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ORIGINAL ARTICLE

Shape and size of mung beans during drying[1]

Forma e tamanho dos grãos de feijão mungo durante a secagem

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HIGHLIGHTS:
The high sphericity index of mung beans aids their separation and classification.
Reducing moisture content enhances cotyledon separation.
Moisture content significantly affects the physical properties of mung beans.

ABSTRACT: This study investigates the impact of drying on the shape and size of mung beans (*Vigna radiata* L.), which are well-regarded for their nutritional, medicinal, and agronomic benefits. Understanding their physical properties at varying moisture levels is crucial for improving agricultural practices from planting through post-harvest. Initially harvested at about 27% moisture content (wet basis, wb), the beans were air-dried naturally to approximately 9% moisture content (wb). The analysis involved measuring the orthogonal axes, length, width, and thickness of 30 representative beans. Parameters such as circularity, sphericity, volume, surface area, projected area, surface-to-volume ratio, and geometric diameter were calculated based on these measurements. Findings indicate that drying reduces the size of mung beans but maintains their circular and spherical shape. The length and width diminish more than the thickness. As drying progresses, the surface-to-volume ratio increases, while the projected area, surface area, and geometric diameter decrease.

Key words: *Vigna radiata* L., physical properties, sphericity index

RESUMO: Objetivou-se com esta pesquisa determinar e avaliar o comportamento da forma e do tamanho do feijão mungo durante a secagem. O feijão mungo tem sido destaque no meio científico e agronômico devido suas propriedades nutricionais, medicinais e produtivas, e o conhecimento de suas propriedades físicas em diferentes teores de água é fundamental para otimização dos processos de plantio, colheita e pós-colheita. Os grãos foram colhidos com o teor de água de aproximadamente 27% (base úmida, bu), e posteriormente submetidos à secagem artificial com ventilação natural, até atingirem o teor de água de aproximadamente 9% (bu). Ao longo do processo de secagem a forma e o tamanho dos grãos foram avaliados mediante determinação dos eixos ortogonais, comprimento, largura e espessura em 30 grãos por repetição. De posse desses dados foram calculados a circularidade, esfericidade, volume, área superficial, área projetada, relação superfície-volume e diâmetro geométrico. A secagem reduz o tamanho dos grãos de feijão mungo, sem alterar de maneira expressiva a sua forma, que pode ser considerada circular e esférica. O comprimento e a largura dos grãos se reduzem em proporção maior que à espessura. A relação superfície/volume aumenta com a secagem, e a área projetada, área superficial e diâmetro geométrico diminuem.

Palavras-chave: *Vigna radiata* L., propriedades físicas, índice de esfericidade

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Introduction

Pulses, often referred to as dried legumes, are highly valued for their protein content, which is two to three times greater than that found in cereals (Sinha et al., 2020). Among various beans, mung bean (*Vigna radiata* L.) stands out and has captured the interest of researchers and producers globally. This legume thrives in warm temperate regions and tolerates the challenging conditions of arid and semi-arid environments (Huppertz et al., 2023). Asia dominates mung bean production, contributing 90% of the global output, with India alone responsible for about half of this total (Pereira et al., 2019). In Brazil, where production is still emerging, about 95% of the crop is exported, primarily from the state of Mato Grosso (Favero et al., 2021).

Mung beans are not only rich in carbohydrates and proteins but also fats, vitamins, fibers, and essential minerals such as sodium, potassium, iron, and calcium (Ullah et al., 2014). They are also recognized for their potential health benefits in complementary and alternative medicine (Ganesan & Xu, 2018).

Despite its longstanding cultivation in Brazil (Abud et al., 2022; Noleto et al., 2023), research on the physical properties of mung beans, which are critical for designing post-harvest processing equipment, is lacking (Dhurve & Arora, 2022; Silva et al., 2022). Understanding these properties, including linear dimensions for modeling drying, heating, and cooling processes (Dhurve & Arora, 2022), as well as size (surface area, projected area, and volume) and shape (circularity and sphericity) essential for peeling processes (Sirisomboon et al., 2007), is crucial.

Physical traits are influenced by genetic factors, growing conditions, and post-harvest processes, with drying notably altering the shape and size of the product (Siqueira et al., 2012). This study aims to investigate and analyze the impact of drying on the shape and size of mung beans.

