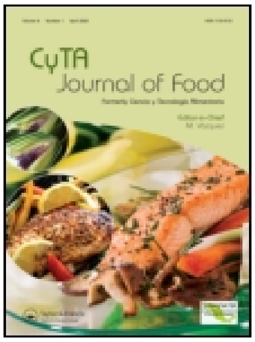

CyTA - Journal of Food

ISSN: 1947-6337 (Print) 1947-6345 (Online) Journal homepage: http://www.tandfonline.com/loi/tcyt20

Rehydration properties of precooked whole beans (Phaseolus vulgaris) dehydrated at room temperature

J.A. Ulloa , C.R. Bonilla-Sánchez , M.A. Ortíz-Jiménez , P. Rosas-Ulloa , J.C. Ramírez-Ramírez & B.E. Ulloa-Rangel

To cite this article: J.A. Ulloa , C.R. Bonilla-Sánchez , M.A. Ortíz-Jiménez , P. Rosas-Ulloa , J.C. Ramírez-Ramírez & B.E. Ulloa-Rangel (2013) Rehydration properties of precooked whole beans (Phaseolus vulgaris) dehydrated at room temperature, CyTA - Journal of Food, 11:1, 94-99, DOI: 10.1080/19476337.2012.699104

To link to this article: http://dx.doi.org/10.1080/19476337.2012.699104

Published online: 09 Jul 2012.

CyTA – Journal of Food
Vol. 11, No. 1, February 2013, 94–99

Rehydration properties of precooked whole beans (*Phaseolus vulgaris*) dehydrated at room temperature

Propiedades de rehidratación de frijol entero precocido (*Phaseolus vulgaris*) deshidratado a temperatura ambiente

J.A. Ulloa[a,b,c]*, C.R. Bonilla-Sánchez[b], M.A. Ortíz-Jiménez[c], P. Rosas-Ulloa[a], J.C. Ramírez-Ramírez[d] and B.E. Ulloa-Rangel[b]

[a]*Centro de Tecnología de Alimentos, Universidad Autónoma de Nayarit, Ciudad de la Cultura Amado Nervo, 63155 Tepic, Nayarit, México;* [b]*Unidad Académica de Ciencias Químico Biológicas y Farmaceúticas, Universidad Autónoma de Nayarit, Ciudad de la Cultura Amado Nervo, 63155 Tepic, Nayarit, México;* [c]*Área de Ciencias Básicas e Ingenierías, Universidad Autónoma de Nayarit, Ciudad de la Cultura Amado Nervo, 63155 Tepic, Nayarit, México;* [d]*Unidad Académica de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Nayarit, Carretera a Chapalilla, 63700 Compostela, Nayarit, México*

(*Received 5 March 2012; final version received 27 May 2012*)

The aim of this research was to study the rehydration behavior of precooked whole beans (*Phaseolus vulgaris*) dehydrated at room temperature (25°C) and soaked in water at three temperatures (40, 60, and 80°C). The water absorption of the beans was determined by the gain in weight. The dehydration kinetic at room temperature of the beans was adequately described by the Logarithmic model ($R^2 = 0.9989$) with a dehydration rate constant (k_d) value of 1.96×10^{-3} min^{-1}. A semi-empirical first-order differential equation adequately described the rehydration characteristics of precooked whole bean under the experimental conditions ($R^2 = 0.9934$–0.9976). The rehydration rate constant (k_r) increased from 6.10×10^{-2} to 12.14×10^{-2} min^{-1} with an increase in the temperature from 40 to 80°C. The temperature dependence of k_r was well described by Arrhenius-type equation ($R^2 = 0.8785$), with estimated activation energy of 16.03 kJ mol^{-1} K^{-1}.

Keywords: precooked whole bean; water absorption; rehydration kinetic; dehydration kinetic

El propósito de este trabajo fue estudiar el comportamiento de rehidratación de frijol (*Phaseolus vulgaris*) entero precocido deshidratado a temperatura ambiente (25°C) y remojado en agua a tres temperaturas (40, 60 y 80°C). La absorción de agua del frijol se determinó por la ganancia de peso. La cinética de deshidratación a temperatura ambiente del frijol fue descrita adecuadamente por el modelo Logarítmico ($R^2 = 0{,}9986$) con un valor de la constante de velocidad de deshidratación (k_d) de $1{,}96 \times 10^{-3}$ min^{-1}. Una ecuación diferencial empírica de primer orden describió adecuadamente las características de rehidratación del frijol entero precocido bajo las condiciones experimentales ($R^2 = 0{,}9933$ a $0{,}9976$). La constante de velocidad de rehidratación (k_r) se incrementó de $6{,}10 \times 10^{-2}$ a $12{,}14 \times 10^{-2}$ con el aumento de temperatura de 40 a 80°C. La dependencia de temperatura de k_r fue descrita por la ecuación de Arrhenius ($R^2 = 0{,}8785$), con una energía de activación estimada de 16,03 kJ mol^{-1}K^{-1}.

