



Ciência e Tecnologia de Alimentos

ISSN: 0101-2061

revista@sbcta.org.br

Sociedade Brasileira de Ciência e
Tecnologia de Alimentos
Brasil

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Ciência e Tecnologia de Alimentos, vol. 32, núm. 1, abril-junio, 2012, pp. 151-155
Sociedade Brasileira de Ciência e Tecnologia de Alimentos
Campinas, Brasil

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Adzuki beans (*Vigna angularis*) seed quality under several drying conditions

Qualidade de sementes de feijão adzuki (*Vigna angularis*) submetidas a diversas condições de secagem

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Abstract

This study analyzed the drying process and the seed quality of adzuki beans (*Vigna angularis*). Grains of adzuki beans, with moisture content of 1.14 (decimal dry basis) at harvest and dried until the moisture content of 0.11 (decimal dry basis) were used. Drying was done in an experimental drier maintained at controlled temperatures of 30, 40, 50, 60, and 70 °C and relative humidity of 52.0, 28.0, 19.1, 13.1, and 6.8%, respectively. Physiological and technological seed quality was evaluated using the germination test, Index of Germination Velocity (IGV), electrical conductivity, and water absorption, respectively. Under the conditions tested in the present study, it can be concluded that drying time for adzuki beans decreases with the higher air temperatures of 60 and 70 °C, and it affected the physiological and technological seed quality. Thus, to avoid compromising adzuki seeds quality, it is recommended to promote its drying up to 50 °C.

Keywords: physiological quality; drying conditions; technological quality; seed drying.

Resumo

Objetivou-se no presente trabalho analisar o processo de secagem do feijão adzuki (*Vigna angularis*), bem como avaliar a qualidade das sementes, submetidas à secagem em diversas condições de ar. Foram utilizados grãos de feijão adzuki (*Vigna angularis*), colhidos com teor de água de 1,14 (decimal base seca) e secos até o teor de 0,11 (decimal base seca). A secagem do feijão adzuki foi realizada em secador experimental mantido nas temperaturas controladas de 30, 40, 50, 60 e 70 °C e umidades relativas de 52,0; 28,0; 19,1; 13,1 e 6,8%, respectivamente. Para analisar a qualidade fisiológica e tecnológica das sementes realizou-se o teste de germinação, Índice de Velocidade de Germinação (IVG), condutividade elétrica e absorção de água, respectivamente. Nas condições em que foi desenvolvido o presente trabalho, conclui-se que o tempo de secagem do feijão adzuki diminui para as temperaturas mais elevadas do ar de 60 e 70 °C e afetam as qualidades fisiológica e tecnológica das sementes. Assim, para não haver comprometimento da qualidade das sementes do feijão adzuki recomenda-se promover a sua secagem até a temperatura máxima do ar de 50 °C.

Palavras-chave: qualidade fisiológica; condições de secagem; qualidade tecnológica; secagem de sementes.

1 Introduction

Edible beans are cultivated in almost all tropical and subtropical countries playing a key role in human nutrition, especially due to its low cost. It is a protein rich food, a popular food item grown throughout Brazil and preferred by people with diverse feeding habits and it is.

The genus *Vigna* has about 160 species, seven of which are cultivated. Among these, adzuki beans (*Vigna angularis*) are produced mostly in Asia (VIEIRA; VIEIRA; ANDRADE, 1992) and are consumed mainly in China, Japan, and Korea. Japan is the major producer and importer of adzuki beans, which occupies about 100 thousand hectares of planted area. There are no precise data about farmers, production, or planted area with this type of beans in Brazil, which is mostly used in Japanese colonies mainly as deserts and uncountable oriental delicacies (VIEIRA; VIEIRA; MOURA, 2000).

At the post-harvest stage, drying is the most widely used process to assure beans quality and stability taking into account that

reducing the moisture content of the material reduces biological activity as well as chemical and physical changes that occur during storage (RESENDE et al., 2008a). However, drying at temperatures and air moisture that generate large rates of water removal can substantially affect seed quality (ALMEIDA et al., 2009).

Drying agricultural produce consists of the removal of high moisture content inside the grain by evaporation, generally caused by forced convection of heated air, thus allowing the maintenance of quality during storage for long periods (AFONSO JÚNIOR; CORRÊA, 1999).

The phenomenon of reducing the grain moisture content involves, simultaneously, the transfer of heat and mass, which can substantially change its quality, depending on the drying method and the conditions used (HALL, 1980).