Material and Methods

Mung beans (*Vigna radiata* L. R. Wilczek), of the 'Australiano' cultivar, were harvested in the experimental area of the Federal University of Grande Dourados (22° 11' 58" S; 54° 56' 17" W and altitude of 430 m), located in Dourados city, Mato Grosso do Sul state, Brazil. The beans were harvested with an initial moisture content of approximately 27% (wet basis, wb). The harvesting, threshing, and separation of impurities were all conducted manually.

Drying occurred artificially using natural ventilation at a temperature of 27.74 ± 1.05 °C and relative air humidity of 31.60 ± 7.13%, between the 13th and 14th of December 2022. The beans were sun-dried until they reached a moisture content (MC) of approximately 9% (wb). Moisture contents measured during the drying process included 27.03, 21.29, 19.23, 17.20, 15.12, 13.05, 10.94, and 8.93% (wb), based on previous studies of volumetric shrinkage and considerations of harvest moisture content and safe storage (Lima et al., 2021; Coradi et al., 2016).

The volume of the beans was calculated using Eq. 1 (Mohsenin, 1986). Bean dimensions length, width, and thickness were measured using a digital caliper with 0.01 mm resolution.

$$V_g = \frac{\pi \times A \times B \times C}{6} \quad (1)$$

Where:

V_g - bean volume (mm³);
A - bean length (mm);
B - bean width (mm); and,
C - bean thickness (mm).

The shape of mung beans, characterized by sphericity and circularity, was determined from the orthogonal axes, averaging measurements from 30 beans used as replicates, with four replicates for each moisture content condition.

Sphericity (S_{ph}) was determined according to Eq. 2 (Mohsenin, 1986).

$$S_{ph} = \frac{\sqrt[3]{A \times B \times C}}{A} \times 100 \quad (2)$$

Sphericity index (φs) was calculated using Eq. 3 (Bayram, 2005).

$$\varphi_s = \frac{\sum \left(D_i - D_{eq}\right)^2}{\left(D_{eq} \times N\right)^2} \quad (3)$$

Where:

φ_s - sphericity index;
D_i - mean of the dimensions of orthogonal axes (mm);
D_{eq} - equivalent diameter (mm); and,
N - number of measurements.

The equivalent diameter D_{eq} of beans was determined by the volume (V_g), through Eq. 4:

$$D_{eq} = \sqrt[3]{V_g \times \frac{6}{\pi}} \quad (4)$$

Circularity (C_c) of beans in natural repose position was obtained by Eq. 5:

$$C_c = \frac{B}{A} \times 100 \quad (5)$$

Surface area (S) (mm²) was estimated by analogizing to a sphere with the same mean geometric diameter, using Eq. 6 (Tunde-Akintunde & Akintunde, 2004).

$$S = \pi D_g \quad (6)$$

According to Mohsenin (1986) Eq. 7:

$$D_g = \sqrt[3]{A \times B \times C} \quad (7)$$

Where:

D_g - mean geometric diameter (mm).

The projected area (Ap) (mm^2) of the beans was determined using Eq. 8:

$$A_p = \frac{\pi AB}{4} \tag{8}$$

Surface-to-volume ratio (SV) was calculated using Eq. 9:

$$SV = \frac{S}{V_g} \tag{9}$$

To examine changes during drying, cross-section observations were made of the beans to assess the degree of cotyledon separation.

Data analysis included variance analysis and regression at a significance level of $p \leq 0.05$.

Results and Discussion

The mean values of length, width, and thickness of mung beans tended to decrease during drying (Figure 1). Length showed the greatest reduction (6.94%), followed by width (5.67%) and thickness (3.18%).

Although thickness decreased, it was the only orthogonal axis that displayed a quadratic behavior. Thickness values initially increased at the beginning of drying and then decreased from a moisture content of 17% (wb), eventually becoming greater than the width during drying. This behavior may be linked to the contraction and separation of cotyledons, leading to the formation of an empty space inside the bean (Figures 2A-H).

The separation of cotyledons has also been observed in other agricultural products, such as peanuts (Araujo et al., 2014) and fava beans (Silveira et al., 2019). This phenomenon is related to changes in the intergranular porosity, which is a crucial factor in bean processing. Silveira et al. (2019) also reported a reduction in unit mass and volume, associating this behavior with the irregularity of agricultural products and the volumetric contraction that occurs as cotyledons separate during drying.