Palabras clave: frijol entero precocido; absorción de agua; cinética de rehidratación; cinética de deshidratación

Introduction

The common bean (*Phaseolus vulgaris* L.), together with corn (*Zea mays* L.), constitutes the staple diet for most Mexicans and has been used in the preparation of traditional dishes and meal for many years (Morales-De León, Vázquez-Mata, Torres, Gil-Zenteno, & Bressani, 2007). Beans are a good source of carbohydrates, proteins, dietary fiber (mainly insoluble fiber), vitamins (thiamin, riboflavin, niacin, pyridoxine, and folic acid), and to a lesser extent certain minerals such as calcium, iron, copper, zinc, phosphorus, potassium, and magnesium, and the hull contains flavonoids, which function as antioxidants (Granito, Guinand, Pérez, & Pérez, 2009; Kigel, 1999; Santalla, Fuello, Rodino, Montero, & Ron, 1999).

Clinical studies have shown that regular consumption of beans helps to decrease colon cancer incidence and multiplicity (Hangen & Bennink, 2002; Reynoso-Camacho et al., 2007), alterations in the gastrointestinal tract, cardiovascular disease, and diabetes (Bazzano et al., 2001). Compared to other carbohydrate sources, beans have a low glycemic index, which might help people to control their blood glucose level during diabetes and other chronic degenerative diseases (Atkinson, Foster-Powell, & Brand-Miller, 2008; Expert Committee, 2003; Silva-Cristobal, Osorio-Díaz, Tovar, & Bello-Pérez, 2010).

Beans also contain several antinutritional factors such as inhibitors of trypsin, chymotrypsin, and amylase, as well as phytic acid, flatulence-producing oligosaccharides, saponins, and lectins, which interfere with nutrient bioavailability (Krupa, 2008; Muzquiz, Burbano, Ayet, Pedrosa, & Cuadrado, 1999). However, the content of all of these antinutritional factors can be reduced or eliminated by certain culinary practices, such as discarding the soaking water before cooking, or the use of a soaking solution of sodium bicarbonate or citric acid prior to cooking (Fernandes, Nishida, & Da Costa Proença, 2010; Yazmin, Zeb, Khalil, Paracha, & Khattak, 2008).

*Corresponding author. Email: arulloa5@gmail.com

ISSN 1947-6337 print/ISSN 1947-6345 online

http://dx.doi.org/10.1080/19476337.2012.699104
http://www.tandfonline.com

The main problem in utilization of beans is the need for prolonged soaked and cooking (Piergiovanni, 2011; Rocha-Guzmán et al., 2008; Vasconcelos-García et al., 2011). Dehydrated precooked beans could be an alternative for fast preparation and promotion of consumption of beans. Some studies have been performed with the objective of defining the process conditions for the production of dehydrated precooked beans of acceptable quality (Cai & Chang, 1997; Su & Chang, 1995). However, butterflying and splitting are the major problems, which usually result in loss of bean structure, flavor, texture, and identity.

The high rate of dehydration of cooked beans causes the seed coat splitting, which could be minimized by the use of low air velocity and low temperature during drying (Cai & Chang, 1997). Few studies have focused on the use of low drying air temperature and the impact it has on product quality (Iguaz, Martin, Mate, Fernadez, & Virseda, 2002; Ondier, Siebenmorgen, & Mauromoustakos, 2010).

Rehydration, which is a complex process aimed at the restoration of raw material properties when dried material comes in contact with water, can be considered as a measure of the injury to the material caused by drying and treatment preceding dehydration. The objective of rehydration study is to evaluate products with as much as original characteristics and as fast as possible. Rehydration cannot be simply treated as the reverse process of dehydration. It is not indifferent to the drying method and its effect on the material undergoing rehydration cannot be disregarded (Dadali, Demirhan, & Ozbek, 2008).

Therefore, the main objective of this study was to investigate the properties of rehydration of precooked whole beans dehydrated at room temperature.

Materials and methods

Bean processing

Bean (*Phaseolus vulgaris*) seeds from the variety Canario, which are highly consumed in the Western region of México, used for this study were obtained from the Mercado de Abastos, located at Tepic, Nayarit, Mexico, and stored at room temperature. Bean seeds from the variety Canario are medium-size (35–38 g/100 seeds), cylindrical, and yellowish cream. Before processing, the dry beans were sorted to remove broken, cracked, and damaged beans. Batches of 200 g were washed with tap water. One part of beans was blanched in four parts (w/w) tap water at 95°C for 3 min. After blanching, the beans were soaked in seven parts of tap water at 45°C for 120 min and then the hydrated beans were cooked in a pot at 97°C for 90 min.