Miranda et al. (1999) reported that soybean seed physiological quality was not affected after drying in a dryer

Received 24/8/2010

Accepted 28/8/2011 (005007)

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DOI: <http://dx.doi.org/10.1590/S0101-20612012005000013>

with air flow of 28.4 m³/min/t, and 50 °C. The temperature of the mass did not exceed 47.8 °C. However, Ahrens and Lollato (1997) working with the same type of silo dryer, found no satisfactory results after dry bean seeds inflated with air to 35 °C due to reduction in physiological seed quality caused probably by high airflow and the delay in drying due to the high initial moisture content. In general, according to Ahrens, Villela and Doni-Filho et al. (2000), the Poaceae seeds are less sensitive to thermal damage during the drying process than the Fabaceae seeds due to the fact that the latter have more exposed embryos than the former. Seed germination is an organized consequence of metabolic activities divided into phases resulting in the formation of a seedling. This is a critical step of the vegetable biocycle since it is associated with several extrinsic (physical environment) and intrinsic factors, i.e., physio-metabolic processes (POPINIGIS, 1985). This event can be affected by the drying process, which can cause physiological and mechanical damage in the seed.

The germination process starts with water soaking by the seed tissues followed by the return of metabolic activities, especially by the synthesis of new enzymes and increased activity of pre-existing hydrolases and the reserve composts mobilization for growth of the embryo axis (SALES, 2002).

Electrical conductivity test is used in the evaluation of seed vigor (VIEIRA; KRYZANOWSKI, 1999). This test determines the amount of electrolytes leached from a seed soaking solution, and it is a good indicator of mechanical damage in the seeds. This test has presented good performance in studies evaluating mechanical damage in bean seeds, such as those reported for cultivar IAPAR 44 (SANTOS et al., 2003), Carioca cultivar (ARAGÃO et al., 2002), and variety Ouro Negro 1992 (ANDRADE et al., 1999).

Considering the importance of drying tropical agricultural produce and the range of bean species, this study analyzed adzuki beans (*Vigna angularis*) drying process and evaluated seed quality, subjected to drying under several air conditions, through the analyses of germination percentage, Index of Germination Velocity (IGV), electrical conductivity, and water soaking.

2 Materials and methods

This study was carried out in the Post-harvest Plant Products Laboratory of the Instituto Federal de Educação, Ciência e Tecnologia Goiano - Campus Rio Verde (IF Goiano - Campus Rio Verde), located in the city of Rio Verde, GO.

Adzuki beans (*Vigna angularis*) grains were cultivated in the summer cropping season of 2007/2008 at the experimental area of IF Goiano - Campus Rio Verde, manually harvested, with moisture content of approximately 1.14 (decimal dry basis).

The moisture content of the product was determined gravimetrically using an oven at 105 ± 1 °C, for 24 hours in three replicates (BRASIL, 2009).

Drying of adzuki beans was done in an experimental drier maintained at controlled temperatures of 30, 40, 50, 60, and 70 °C and relative humidity of 52.0, 28.0, 19.1, 13.1, and 6.8%,

respectively. Removable aluminum trays were placed inside the drier containing 0.3 kg beans, each in four repetitions. The samples were periodically weighed during the drying process until the end point of drying, approximately 0.11 (decimal d.b.), defined as the recommended moisture content for safely storing the product. The reduction in moisture content during the drying process was followed by gravimetric determination of weight loss (gravimetric method) using an analytical balance with readability as low as 0.01 g, knowing the initial moisture content of the product, to reach the final moisture content.

Temperature and relative humidity inside the experimental drier were monitored using a psychrometer.

The germination test was performed with 4 sub-samples of 30 seeds each in rolls with germitest paper in a "Mangesdorf" germinator adjusted to 25 ± 2 °C. The amount of water added was equivalent to 2.5 times the mass of the dry substrate to adequately moisten the seeds and, consequently, to standardize the test. The readings were done from the 2nd day to the 39th day of sowing, according to the criteria established by the Rules for Seed Analysis with adaptation (BRASIL, 2009). In this evaluation, the average percent germination and the index of germination velocity (IGV) were determined.

For the determination of water absorption after drying, the methodology described by Resende et al. (2008b) was used.