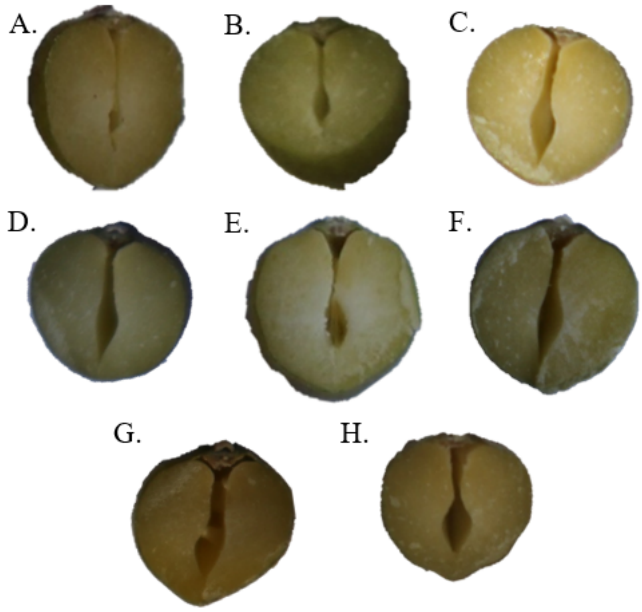
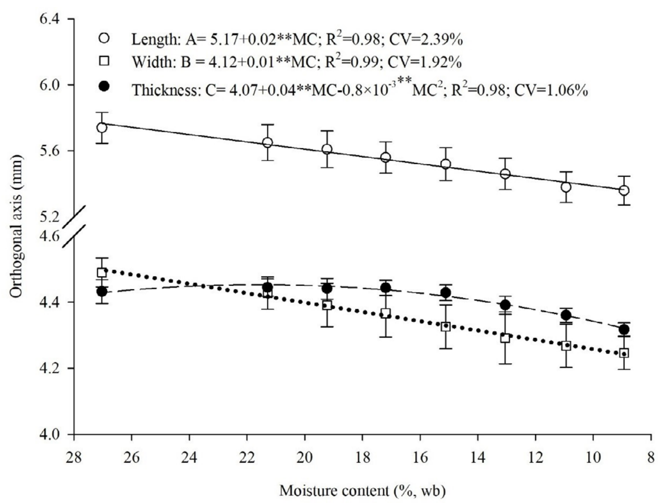


Figure 2. Cross sections of mung beans with moisture contents of 29 (A), 23.94 (B), 22 (C), 20 (D), 18 (E), 16 (F), 14 (G), and 12% (H)

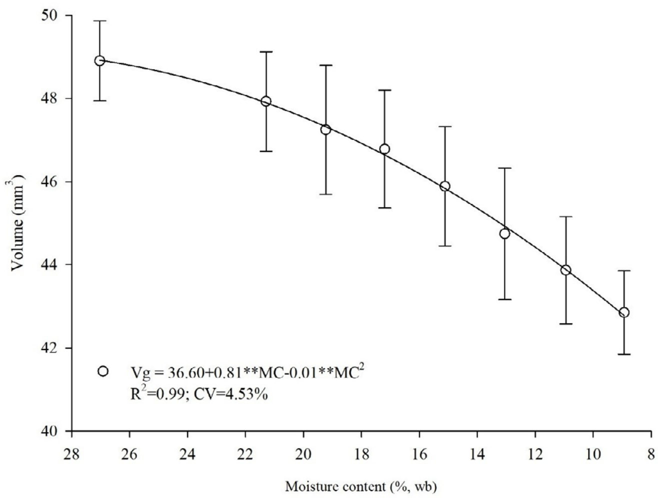
The reduction in the orthogonal axes led to a 12.6% reduction in volume (Figure 3). Volumetric contraction associated with moisture content is commonly reported in the scientific literature (Siqueira et al., 2013; Benestante et al., 2023). This contraction is important during drying because it helps predict the reduction in the volume occupied by the bean mass as moisture content decreases (Quequeto et al., 2018).

The intensity of this contraction depends on the product's shape, the presence of peel and tegument, and their composition. Each product has unique characteristics in terms of shape and chemical composition, causing them to behave differently during drying (Siqueira et al., 2012). Ratti (1994) also notes that changes during drying depend on the sample structure and the type of product.