Dehydration procedure

The cooked beans were dehydrated in a cabinet drier at room temperature (25°C) under an air velocity of 180 ± 1 m min^{-1} and relative humidity of 55 ± 5%. In this dryer, air was flowing horizontally through cooked beans. The velocity of air passing through system was measured by a CEM DT-618 thermo-anemometer (Shenshen Everbest Machinary Industry, Co., Ltd, Nanshan, Shenzhen, China). For dehydration, 400 g of precooked beans were uniformly spread in a single layer on a rectangular tray formed by an aluminum frame (size 40 cm × 30 cm) and a plastic mesh where the distance between wires was 1.3 mm. The samples of beans were removed of dryer at time intervals of 30 min during the dehydration process and their weights were recorded with a digital scale with 0.01 g accuracy (Ohaus Corporation, USA). Dehydration of the cooked beans continued until the decrease in weight was negligible, which was achieved at a final moisture content of 140 $\pm$ 20 g water/kg dry matter. Three replication of the dehydration experiment were carried out. The final moisture content was considered to be the value of equilibrium moisture content. Moisture ratio (MR) was calculated with the following equation:

$$\mathrm{MR} = (M_{\mathrm{td}} - M_{\mathrm{ed}})/(M_{0\mathrm{d}} - M_{\mathrm{ed}}) \tag{1}$$

where M_{td} is the moisture content at any time for the dehydration study (% g water/kg dry matter); M_{ed} is the equilibrium moisture content for the dehydration study (% g water/kg dry matter); and $M_{0\mathrm{d}}$ is the initial moisture content for the dehydration study (% g water /kg dry matter).

The experimental dehydration data (MR) was fitted to the Logarithmic model, according to the following equation:

$$\mathrm{MR} = a\ \exp(-k_{\mathrm{d}} t) + c \tag{2}$$

where k_{d} is the dehydration rate constant (min^{-1}); t is the dehydration time (min), and a and c are the dehydration coefficients.

Proximal composition and physicochemical analyses of raw and precooked beans

Moisture, crude protein (N × 6.25), crude fiber, ethereous extract, and ash contents were determined in triplicate according to the Association of Official Analytical Chemists (AOAC, 1995) methods. Water activity (a_{w}) was measured in triplicate at 25°C using a Decagon Aqualab meter CX-2 (Pullman, Washington, USA), on coarse powder samples (3 g), which were obtained by grinding of raw and precooked beans using a mortar and pestle. Prior to testing samples, the water activity meter was turned on and allowed to warm up for 30 min and calibrated by filling a plastic disposable cup half filled with a saturated sodium chloride solution. The accuracy of water activity values was ± 0.003. The color was determined with a Minolta CR-300 color meter (Minolta, Tokyo, Japan). The measured values were expressed according to the CIELAB color scale L^* (lightness), a^* (redness–greenness), and b^* (yellowness–blueness). The L^*, a^*, and b^* values of the white standard tile used as reference were 97.14, 0.19, and 1.84, respectively. The color measurement was directly on the surface of each bean in a sample of 10 raw and precooked beans. Precooked whole beans were judged to be split if they had either a crack between the cotyledons or a transverse fissure in the seed coat >2 mm wide. The beans with split seed coats or cracked cotyledons in each lot were counted. The results are reported as the percentage split beans. Butterflied beans were defined as those with two cotyledons separated by more than half of the length of the bean (Su & Chang, 1995).

Rehydration procedure

Water absorption of dehydrated precooked beans was determined according to the modified method of Abu-Ghannam and McKenna (1997). A sample of 30 beans (≈10 g, weighed exactly) was placed in a net basket and immersed into a 250-mL glass jar with lid containing 100 mL distilled water, which was previously heated to the required soaking temperature (40, 60, or 80°C) by placement in a water bath (±1°C) thermostatically controlled at the required temperature. Water absorption was recorded in a scale digital (Ohaus Corporation, USA) by increase of the bean weight every 3 min until the difference between consecutive weight measurements was insignificant (0.05 ± 0.01 g), which was considered to represent the saturation moisture content. There was no correction for lost solids. After the specified soaking time, the beans were removed from the soaking solution, drained on a kitchen strainer for 0.5 min, blotted with paper tissue, and weighed. The weight gain was measured, and the beans were returned to the soaking solution at the required temperature. All soaking tests were triplicated and recorded on a percentage moisture dry matter.

With consideration that the rate of water uptake by beans is directly proportional to the difference between saturation moisture content and moisture content at any given time (Abu-Ghannam & McKenna, 1997; Krokida & Marinos-Kouris, 2003), the rate of rehydration (RR, % g water/g dry solids min^{-1}) can be expressed as:

$$RR = dM/dt = k_r(M_{tr} - M_{er}) \quad (3)$$

where k_r is the rehydration rate constant (min^{-1}); M_{tr} is the moisture content at any given time for rehydration study (% g water/ kg dry matter); and M_{er} is the equilibrium moisture content for the rehydration study (% g water/ kg dry matter).

To illustrate the effects of soaking temperature on RR, the Arrhenius equation was applied. The Arrhenius law can be represented as:

$$k_r = k_0 \exp(E_a/RT) \quad (4)$$

where k_0 is the pre-exponential factor having units equivalent to the rehydration constant; E_a is the activation energy (kJ mol^{-1}); R is the universal gas constant (8.314 kJ mol^{-1} K^{-1}); and T is the absolute temperature (K). The value of E_a was determined by plotting the natural logarithm of k_r versus the reciprocal of the absolute temperature.

