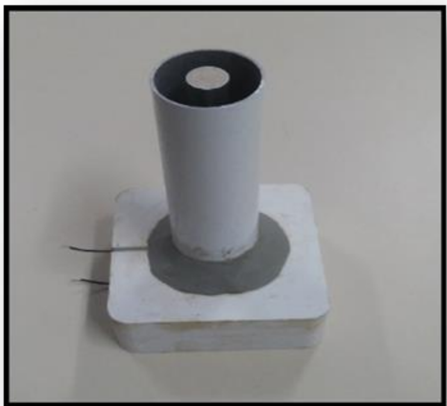

Figure 3. Cylindrical capacitive sensor for determination of dielectric property of seeds.
Figura 3. Sensor capacitivo cilíndrico para determinação da propriedade dielétrica das sementes.

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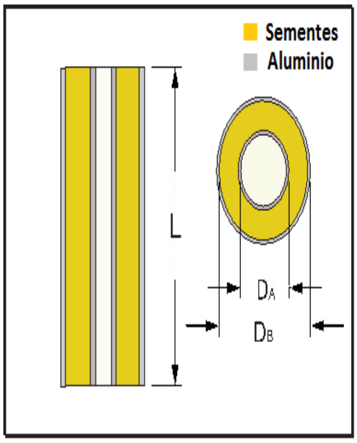

Figure 4. Concentric metal cylinders with different diameters Araújo (2017).
Figura 4. Cilindros de metal concêntricos com diferentes diâmetros Araújo (2017).

Figure 5. Concentric metal cylinders connected to the capacitance meter.
Figura 5. Cilindros de metal concêntricos conectados ao medidor de capacitância.

Specific mass: an electronic scale with a resolution of 0.01 g and a measuring cylinder with a capacity of 0.25 L (Figure 6) were used (SIQUEIRA et al., 2012). In order to guarantee the natural accommodation of the seeds, in addition to the homogeneity between replicates, a funnel was used, supported to the container where they were poured. In order to evaluate the specific mass (ρ), its mass was divided by its volume, (GUIMARÃES et al., 2015), that is, the grain mass contained in a volume unit (Figure 6).

$$\rho = \frac{\mathbf{M\ sample}}{\mathbf{V\ cylinder}} \qquad \text{(Equation 4)}$$

Where,

ρ- apparent weight

M- sample mass

V- volume of the measuring cylinder

Figure 6. Seed mass contained in a volume unit.
Figura 6. Massa de sementes contida em uma unidade de volume.

Mass of one thousand seeds: eight samples composed of 100 seeds (amaranth and quinoa) were used, where they were counted manually and later weighed (BRASIL, 2009).

Statistical analysis: Descriptive statistics were performed, analyzing mean, and coefficient of variation. After the data were tabulated or represented in graphs.

RESULTS

The values found for all variables studied in the two species, BRS Alegria amaranth and BRS Piabiru quinoa were found, with water contents of 13.1% and 12.5%, respectively (Table 3). For the porosity variable, the mass values of the amaranth and quinoa grains are presented in (Table 1).

Table 1. Measures obtained for sphericity (%), porosity (%) and angle of repose (°) of amaranth and quinoa seeds.
Tabela 1. Medidas obtidas para esfericidade (%), porosidade (%) e ângulo de repouso (°) de sementes de amaranto e quinoa.

Species	Sphericity (%)	Porosity (%)	Angle of repose (°)
Amaranth	95,05	35,5	25,002
Quinoa	51,61	39,7	28,264
C.V. (%)	5,92	11,5	3,13

The porosity observed in this water content of the crops was 35.5 and 39.7% of amaranth and quinoa, respectively. Abalone et al. (2004), evaluating the physical properties of amaranth seeds verified that the porosity, in approximately 15% of the water content, remained between 35 and 40%. As the water content of amaranth seeds increased, their porosity increased, that is, seeds stored with a higher or lower water content may influence this characteristic.

The results presented from the angle of repose (Table 1) are 25.00° and 28.26° slope angle for amaranth and quinoa. Moscon (2015) found angles of 23.49° for amaranth and 37° for quinoa, for water contents similar to the present work. In chia seeds, found slope angles between 16° and 18°. Vilche et al. (2003) observed that there are differences in the angles formed depending on the surface used and also the water content of the seeds.