** - Significant at $p \leq 0.01$ by F test; MC – Moisture content; CV – Coefficient of variation

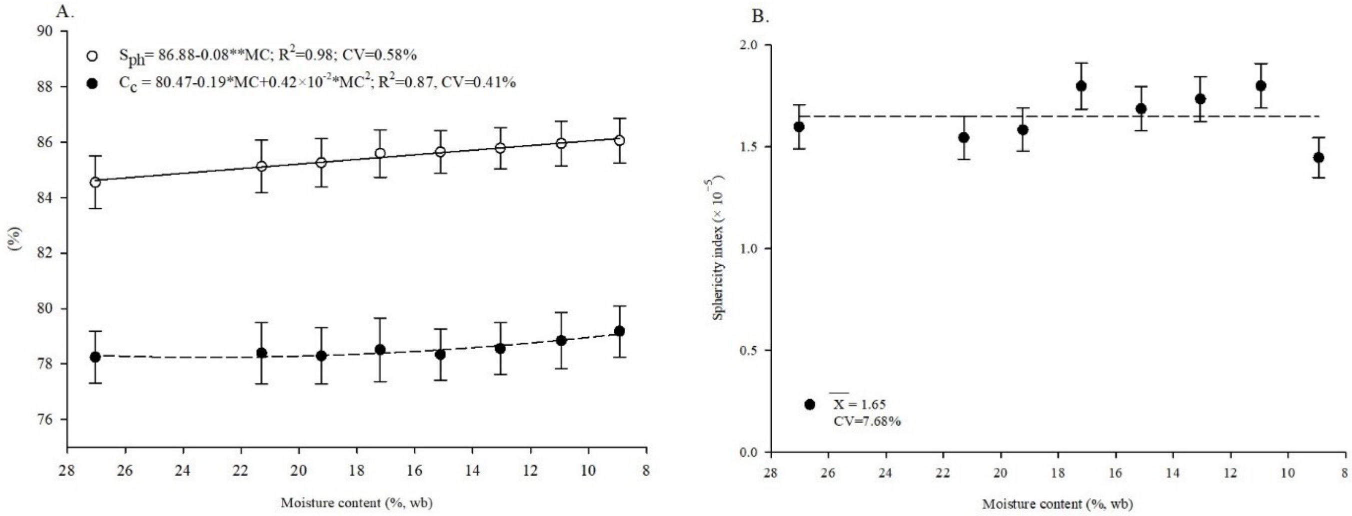
Figure 1. Mean values of the orthogonal axes of mung beans as a function of moisture contents