The samples were subjected to soaking in distilled water for a period of 12 hours. Product soaking was done in the laboratory environment, at 25 ± 2 °C. Beakers (100 mL capacity) containing 80 mL distilled water with 20 g beans were used, mass ratio 4:1. After the maceration period, the samples were removed from the beakers and placed over paper towels to blot the surface water for 2 minutes. The moisture content after soaking was obtained by the Equation 1.

$$U^* = \frac{M_e - M_s}{M_s} \quad (1)$$

where: U*: Moisture content of the product, (decimal dry basis); M_e: Mass after soaking, kg; M_s: Dry mass of the product, kg.

The test of electric conductivity was performed in the bean grains, according to the methodology described by Vieira and Krzyzanowski (1999). Four sub-samples of 50 grains were weighed for each treatment. The samples were placed in plastic cups contained 75 mL deionized water and maintained in controlled temperature chamber at 25 °C for 24 hours. Subsequently, electric conductivity was measured with a conductivimeter.

The experimental design was completely randomized with 5 treatments (drying temperatures at 30, 40, 50, 60, and 70 °C), with four replications. The data were analyzed using Analysis of variation and regression. The models were selected based on the significance of the equation (F test at 5% probability), the coefficient of determination (R²), and the knowledge of the development of the biological phenomenon.

3 Results and discussion

Figure 1 presents the average values of moisture content of adzuki beans grains during drying at several temperature and relative humidity.

The time required for adzuki beans to reach the moisture content of 0.11 (decimal d.b.) was 49.0, 23.0, 16.5, 10.0, and 7.0 hours, for the temperatures of 30, 40, 50, 60, and 70 °C, respectively (Figure 1). Therefore, the time required for drying was smaller at 70 °C, in relation to the other treatments analyzed (30, 40, 50, and 60 °C) indicating the greater speed of water removal under this condition. As expected, time was affected by drying temperature, with the greatest difference between the drying temperatures of 70 and 30 °C. Similar results were observed by Corrêa et al. (2007) during drying of red beans (*Phaseolus vulgaris* L.), with time required for the beans to reach the moisture content of 12% (wet basis) of 20.0, 8.0, and 5.3 hours, for the temperatures of 35; 45, and 55 °C, respectively.

It can also be seen in Figure 1 that as air temperature increased, there was greater water removal rate. This behavior was also observed for several agricultural products: hazelnuts (OZDEMIR; DERVES, 1999); rough rice (BASUNIA; ABE, 2001); sultana grapes (YALDIZ; ERTEKIN; UZUN, 2001); grapes (AZZOUZ et al., 2002); green and red peppers (KAYMAK-ERTEKIN, 2002); red pepper (AKPINAR; BICER; YILDIZ, 2003); prickly pear (LAHSASNI et al., 2004); eggplant (ERTEKIN; YALDIZ, 2004); parboiled wheat (MOHAPATRA; RAO, 2005); adzuki beans (ALMEIDA et al., 2009); and jatropha (ULLMANN et al., 2010).

Figures 2 and 3 present, respectively, the germination percentage and the Index of Germination Velocity (IGV) of adzuki beans evaluated immediately after drying under several conditions of temperature and relative humidity.

The average percentage germination was 95, 96, 94, 71, and 20% for the drying temperatures of 30, 40, 50, 60, and 70 °C, and relative humidity of 52.0, 28.0, 19.1, 13.1, and 6.8%, respectively (Figure 2).

The average IGV values were 9.1, 11.0, 10.8, 6.8, and 2.0 for the drying temperatures of 30, 40, 50, 60, and 70 °C, respectively (Figure 3). Therefore, germination percentages and IGV were smaller for seeds dried at 60 and 70 °C in comparison with all other treatments analyzed (30, 40, and 50 °C) indicating the greater damage caused in the seed cell membranes under these conditions. The physiological seed quality measured by the germination and IGV tests were greatly affected at the drying temperatures of 60 and 70 °C, and the germination values were below the minimum established for beans market in Brazil is 80% (BRASIL, 2005). The high initial moisture content of seeds, 53% (wet basis), reduced during drying to 10.5% (wet basis), which could have affected the germination and IGV results for the beans subjected to the treatments at 60 and 70 °C. According to Afonso Júnior and Corrêa (1999), seed harvested at higher moisture content are more sensitive to quality loss during drying, especially at elevated temperatures due to the increased rate of removal of water from them. Drying bean seeds at 35 °C with an initial moisture content of 33.4% (wet basis) until the final moisture content of 11.0% (wet basis), Andrade et al. (2006) found lower germination and vigor values compared to those of bean seeds subjected to the same drying conditions but with initial moisture contents of 25.1 and 29.4% (wet basis). In addition, the variation in germination and IGV for drying adzuki beans, in the range of 30 to 70 °C, can be