For the sphericity in the amaranth crop it was 93%, whereas for the quinoa crop it was 52% (Table 1). This result indicates that grains / seeds that approach the unit (1) of sphericity, the more spherical is the grain (GUIMARÃES, 2015). In Table 2 and Figure 1, the three-dimensional dimensions of the two crops (amaranth and quinoa) are presented.

Table 2. Observed values of three-dimensional dimensions (width, thickness and length in mm) of amaranth (BRS Alegria) and quinoa seeds (BRS Piabiru).
Tabela 2. Valores observados das dimensões tridimensionais (largura, espessura e comprimento em mm) de sementes de amaranto (BRS Alegria) e quinoa (BRS Piabiru).

		Three-dimensional dimensions (mm)				
Crop		Average	Standard deviation	Kurtosis	Median	CV (%)
Amaranth	l*	0.825	0.037	0.512	0.840	4.44
	w**	1.287	0.084	-0.986	1.270	6.49
	t***	1.389	0.078	-0.338	1.370	5.62
Quinoa	l*	2.025	0.116	-1.188	2.020	5.73
	w**	2.041	0.104	-1.019	2.020	5.09
	t***	1.060	0.056	-0.959	1.060	5.32

* length

**width

***thickness

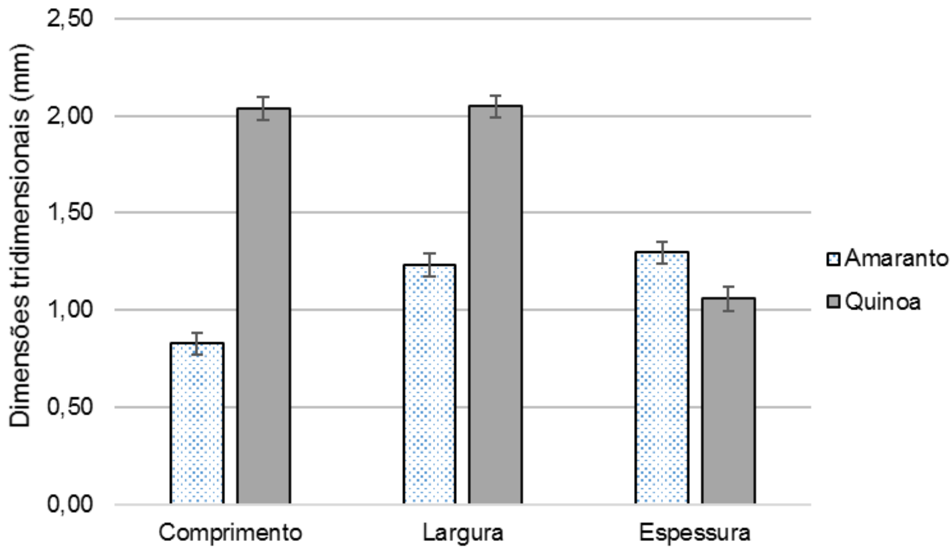

Figure 7. Three-dimensional dimensions (width, thickness and length mm) of amaranth (BRS Alegria) and quinoa seeds (BRS Piabiru).

Figura 7. Dimensões tridimensionais (largura, espessura e comprimento mm) de sementes de amaranto (BRS Alegria) e quinoa (BRS Piabiru).

The values observed were 0.82 mm, 1.28 mm and 1.38 mm in length, width and thickness, respectively for amaranth and 2.02 mm, 2.04 mm and 1.06 mm in length, width and thickness, respectively for quinoa seeds. These parameters are used for the sizing and selection of the size and shape of the sieves in the sorting of the grains.

Another important physical property in the design of industrial processes in harvest and post-harvest operations is the electrical property, since it determines the moisture of grains and seeds. Table 3 presents the results of dielectric permittivity, specific mass and mass of 1000 seeds of amaranth and quinoa seeds.

Table 3. Measures obtained for relative dielectric permittivity, specific mass (kg m^{-3}) and mass of 1000 seeds (g) of amaranth and quinoa seeds.

Tabela 3. Medidas obtidas para a permissividade dielétrica relativa, massa específica (kg m-3) e massa de 1000 sementes (g) de sementes de amaranto e quinoa.