** - Significant at $p \leq 0.01$ by F test; MC – Moisture content; CV – Coefficient of variation

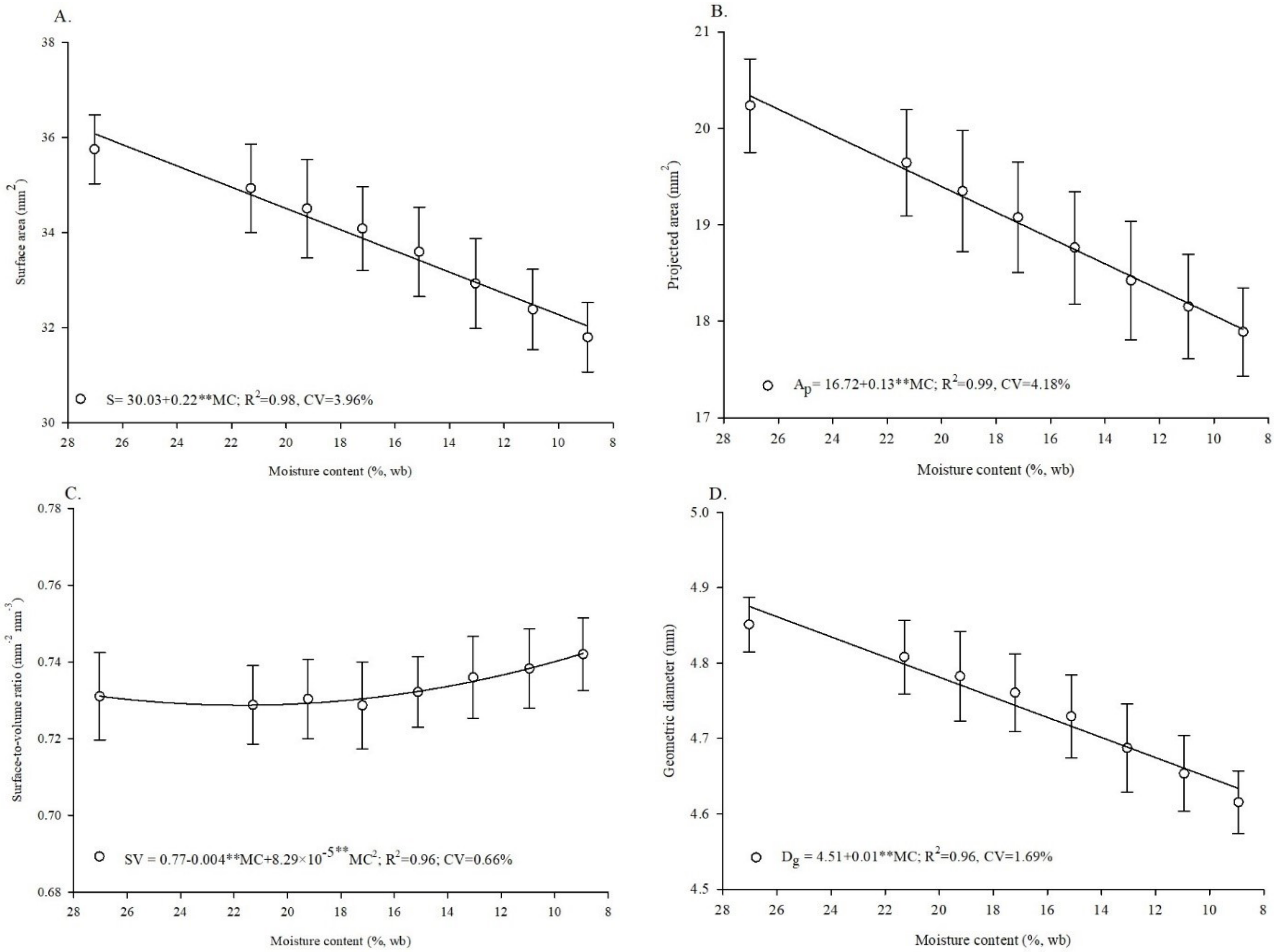
Figure 3. Mean volume of mung beans as a function of moisture contents

The circularity of mung beans showed minimal change, increasing from 78.31% at the initial moisture content to 79.08% at the final moisture content (Figure 4). This behavior is like that observed in soybean seeds (Hauth et al., 2018). The beans became slightly more spherical during drying, with a variation of less than 2% (Figure 4A). Estimated values ranged from 84.63 to 86.14% across the studied moisture content range, indicating that the beans are spherical (Garnayak et al., 2008). John & Ifeyinwa (2023) found sphericity values ranging from 69.4 to 88.3% when studying different mung bean varieties and locations in Nigeria.



* and ** - Significant at p < 0.05 and p < 0.01 by F test, respectively; S_{ph} – Sphericity; C_c – Circularity; CV – Coefficient of variation

Figure 4. Mean circularity and sphericity of mung beans (A) and sphericity index of mung beans (B) at different moisture contents



** - Significant at p ≤ 0.01 by F test; CV – Coefficient of variation; MC – Moisture content; S – Surface area; Ap – Projected area; SV – Surface-to-volume index; Dg – Geometric diameter

Figure 5. Mean values of surface area (A), projected area (B), surface-to-volume ratio (C), and geometric diameter (D) of mung beans as a function of moisture content

Figure 4B shows the sphericity index of mung beans during drying. The closer the values are to zero, the more spherical the beans are. The mean sphericity index was 1.65 $\times 10^{-5}$, with no significant trend observed across the moisture content range. Therefore, the sphericity index of mung beans did not change significantly during drying, confirming the behavior shown in Figure 4B. This consistency allows for the design of separators or classifiers based on the same principle, varying only the degree of perforation, since the product tends to contract as moisture content decreases (Akhmadiev et al., 2020).

The sphericity index allows for the comparison of various products. Bayram (2005) calculated the similarity of beans such as wheat, lentils, and chickpeas to a perfect sphere, finding that chickpeas were the most spherical with an index of 2.40 $\times 10^{-3}$. Therefore, mung beans can be considered more spherical than many other agricultural products, facilitating their separation and classification in the bean processing chain.

Surface area values decreased linearly as the moisture content of mung beans decreased (Figure 5A), ranging from 36.08 to 32.03 mm^2. Similarly, Gomes et al. (2018) observed a reduction in surface area as moisture content decreased in cowpea seeds. This behavior results from the volumetric contraction of the product during drying (Costa Júnior et al., 2021).