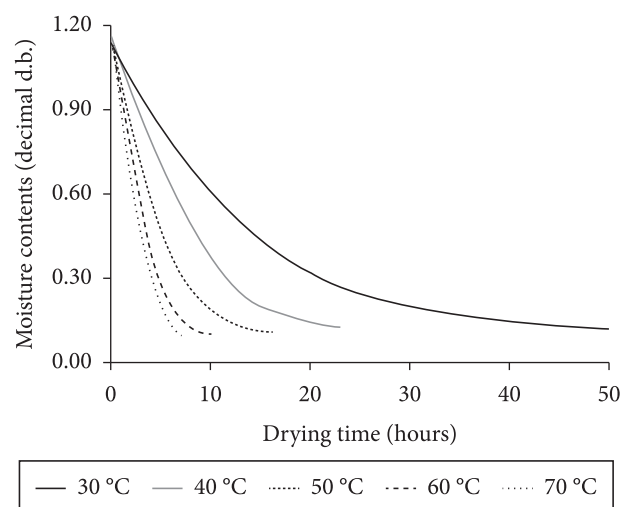


Figure 1. Average values of moisture contents of adzuki beans grains (decimal d.b.) as a function of drying time (hours) for the temperatures of 30, 40, 50, 60, and 70 °C.

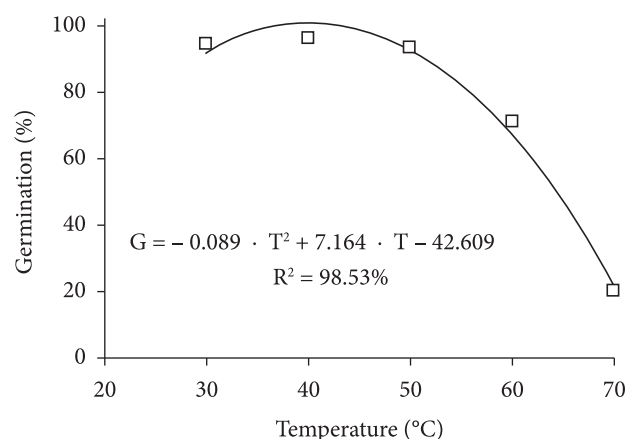


Figure 2. Average percentage of germinated seeds (G) of adzuki beans as a function of drying temperature (T) of 30, 40, 50, 60, and 70 °C.

adequately described by a quadratic equation, as observed by the determination coefficients values above 98.5% (Figures 2 and 3).

Figure 4 presents the results of electrical conductivity of adzuki beans subjected to drying under several conditions of temperature and relative humidity.

The average values of the test of electric conductivity increased quadratically with increasing drying temperatures presenting magnitudes of 55.7, 72.4, 90.8, 189.6, and 286.9 $\mu\text{S}\cdot\text{cm}^{-1}\cdot\text{g}^{-1}$, respectively, for the temperatures values of 30, 40, 50, 60, and 70 °C (Figure 4). Therefore, the highest average electric conductivity value was found at 70 °C in comparison to the other treatments analyzed (30, 40, 50, and 60 °C) indicating greater damage in the seeds under this condition since an increase in the drying temperature, increases the rate of water removal from the seed causing micro fissures at the cell level. The average electrical conductivity values were affected by the drying temperature, with the greatest difference found between the treatments 30 and 70 °C.

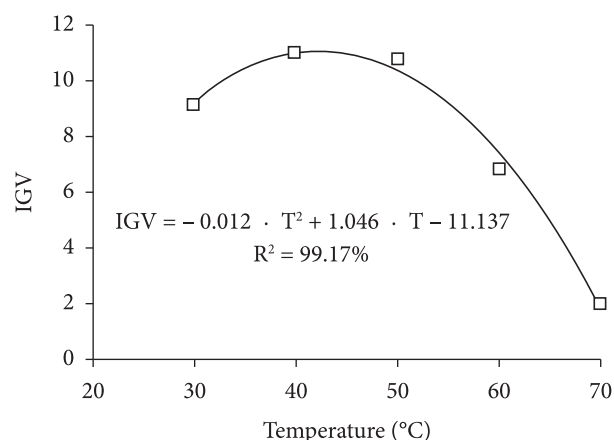


Figure 3. Average Index of Germination Velocity (IGV) of adzuki beans seeds as a function of drying temperatures of 30, 40, 50, 60, and 70 °C.