Species	Relative dielectric permittivity	Specific mass (kg m^{-3})	Mass of 1000 seeds (g)
Amaranth	3.268	804.779	0.078
Quinoa	3.107	720.678	0.301
C.V. (%)	1.69	1.28	2.74

The observation of the results of electrical permittivity of a given material (seed or grain) is used for moisture meters in agroindustries, seed marketing and also in grain harvesters, measuring the humidity in real time. It can be observed that relative electrical permittivity in amaranth seeds was 3.26, whereas for quinoa seeds it was 3.10. The specific mass for the amaranth crop was 804 kg.m-^{3} whereas for quinoa it was 720 kg.m-^{3} (Table 3). The specific mass is obtained from the relationship between the mass of the product and the volume occupied by the mass, this includes the intergranular spaces (DIAS, 2007).

To evaluate the mass of one thousand seeds, the average of amaranth seeds was 0.78 g and quinoa 3.02 g, respectively, at 13.1% and 12.5% water contents (Table 3). Moscou (2015) highlighted the weight of one thousand seeds for quinoa from 3.23g to 12.47% of water content and amaranth at a water content of 11.58% and one thousand seeds of 0.86g. These results depend on several factors such as environments and genetic.

Further research on the physical properties of pseudocereals should be studied, since they are crops with large agricultural growth, due to their numerous benefits.

DISCUSSION

The porosity is defined as the ratio between the volume occupied by the air in the seed mass and the total volume occupied by this mass (DIAS, 2007). The evaluation and determination of this characteristic has an influence on the design of fans and consequently the power of motors in a drying system. It is through this determination that the air pressure required to cross the mass of the product is known (SILVA et al., 2000).

The relationship of the increase in water content was also observed by Vilche et al. (2003) in quinoa seeds. This ratio, compared to amaranth seeds, has become broader. Moscon (2015) verified that the drying of quinoa seeds decreased the porosity of the seed mass of the crop, obeying a linear behavior of the relationship between water content and porosity.

The observed results of the angles formed of amaranth and quinoa grains are inferior to the angles formed by linseed grains 33.4° to 16.81% (COSKUNER; KARABABA, 2007) and superior angle (17.1°) to chia seeds with a 7% water content (IXTAINA et al., 2008). Friction properties such as slope angle or angle of repose are important properties related to storage structures, such as the flow behavior of materials.

Penha et. al. (2007), observed that for water content of 11.9% in quinoa seeds, it obtained values of 2.3mm length, 2.1mm width and 1.3mm thickness. For amaranth seeds, Abalone et. al. (2004) pointed out to the same dimensions values of 1.42 mm, 1.29 mm and 0.87 mm for length, width and thickness, respectively, but in a humidity range of 9.5 - 43.6%. These dimensions depend on each cultivar, ie genetically defined, which can be determined during the period of physiological maturity of the seeds, for example. These changes in the environment may influence the physical properties of the species.

In the case of seeds, it is known that the moisture of a particular batch, for example, is of the utmost importance, since this characteristic can describe its physiological quality, the knowledge of the moisture of the grain or of the seed at the time of harvesting can guarantee product with a higher quality (MOSCON, 2015).

The ability of a material to store or dissipate electrical energy is called electrical capacitance, which is a factor of its permissiveness, this property serves, for example, to elucidate the interactions of the material with the electric field, that consideration is related to the degree of humidity of a sample (GUIMARÃES et al., 2015).

The specific mass as well as the mass of a thousand seeds are basic attributes for the study of drying and storage of agricultural products. The apparent specific mass is the ratio of the mass of the solid and the volume of the solid containing pores. When there are more intergranular spaces (pores), lower mass of product in a given constant volume, there are lower values of apparent specific mass (OLIVEIRA et al., 2014).

Vilcheet. al. (2003) observed that the apparent specific mass of quinoa decreased from 747.0 $kg.m^{-3}$ to 667.0 $kg.m^{-3}$ where its water content ranged from 4.6 to 25.8%. In the case of amaranth seeds, the specific mass also decreased from 840 to 720 $kg.m^{-3}$ in a water content variation from 7.7 to 43.9% (ABALONE et al., 2004). According to Moscon (2015), the specific mass decreases with increasing water content, in a drying process the specific mass can increase. This process can be explained due to the dehydration of the material (grains or seeds), reducing the intercellular spaces, thus modifying the dimensions and the volume (AFONSO JUNIOR; CORRÊA, 2000). This characteristic was observed by Sharanagat and Goswami (2014) in coriander (*Coriandrum sativum*) seeds, Kingsly (2006) in seeds of pomegranate and linseed Selvi (2006).

CONCLUSIONS

Water content in amaranth and quinoa seeds close to 13% provides 25º in the angle of inclination.

The dimensions and sphericities of the quinoa and amaranth seeds are decisive for the selection of the set of sieves and processing.

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