The projected area of mung beans decreased by 11.9% as moisture content dropped from 27.03 to 8.93% (wb), a trend satisfactorily represented by a linear regression model (Figure 5B). Similar behavior has been observed in jatropha (Siqueira et al., 2013), common beans (Jesus et al., 2013), pumpkin seeds (Costa Júnior et al., 2021), and lemon seeds (Benestante et al., 2023).

The surface-to-volume ratio increased as moisture content decreased, which can be explained by the greater reduction in bean volume compared to surface area (Figure 5C). This relationship is further evidenced by the reduction rates relative to moisture content during drying, 0.81 for volume and 0.22 for surface area (Figures 3 and 5A).

The estimated mean values increased by approximately 1.4% across the studied moisture content range. Araujo et al. (2014) reported related results for peanut seeds. A higher surface-to-volume ratio facilitates heat and mass transfer (Mendes et al., 2016). However, it is important to note that the highest values are associated with the driest product. Although it is easier to remove water from a geometric perspective, this must be considered alongside the binding energy of the water with the material, which tends to increase as drying progresses. According to Siqueira et al. (2024), the drying rate decreases over time as the internal transfer of water vapor to the product's surface does not keep pace with the evaporation rate.

A decrease of approximately 4.1% was observed in the geometric diameter (Figure 5D). This behavior was expected because this property is directly correlated with volume, which also decreased (Figure 3). The smaller reduction in geometric diameter relative to volume may be related to the behavior of thickness, which did not decrease linearly due to the separation of cotyledons.

Conclusions

1. Drying reduced the size of mung beans without significantly altering their shape, which remained circular and spherical.
2. The length and width of the beans decreased more than the thickness.
3. The surface-to-volume ratio increased during drying, while the projected area, surface area, and geometric diameter all decreased.

Contribution of authors: Valdiney Cambuy Siqueira: Participation in research design, data collection, analysis, and interpretation, manuscript preparation, literature review, supervision, and project administration. Diogo Santos Crippa: Participation in research design, data collection, analysis, and interpretation, manuscript preparation, and literature review. Allan Dallon Alegre Takagi: Participation in research design, data collection, analysis, and interpretation, manuscript preparation, literature review. Geraldo Acácio Mabasso; Elton Aparecido Siqueira Martins; Mariana Zampar Toledo; Rodrigo Aparecido Jordan; Vanderleia Shoeninger and Guilherme Garcia Santos Gonçalves: Participation in data analysis and interpretation, manuscript preparation, review, and visualization.

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Literature Cited

Abud, H. F.; Mesquita, C. M. D. S.; Sarmento, E. C. S.; Melo, R. D. S.; Lima, K. A. P. D.; Silva, A. K. F. D. Image analysis of the seeds and seedlings of *Vigna radiata* L. Revista Ciência Agronômica, v.53, e20207303, 2022. https://doi.org/10.5935/1806-6690.20220012

Akhmadiev, F. G.; Gizzyatov, R. F.; Nazipov, I. T. Mathematical modeling of kinetics and optimization of grain material separation processes on sieve classifiers. Lobachevskii Journal of Mathematics, v.41, p.1155–1161, 2020. https://doi.org/10.1134/S1995080220070070

Araujo, W. D.; Goneli, A. L. D.; Souza, C. M. A. S.; Gonçalves, A. A.; Vilhasanti, H. C. B. Propriedades físicas dos grãos de amendoim durante a secagem. Revista Brasileira de Engenharia Agrícola e Ambiental, v.18, p.279-286 2014. https://doi.org/10.1590/S1415-43662014000300006

Bayram, M. Determination of the sphericity of granular food materials. Journal of Food Engineering, v.68, p.385-390, 2005. https://doi.org/10.1016/J.JFoodEng.2004.06.014

Benestante, A.; Chalapud, M. C.; Baümler, E.; Carrín, M. E. Physical and mechanical properties of lemon (*Citrus lemon*) seeds. Journal of the Saudi Society of Agricultural Sciences, v.22, p.205-213, 2023. https://doi.org/10.1016/J.Jssas.2022.11.002

Coradi, P. C.; Fernandes, C. H.; Helmich, J. C.; Goneli, A. L. Effects of drying air temperature and grain initial moisture content on soybean quality (*Glycine max* (L.) Merrill). Engenharia Agrícola, v.36, p.866-876, 2016. http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v36n5p866-876/2016