Statistical analyses

The dehydration and rehydration experiments and physicochemical analyses were performed in triplicate and average results reported. Fitting procedures and k_d and k_r values were determined by minimization of the sum of quadratic differences between observed and model/equation predicted values, using the fourth-order Runge–Kutta method programmed in a Microsoft Excel spreadsheet (Chapra & Canale, 2009). Coefficients of determination (R^2) were obtained as a measure of the goodness of the fit of the tested mathematical models to the experimental data.

Results and discussion

Dehydration kinetic

The initial moisture content of the cooked beans used in the dehydration experiment was 2.040 ±19 g water per kg dry matter. MR as a function of dehydration time is shown in Figure 1. MR decreased with time to an asymptotic value of 0 in 25 h. A close fit between the Logarithmical empirical model (Equation 2) and the experimental data was obtained when the k_d value of 1.96 × 10^{-3} min^{-1} (a = 1.111449, c = −0.083903) was identified (R^2 = 0.9989). The same model has been employed to describe the dehydration kinetic of apricots (Doymaz, 2004), sweet pepper (Vengaiah & Pandey, 2007), tomatoes (Khazaei, Chegini, & Bakhshiani, 2008), and sweet cherry (Doymaz & Izmail, 2011).

In recent years, microwave dehydration has gained popularity as an alternative dehydration method for a wide variety of food and agricultural products. Microwave treatment can greatly reduce the dehydration time of the biological products without quality degradation (Mujumdar & Law, 2010; Vadivambal & Jayas, 2007). Dehydration of cooked chickpeas and soybean using a combination of microwave and air convection produced highly rehydratable products in short dehydration times (Gowen, Abu-Ghannam, Frias, & Oliveira, 2006, 2008). However, in the case of precooked whole beans, a low dehydration rate is required to avoid or highly reduce the incidence of splitting or butterflying, which was achieved with the dehydration conditions employed in this experiment. The precooked whole beans dehydrated at room temperature showed only 1.2 ±0.13% splitting, and no butterflying was observed (Table 1).

Proximal composition and physicochemical characteristics of raw and precooked beans

Table 1 shows the proximal composition and some physicochemical characteristics of raw and precooked beans. The proximal composition of the precooked beans dehydrated at room temperature compared with that of raw beans was not changed substantially by processing. Other studies have

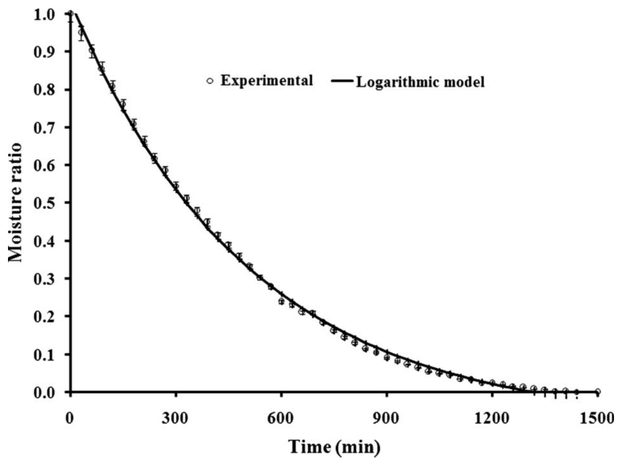

Figure 1. Dehydration kinetic at room temperature (25°C) of cooked whole beans (○, experimental data; ————, Logarithmic model). Vertical bars represent the standard deviation of data from three experiments.

Figura 1. Cinética de deshidratación a temperatura ambiente (25°C) del frijol entero precocido (○, datos experimentales; ————, modelo Logarítmico). Las barras verticales representan la desviación estándar de tres experimentos.

Table 1. Proximal composition and physicochemical properties of raw and precooked beans dehydrated at room temperature (25°C).

Tabla 1. Composición proximal y propiedades fisicoquímicas de frijol crudo y precocido deshidratado a temperatura ambiente (25°C).

Parameters	Value	
	Raw	Precooked
Moisture (g/kg)	120.0 ± 1.1	122.5 ± 0.7
Ash (g/kg)	37.0 ± 1.5	35.0 ± 0.6
Protein (g/kg)	235.7 ± 0.9	231.2 ± 0.1
Ethereous extract (g/kg)	26.5 ± 1.1	21.9 ± 0.8
Total carbohydrates (g/kg)	580.8 ± 0.21	589.4 ± 1.7
Water activity	0.628 ± 0.05	0.635 ± 0.01
*L**	79.04 ± 0.32	95.20 ± 0.56
*a**	0.32 ± 0.24	0.29 ± 0.13
*b**	22.01 ± 0.53	4.28 ± 0.38
Splitting (%)	NA	1.20 ± 0.13

Note: Values are means ± standard deviation of three replicates; NA = not applicable

Nota: Valores promedio ± desviación estándar de tres repeticiones; NA = no aplicable.