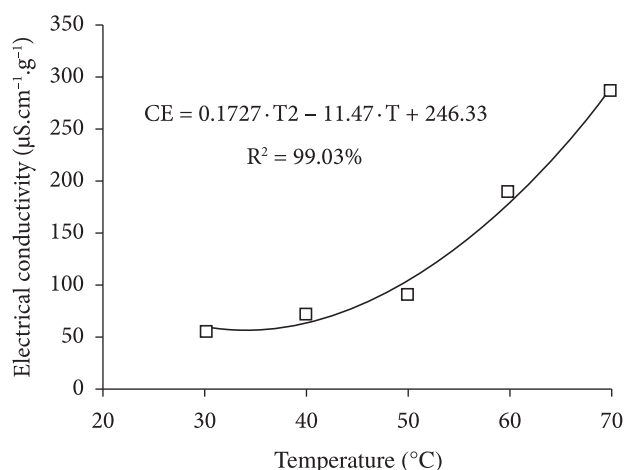


Figure 4. Average values of electrical conductivity (CE) in the soaking solution of adzuki beans as a function of drying temperatures (T) of 30, 40, 50, 60, and 70 °C.

As expected, the seeds initial moisture content (53%, wet basis) affected more the treatments with greater temperatures (50, 60, and 70 °C), expressed by the greater conductivities. Similar results were found by Andrade et al. (1999) investigating the drying process of bean seeds (*Phaseolus vulgaris* L.) variety “Ouro Negro 1992” with initial moisture content of 33.4% (wet basis) and final moisture content of 11.0% (wet basis). Furthermore, a quadratic equation adequately described the evolution of electric conductivity of adzuki beans in relation to the drying temperatures (Figure 4).

Figure 5 presents the average values of water absorption by adzuki beans evaluated immediately after drying under several temperatures.

The average values of water absorption increased linearly according to the different drying air conditions presenting values of 0.75, 0.89, 0.90, 1.07, and 1.20 (decimal dry basis) for the drying temperatures of 30, 40, 50, 60, and 70 °C, respectively (Figure 5). The drying temperature of 70 °C presented the greatest water absorption indicating greater mechanical damage

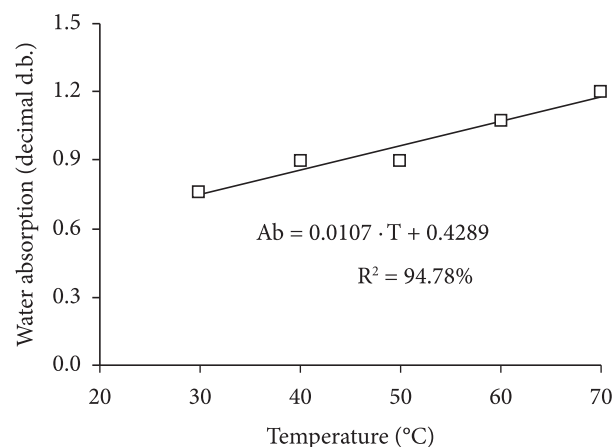


Figure 5. Average values of water absorption (Ab) by adzuki beans as a function of drying temperatures (T) of 30, 40, 50, 60, and 70 °C.

due to the high drying temperature than that of the other temperatures (30, 40, 50, and 60 °C). According to Resende et al. (2008b), in a study on different soaking temperatures of common beans as a function of storage time, greater water absorption was found for the periods that presented high pest infestation (*Acanthochelides obtectus*) due to greater mechanical damage in bean seeds. Investigating the drying of bean seeds with initial moisture content of 25% (wet basis) to final moisture content of 13% (wet basis) in the sun and intermittent dryer, Ahrens and Lollato (1997) found that the rate of cracked seeds increased during intermittent drying in the dryer at 60 °C.

It is also observed in Figure 5 that the simple linear model represents well the variation in water absorption as a function of drying temperature, represented by the high determination coefficient (R^2).

4 Conclusions

Under the conditions of this study, it can be concluded that increasing the drying air temperature reduces the drying time. Air temperatures of 60 and 70 °C negatively affected the physiological and technological seed quality. Therefore, in order to avoid damages to adzuki beans quality, it is recommended that the drying temperature should not exceed 50 °C.

Acknowledgements

The authors acknowledge the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Instituto Federal Goiano - Campus Rio Verde (IF Goiano - Campus Rio Verde) for the financial support.

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