Costa Júnior, J. R. da; Oliveira, D. E. C. de; Carvalho, J. M. G.; Bueno, S. G. S.; Ferreira, V. B.; Alves, E. M. Forma e tamanho de sementes de duas variedades de abóboras durante a secagem. Nativa, v.9, p.1-8, 2021. https://doi.org/10.31413/Nativa.v9i1.10274

Dhurve, P.; Arora, V. K. Investigation of geometric and gravimetric properties of pumpkin seeds (*Cucurbita maxima*) under tray drying. Materials Today: Proceedings, v.59, p.437-441, 2022. https://doi.org/10.1016/J.Matpr.2021.11.452

Favero, V. O.; Carvalho, R. H. de; Leite, A. B. C.; Freitas, K. M. de; Zilli, J. É.; Xavier, G. R.; Rumjanek, N. G.; Urquiaga, S. Characterization and nodulation capacity of native bacteria isolated from mung bean nodules used as a trap plant in Brazilian tropical soils. Applied Soil Ecology, v.167, e104041, 2021. https://doi.org/10.1016/J.Apsoil.2021.104041

Ganesan, K.; Xu, B. A critical review on phytochemical profile and health promoting effects of mung bean (*Vigna radiata*). Food Science and Human Wellness, v.7, p.11-33, 2018. https://doi.org/10.1016/J.FShw.2017.11.002

Garnayak, D. K.; Pradhan, R. C.; Naik, S. N.; Bhatnagar, N. Moisture-dependent physical properties of jatropha seed (*Jatropha curcas* L.). Industrial Crops and Products, v.27, p.123-129, 2008. https://doi.org/10.1016/J.IndCrop.2007.09.001

Gomes, F. H. F.; Lopes Filho, L. C.; Oliveira, D. E. C. de; Resende, O.; Soares, F. A. L. Tamanho e forma de grãos de feijão-caupi em função de diferentes teores de água. Revista Engenharia na Agricultura, v.26, p.407-416, 2018. https://doi.org/10.13083/reveng.v26i5.957

Hauth, M. R.; Botelho, F. M.; Hoscher, R. H.; Botelho, S. de C. C.; Oliveira, G. H. H. de. Physical properties of different soybean cultivars during drying. Engenharia Agrícola, v.38, p.590-598, 2018. https://doi.org/10.1590/1809-4430-Eng.Agric.v38n4p590-598/2018

Huppertz, M.; Kachhap, D.; Dalai, A.; Yadav, N.; Baby, D.; Khan, M. A.; Bauer, P.; Panigrahi, K. C. Exploring the potential of mung bean: From domestication and traditional selection to modern genetic and genomic technologies in a changing world. Journal of Agriculture and Food Research, v.14, e100786, 2023. https://doi.org/10.1016/j.jafr.2023.100786

Jesus, F. F. de; Souza, R. T. G. de; Teixeira, G. S. C. da; Teixeira, I. R.; Devilla, I. A. Propriedades físicas de sementes de feijão em função de teores de água. Revista Engenharia na Agricultura, v.21, p.09-18, 2013. https://doi.org/10.13083/reveng.v21i1.390

John, I. O.; Ifeyinwa, O. G. Effect of moisture content on the physical properties of mung bean varieties grown in Abakaliki, Ebonyi State, Nigeria. Agricultural Engineering International: CIGR Journal, v.25, p.159-175, 2023. https://cigrjournal.org/index.php/Ejounral/article/view/6611

Lima, R. E.; Coradi, P. C.; Nunes, M. T.; Bellochio, S. D. C.; Silva Timm, N. da; Nunes, C. F.; Carneiro, L. de O.; Teodoro, P. E.; Campabadal, C. Mathematical modeling and multivariate analysis applied earliest soybean harvest associated drying and storage conditions and influences on physicochemical grain quality. Scientific Reports, v.11, e23287, 2021. https://doi.org/10.1038/s41598-021-02724-y

Mendes, U. C.; Resende, O.; Donadon, J. R.; Almeida, D. P.; Rocha, A. C. da; Oliveira, D. E. C. Effect of drying on the physical properties of adzuki bean. Semina: Ciências Agrárias, v.37, p.3871-3879, 2016. https://doi.org/10.5433/1679-0359.2016v37n6p3871

Mohsenin, N. N. Physical properties of plant and animal materials. 2nd ed. Nova York: Gordon and Breach Science, 1986, 891p.