reported similar values for moisture, protein, and a_w of ready-to-eat beans obtained by dehydration with air at 49–65°C (Su & Chang 1995). On the other hand, only a slight increase in a_w was observed for precooked beans dried at room temperature, but not sufficient to disturb the microbial stability of the beans, because it is generally accepted that no microbial growth will occur at $a_w < 0.66$ (Labuza, 1980). With respect to color, the precooked beans became whiter (increased *L** value) and less yellow (decreased *b** value) than raw beans, while redness was unchanged. The most common factors that can affect the color of foods during processing are pigment degradation, browning reactions, ascorbic acid oxidation, acidity, and the presence of copper and iron in the cooking medium (Bayram, Oner, & Kaya, 2004). The decrease in redness and yellowness of legumes might be explained by the degradation of color pigments during cooking, while the darkening process caused by the presence of metals during cooking might results as increase in redness and yellowness (Guzel & Sayar, 2012). In this study, the decrease in yellowness of precooked bean could be due to the degradation of pigments during the cooking.

Rehydration characteristics

As shown in Figure 2, water absorption curves of precooked whole beans exhibited an initial high RR followed by progressively lower uptake rates at later stages. The rapid initial water uptake by legumes is attributed to the filling of capillaries on the surface of the seed coats and at the hilum. The decline in rehydration rates at later stages is related to the combined effects of increased extraction rates of soluble materials and lower water absorption presumably because of the filling of free capillaries and intermicellar spaces with water. Subsequently, amounts of water absorbed with further soaking were minimal until equilibrium was attained, which signaled the maximum water capacity of precooked beans dehydrated at room temperature. Similar rehydration patterns for a variety of legumes have been reported previously (Abu-Ghannam & McKenna, 1997; Berrios et al., 1999; Yildirim, Oner, & Bayram, 2010).

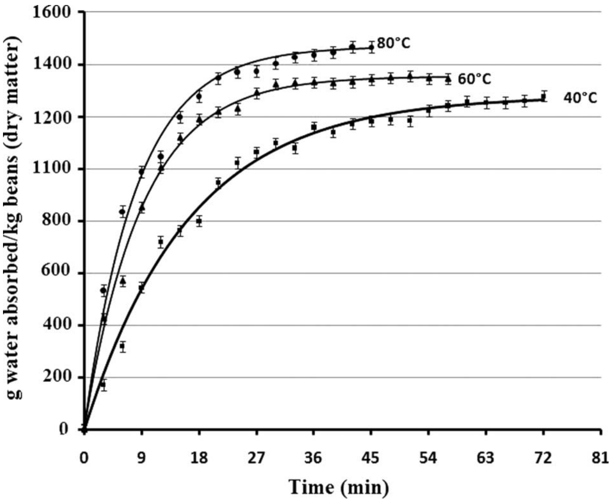

Figure 2. Effect of temperature on rehydration of precooked beans dehydrated at room temperature (■, ▲ , ●: experimental data; ————: Logarithmic model). Vertical bars represent the standard deviation of data for triplicate experiments.

Figura 2. Efecto de la temperatura en la rehidratación del frijol precocido deshidratado a temperatura ambiente (25°C) (■, ▲ , ●: datos experimentales; ————: modelo Logarítmico). Las barras verticales representan la desviación estándar de tres experimentos.

The k_r value at different soaking temperatures for precooked beans dehydrated at room temperature, as well as the empirical rehydration equations related to the rate of moisture absorption, are shown in Table 2. In general, increasing the soaking temperature resulted in an increase in k_r as well as the equilibrium moisture content. Increasing the soaking temperature from 40 to 60°C resulted in an increase in k_r by as much as 1.8-fold, but the effect was not as obvious when the rehydration temperature increased from 60 to 80°C, which resulted in an increase of only 1.1-fold.

Rehydration characteristics of a dehydrated product can be used as a quality index. Such characteristics reflect the physical and chemical changes that occurred during dehydration, and those changes, in turn, are influenced by the composition of the samples, by the conditions imposed during drying, and by any pretreatment to which the products have been subjected (Maskan, 2001). The amount and rate of water absorbed determine the sensorial properties and the preparation time required by the consumer. During rehydration, volume changes in biological materials are often proportional to the amount of absorbed water: the increase in volume because of water absorption equals the volume of imbibed water. Some research shows that the rehydration temperature markedly affects the increase in volume; moisture content (for the same processing time) increases with an increase in temperature, as was observed in the present study for precooked beans. This trend has been observed for temperatures in the range of 40–80°C for many fruits and vegetables (Krokida & Marinos-Kouris, 2003).

The values of ln k_r plotted against the reciprocal of temperature for precooked beans dehydrated at room temperature are shown in Figure 3. The high value of R^2 confirmed that the water absorption rate of precooked beans dehydrated at room temperature during soaking was temperature dependent. The slope of the resulting straight line was used to calculate E_a, which was16.03 kJ mol^{-1} K^{-1}.

Table 2. Rehydration characteristics of precooked whole beans dehydrated at room temperature for different soaking temperatures.

Tabla 2. Características de rehidratación del frijol entero precocido deshidratado a temperatura ambiente para diferentes temperaturas de remojo.

Soaking temperature	Rehydration rate constant (k_r, min^{-1})	Equilibrium moisture content (% dry basis)	Regression equation of rate of rehydration (RR)[b]	R^2
40°C	6.10×10^{-2} ($\pm 1.34 \times 10^{-3}$)	127.6 (±1.8)	$RR = 7.8019 - 0.061M_{tr}$	0.9934
60°C	11.00×10^{-2} ($\pm 2.31 \times 10^{-3}$)	135.5 (±1.7)	$RR = 14.905 - 0.110M_{tr}$	0.9884
80°C	12.14×10^{-2} ($\pm 2.18 \times 10^{-3}$)	146.7 (±1.5)	$RR = 17.809 - 0.121M_{tr}$	0.9976

Note: Values in brackets are the standard deviations of the means of three replicates. M_{tr} = rehydration moisture content at any given time.

Nota: Los valores dentro de los paréntesis son las desviaciones estándar de los promedios de tres réplicas. M_{tr} = contenido de humedad en la rehidratación a cualquier tiempo dado.

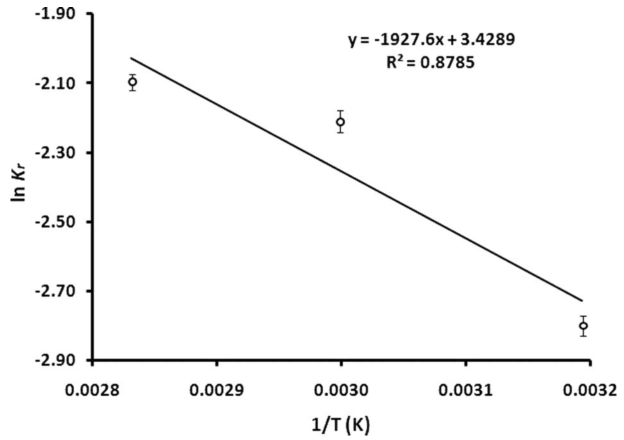

Figure 3. Arrhenius plot of rehydration rate constant versus reciprocal temperature (K) for precooked beans dehydrated at room temperature (25°C). Vertical bars represent the standard deviation of data for triplicate experiments.

Figura 3. Gráfica de Arrhenius de la constante de velocidad de rehidratación contra el recíproco de la temperatura (K) para el frijol precocido deshidratado a temperatura ambiente (25°C). Las barras verticales representan la desviación estándar de tres experimentos.

Conclusions

By dehydration at room temperature with an air velocity of 180 m min^{-1} and relative humidity of 55 ±5%, it was possible to obtain precooked whole beans that showed only 1.2 ±0.13% splitting. However, more studies must be conducted to minimize the total time of preparation of precooked whole bean, mainly by optimizing the time of soaking, cooking, and dehydration, thus ensuring product quality. The dehydration data for the cooked whole beans were well described using the Logarithmic equation. A semi-empirical first-order differential equation, based on the rule that the rate of water uptake is directly proportional to the difference between equilibrium moisture content and moisture content at any given time, adequately described the rehydration characteristics of precooked whole beans dehydrated at room temperature and thus could be used to estimate the moisture content of the beans at a given temperature within the experimental conditions considered. The water absorption rate of precooked whole beans increased with the increase in temperature and can be described by an Arrhenius-type equation from which the activation energy can be calculated.

Acknowledgments

The authors wish to thank Promep-SEP-México for providing funds to support this research through grant 2649-UAN-CA-6.

References

Abu-Ghannam, N., & McKenna, B. (1997). Hydration kinetics of red kidney beans (*Phaseolus vulgaris* L.). *Journal of Food Science*, *62*, 520–523. doi: 10.1111/j.1365–2621.1997.tb04420.x.

Association of Official Analytical Chemist (AOAC). (1995). *Official methods of analysis*. Arlington: AOAC International.

Atkinson, F.S., Foster-Powell, K., & Brand-Miller, J.C. (2008). International tables of glycemic index and glycemic load values: 2008. *Diabetes Care*, *31*, 2281–2283. doi: 10.2337/dc08–1239.

Bayram, M., Oner, M.D., & Kaya, A. (2004). Influence of soaking on the dimensions and colour of soybean for bulgur production. *Journal of Food Engineering*, *61*, 331–339. doi: 10.1016/S0260–8774(03)00137–7.

Bazzano, I.A., He, J., Ogden, I., Loria, C., Vupputuri, S., Myers, I., & Whelton, P.K. (2001). Legume consumption and risk of coronary heart disease in USA men and women. *Archives of Internal Medicine*, *161*, 2573–2578. doi: 10.1001/archinte.161.21.2573.

Berrios, J.D.J., Barry, G.S., & Cheong, W.A. (1999). Physico-chemical characterization of stored black beans (*Phaseolus vulgaris* L.). *Food Research International*, *32*, 669–676. doi: 10.1016/S0963–9969(99)00144–1.

Cai, T.D., & Chang, K.C. (1997). Processing to improve quality of dehydrated precooked pinto beans. *Journal of Food Science*, *62*, 141–144. doi: 10.1111/j.1365–2621.1997.tb04386.x.