Noleto, M. P.; Menezes Júnior, J. Â. N. D.; Olibone, D., Gobbi, S. D.; Pivetta, L. G.; Silva, K. J. D. Adaptability and stability of mungbean genotypes in the Mid-North of Mato Grosso, Brazil. Ciência e Agrotecnologia, v.47, e012222, 2023. https://doi.org/10.1590/1413-7054202347012222

Pereira, C. S.; Villa Neto, R. D.; Fiorini, I. V. A.; Pontelo, L.; Silva, A. A. Doses de nitrogênio e níveis de irrigação em feijão mungo (*Vigna radiata* L.). Tecno-Lógica, v.23, p.63-69, 2019. https://doi.org/10.17058/tecnolog.v23i1.12512

Quequeto, W. D.; Siqueira, V. C.; Schoeninger, V.; Martins, E. A.; Isquierdo, E. P.; Silva, F. P. D. Physical properties of buckwheat (*Fagopyrum esculentum* Moench) grains during convective drying. Revista Brasileira de Engenharia Agrícola e Ambiental, v.22, p.793-798, 2018. https://doi.org/10.1590/1807-1929/agriambi.v22n11p793-798

Ratti, C. Shrinkage during drying of foodstuffs. Journal of Food Engineering, v.23, p.91-105, 1994. https://doi.org/10.1016/0260-8774(94)90125-2

Silva, L. S. da; Carvalho, A. J. de; Siqueira, W. da C.; Rocha, M. de M.; Borges, J. B.; Barbosa, E. da S.; Barbosa, J. A. E. Physical properties of grains of cowpea genotypes. Revista Brasileira de Engenharia Agrícola e Ambiental, v.27, p.216-222, 2022. https://doi.org/10.1590/1807-1929/Agriambi.v27n3p216-222

Silveira, D. C. da; Leite, A. C. N.; Santos, N. C.; Gomes, J. P. Physical characteristics of fava beans (*Phaseolus lunatus* L.). Revista Verde de Agroecologia e Desenvolvimento Sustentável, v.14, p.518-523, 2019. https://doi.org/10.18378/rvads.v14i4.6811

Sinha, S.; Mishra, S. B.; Kumar, A.; Pandey, S. S. Estimation of gene effects for yield attributing traits in mungbean (*Vigna radiata*) and urdbean (*Vigna mungo*) for intra and interspecific crosses. Electronic Journal of Plant Breeding, v.11, p.81-85, 2020. https://doi.org/10.37992/2020.1101.014

Siqueira, V. C.; Crippa, D. S.; Mabasso, G. A.; Westemaier, E. da S.; Martins, E. A. S.; Schoeninger, V.; Castro, L. K. de; Toledo, M. Z. Drying kinetics and mass transfer parameters of mung beans dried using a convective dryer. Food Science and Technology, v.44, e00169, 2024. https://doi.org/10.5327/fst.00169

Siqueira, V. C.; Resende, O.; Chaves, T. H. Shape and size of jatropha beans (*Jatropha curcas* L.) during drying at different temperatures. Revista Ceres, v.60, p.820-825, 2013. https://doi.org/10.1590/S0034-737X2013000600010

Siqueira, V. C.; Resende, O.; Chaves, T. H.; Soares, F. A. L. Forma e tamanho dos frutos de pinhão-manso durante a secagem em cinco condições de ar. Revista Brasileira de Engenharia Agrícola e Ambiental, v.16, p.864-870, 2012. https://doi.org/10.1590/S1415-43662012000800008

Sirisomboon, P.; Kitchaiya, P.; Pholpho, T.; Mahuttanyavanitch, W. Physical and mechanical properties of *Jatropha curcas* L. fruits, nuts and kernels. Biosystems Engineering, v.97, p.201-207, 2007. https://doi.org/10.1016/J.Biosystemseng.2007.02.011

Tunde-Akintunde, T. Y.; Akintunde, B. O. Some physical properties of sesame seed. Biosystems Engineering, v.88, p.127-129, 2004. https://doi.org/10.1016/J.Biosystemseng.2004.01.009

Ullah, R.; Ullah, Z.; Al-Deyab, S. S.; Adnan, M.; Tariq, A. Nutritional assessment and antioxidant activities of different varieties of *Vigna radiata*. Scientific World Journal, p. 871753, 2014. https://doi.org/10.1155/2014/871753