Chapra, S.C., & Canale, R.P. (2009). *Métodos numéricos para ingenieros* (pp. 750–764). México, D.F.: McGraw Hill-Interamericana Editores, S.A.de C.V.

Dadali, G., Demirhan, E., & Ozbek, B. (2008). Effect of drying conditions on rehydration kinetics of microwave dried spinach. *Food and Biproducts Processing*, *86*, 235–241. doi: 10.1016/j.fbp.2008.01.006.

Doymaz, I. (2004). Effect of pretreatments using potassium metabisulphide and alkaline ethyl oleate on the drying kinetics of apricots. *Biosystems Engineering*, *89*, 281–287. doi: 10.1016/j.biosystemseng.2004.07.009.

Doymaz, I., & Ismail, O. (2011). Drying characteristics of sweet cherry. *Food and Bioproducts Processing*, *89*, 31–38. doi: 10.1016/j.fbp.2010.03.006.

Expert Committee. (2003). Report of the expert committee on the diagnosis and classification of diabetes mellitus. *Diabetes Care*, *26* (Suppl. 1), 5–20. Retrieved from http://care.diabetesjournals.org/content/26/suppl_1/s5.full.pdf.

Fernandes, A.C., Nishida, W., & Da Costa Proença, R.P. (2010). Influence of soaking on the nutritional quality of common beans (*Phaseolus vulgaris* L.) cooked with or without the soaking water: a review. *International Journal of Food Science and Technology*, *45*, 2209–2018. doi: 10.1111/j.1365–2621.2010.02395.x.

Gowen, A., Abu-Ghannam, N., Frias, J., & Oliveira, J. 2006. Optimisation of dehydration and rehydration properties of cooked chickpeas (*Cicer aritinum* L.) undergoing microwave-hot air combination drying. *Trends in Food Science and Technology*, *17*, 177–183. doi: 10.1016/j.tifs.2005.11.013.

Gowen, A.A., Abu-Ghannam, N., Frias, J., & Oliveira, J. (2008). Modeling dehydration and rehydration of cooked soybeans subjected to combined microwave–hot-air drying. *Innovative Food Science and Emerging Technologies*, *9*, 129–137. doi: 10.1016/j.ifset.2007.06.009.

Granito, M., Guinand, J., Pérez, D., & Pérez, S. (2009). Valor nutricional y propiedades funcionales de *Phaseolus vulgaris* procesada: un ingrediente potencial para alimentos. *Interciencia*, *34*, 64–70. Retrieved from http://www.interciencia.org/v34_01/index.html.

Guzel, D., & Sayar. S. (2012). Effect of cooking methods on selected physicochemical and nutritional properties of barlotto bean chickpea, faba bean, and white kidney bean. *Journal of Food Science and Technology*, *49*, 89–95. doi: 10.1007/s13197–011–0260–0.

Hangen, L., & Bennink, M.R. (2002). Consumption of black beans and navy beans (*Phaseolus vulgaris* L.) reduced azoximethane induced colon cancer in rats. *Nutrition and Cancer*, *44*, 60–65. doi: 10.1207/S15327914NC441_8.

Iguaz, A., Martin, M.B., Mate, J.I., Fernandez, T., & Virseda, P. (2002). Modeling of effective moisture diffusivity of rough rice (*Lido* cultivar) at low drying temperatures. *Journal of Food Engineering*, *59*, 253–258. doi: 10.1016/S0260–8774(02)00465-X.

Khazaei, J., Chegini, G.R., & Bakhshiani, M. (2008). A novel alternative method for modeling the effects of air temperature and slice thickness on quality and drying kinetics of tomato slices: superposition technique. *Drying Technology*, *26*, 759–775. doi: 10.1080/07373930802046427.

Kigel, J. (1999). Culinary and nutricional quality of *Phaseolus vulgaris* seeds as affected by environmental factors. *Biotechnolology, Agronomy, Society and Environment*, *3*, 205–209. Retrieved from http://www.bib.fsagx.ac.be/base/text/v3n4/205.pdf.

Krokida, M.K., & Marinos-Kouris, D. (2003). Rehydration kinetics of dehydrated products. *Journal of Food Engineering*, *57*, 1–7. doi: 10.1016/S0260–8774(02)00214–5.

Krupa, U. (2008). Main nutritional and antinutritional compounds of bean seed – A review. *Polish Journal of Food and Nutrition Science*, *58*(2), 149–155. Retrieved from http://journal.pan.olsztyn.pl/?p=rec&s_rok=2008&s_numer=2.

Labuza, T.P. (1980). The effect of water activity on reaction kinetics of food deterioration. *Food Technology*, *34*, 36–42.

Maskan, M. (2001). Drying, shrinkage and rehydration characteristics of kiwifruits during hot air and microwave drying. *Journal of Food Engineering*, *48*, 177–182. doi: 10.1016/S0260–8774(00)00155–2.

Morales-De León, J.C., Vázquez-Mata, N., Torres, N., Gil-Zenteno, L., & Bressani, R. (2007). Preparation and characterization of protein isolate from fresh and hardened beans (*Phaseolus vulgaris* L.). *Journal of Food Science*, *72*, C96–C102. doi: 10.1111/j.1750–3841.2006.00244.x.

Mujumdar, A.S., & Law, C.L. (2010). Drying technology: Trends and applications in postharvest processing. *Food and Bioprocess Technology*, *3*, 843–852. doi: 10.1007/s11947–010–0353–1.

Muzquiz, M., Burbano, C., Ayet, G., Pedrosa, M.M., & Cuadrado, C. (1999). The investigation of antinutritional factors in *Phaseolus vulgaris*. Environmental and varietal differences. *Biotechnolology, Agronomy, Society and Environment*, *3*, 210–216. Retrieved from http://www.pressesagro.be/base/text/v3n4/210.pdf.

Ondier, G.O., Siebenmorgen, T.J., & Mauromoustakos, A. (2010). Low-temperature, low-relative humidity drying of rough rice. *Journal of Food Engineering*, *100*, 545–550. doi: 10.1016/j.jfoodeng.2010.05.004.

Piergiovanni, A.R. (2011). Kinetic of water adsorption in common bean: considerations on the suitability of Peleg's model for describing bean hydration. *Journal of Food Processing and Preservation*, *35*, 447–452. doi: 10.1111/j.1745–4549.2010.00486.x.

Reynoso-Camacho, R., Rios-Ugalde, M.C., Torres-Pacheco, I., Acosta-Gallegos, A., Palomino-Salinas, C., Ramos-Gómez, M., González-Jasso, E., & Guzmán-Maldonado, S.H. (2007). El consumo de frijol común (*Phaseolus vulgaris* L.) y su efecto sobre el cáncer de colon en ratas *Sprague dawley*. *Agricultura Técnica*, *33*, 43–52. Retrieved from http://www.redalyc.org/src/inicio/ArtPdfRed.jsp?iCve=60833105.

Rocha-Guzman, N.E., Gallegos-Infante, J.A., Gonzalez-Laredo, R.F., Bello-Perez, A., Delgado-Licon, E., Ochoa-Martinez, A., & Prado-Ortiz, M.J. (2008). Physical properties of extruded products from three Mexican common beans (*Phaseolus vulgaris* L.) cultivars. *Plant Foods for Human Nutrition*, *63*, 99–104. doi: 10.1007/s11130–008–0076-x.

Santalla, M., Fuello, M.A., Rodino, P.A., Montero, I., & Ron, M.A. (1999). Breeding for culinary and nutritional quality of common bean (*Phaseolus vulgaris* L.) in intercropping system with maize (*Zea mays* L.). *Biotechnolology, Agronomy, Society and Environment*, *3*, 225–229. Retrieved from http://www.bib.fsagx.ac.be/base/text/v3n4/225.pdf.

Silva-Cristobal, L., Osorio-Díaz, P., Tovar, J., & Bello-Pérez, L.A. (2010). Chemical composition, carbohydrate digestibility, and antioxidant capacity of cooked black bean, chickpea, and lentil Mexican varieties. *Cyta – Journal of Food*, *8*, 7–14. doi: 10.1080/19476330903119218.

Su, H.L., & Chang, K.C. (1995). Dehydrated precooked pinto bean quality as affected by cultivar and coating biopolymers. *Journal of Food Science*, *60*, 1330–1332. doi: 10.1111/j.1365–2621.1995.tb04584.x.

Vadivambal, R., & Jayas, D.S. (2007). Changes in quality of microwave-treated agricultural products – a review. *Biosystems Engineering*, *98*, 1–16. doi: 10.1016/j.biosystemseng.2007.06.006.

Vasconcelos-Garcia, R.A., Nascimento-Rangel, P., Zaczuk-Bassinello, P., Brondani, C., Cunha-Melo, L., Tadeu-Sibov, S., & Periera Vianello-Brondani, R. (2011). QTL mapping for the cooking time of common beans. *Euphytica*. Retrieved from http://www.springerlink.com/content/q63v2h0475002k24/fulltext.pdf. doi: 10.1007/s10681–011–0587–7.

Vengaiah, P.C., & Pandey, J.P. (2007). Dehydration kinetics of sweet pepper (*Capsicum annum* L.). *Journal of Food Engineering*, *81*, 282–286. doi: 10.1016/j.jfoodeng.2006.04.053.

Yazmin, A., Zeb, A., Khalil, A.W., Paracha, G.M.-U., & Khattak, A.B. (2008). Effect of processing on anti-nutritional factors of red kidney bean (*Phaseolus vulgaris*) grains. *Food and Bioprocess Technology*, *1*, 415–419. doi: 10.1007/s11947–008–0125–3.

Yildirim, A., Oner, M.D., & Bayram, M. (2010). Modeling of water absorption of ultrasound applied chickpeas (*Cicer arietinum* L.) using Peleg's equation. *Journal of Agricultural Sciences*, *16*, 278–286. Retrieved from www.agri.ankara.edu.tr/journal.