

WATER ABSORPTION KINETICS OF BLANCHED AND UNBLANCHED HYACINTH BEANS (*LABLAB PURPUREUS*)

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Abstract

The suitability of Peleg's equation in describing the water absorption kinetics of blanched and unblanched hyacinth beans seeds was studied at temperatures ranging between 27 and 75°C. Blanched and unblanched hyacinth bean seeds were independently soaked at 27-75°C. Water absorbed during soaking was a function of the soaking temperature and time. Results revealed that lower time was required for the seeds to reach equilibrium moisture content when soaked at high temperatures. Blanching prior to soaking reduced the time to reach equilibrium moisture content. Peleg's equation described the hydration process adequately for the seeds especially for the blanched. The coefficient of determination (R^2) ranged between 48.4 to 99.6% for unblanched and 99.8 to 100% for the blanched beans. Temperature dependence of Peleg's rate constant, k_1 was described by the Arrhenius equation. Activation energy values (E_a) of the hydration process obtained were 9.92 kJ/mole for blanched and 11.31 kJ/mole for unblanched seeds.

Keywords: Activation energy, blanching, hyacinth beans, hydration, modelling, Peleg's equation

Introduction

Hyacinth bean (*Lablab purpureus*) also known as lablab bean, tonga bean, butter bean or poor man's bean is a legume which is consumed in many parts of the world. It is rich in protein with an average value of 24% (Hossain *et al.*, 2016). It also contains good amounts of vitamins and minerals. The immature seeds and pods are edible and cooked as vegetables. The matured dry seeds are also edible but require very long cooking time. Soaking of legumes before cooking is widely practised as it aids in the reduction of cooking time and also gives rise to more evenly textured products (Kumar *et al.*, 2016). Soaking of legumes as an integral part of processing is an age old practice. There is a great

need to understand the water absorption process in legumes during soaking because it affects not only the following process operations but also the quality of the final product (Turhan *et al.*, 2002). During soaking, water is absorbed by the food material and the amount of water absorbed depends on a number of factors such as soaking time and temperature, initial moisture content, physicochemical properties of the food material being soaked as well as the duration of soaking (Agarry *et al.*, 2014). Uрга *et al.* (2006) reported that blanching grass pea before soaking increased water absorption of the grain by more than three-folds. Data obtained from hydration kinetics can be fitted to mathematical model which

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is suitable for predicting the moisture content of the grains as a function of time (Miano and Augusto, 2018). Different models have been used to express the relationship between moisture content and hydration. One of such models is the Peleg's model. This model is very popular and has been used to model the hydration process of various grains (Sopade and Obekpa, 1990; Vasudeva and Vishwanathan, 2010; Abu-Ghannam and McKenna, 1997). Abu-Ghannam and McKenna (1997) studied the hydration kinetics of blanched and unblanched kidney beans and reported that Peleg's equation was more suitable for predicting the water absorption of blanched kidney beans than unblanched kidney beans. A knowledge of the physical properties of grains is also important as this information is necessary in the design of various equipment. There is no work available on water absorption characteristics of blanched and unblanched hyacinth beans. The aim of this work therefore, was to study the hydration behaviours of blanched and unblanched hyacinth beans and the suitability of Peleg's equation in describing the water absorption of the blanched and unblanched hyacinth beans. The physical properties of hyacinth beans were also investigated.

Materials and Methods

Dry hyacinth beans were purchased from a local market in Nsukka, Enugu State, Nigeria. The legume was manually cleaned by removing extraneous materials, broken, cracked and damaged grains. The method described by AOAC (2016) for moisture content was used in determining the initial moisture content of the grains.

Physical Properties

The physical properties of the whole seeds investigated were dimensions, sphericity, volume, surface area, one seed weight, true and bulk densities and porosity of seeds. One hundred seeds were randomly selected and the measurements were taken using standard methods as described by Kumar *et al.* (2016).

Procedure for Blanching

The beans were blanched using the method described by Abu-Ghannam and McKenna (1997). Ten grams of hyacinth bean seeds were blanched by immersion in 100 ml of boiling water for 1.5 min, after which the seeds were removed from the boiling water, allowed to cool and drained. Tissue paper was used to blot off excess water from the blanched

seeds. The difference between the sample weight after blanching and original weight was taken as the moisture content of the blanched beans/10 g of dry beans. The values were later converted to % dry basis (% d. b).

Water Absorption Determination

Soaking of blanched and unblanched hyacinth bean seeds was done using a modification of the method described by Taiwo *et al.* (1994). Ten grams each of blanched and unblanched seeds were soaked in 200 ml of water which was contained in 250 ml beakers. The temperature of the water in the beakers was maintained by placing the beakers in a water bath which was thermostatically controlled. The temperatures used were 27°C, 45°C, 60°C, and 75°C. Throughout the soaking, the water temperature was maintained at $\pm 1^\circ\text{C}$ of the specified temperature. Water absorption was recorded at 30 min intervals. At each interval, the hyacinth bean seeds were removed from the water, excess surface water was blotted off the seeds and the seeds were weighed. The increase in weight was taken to be the water uptake. The process was continued until the difference between consecutive weights was not more than 0.01 g. Determinations were conducted in triplicates and average results were recorded as % dry basis (d. b).

Modelling of Water Absorption

Peleg's model (Peleg, 1998) was used to fit the experimental data. Peleg's equation is as follows:

$$M_t = M_o + (t / k_1 + k_2 t) \quad (1)$$

where:

M_t = average moisture content at time t (% d. b)

M_o = initial moisture content (% d. b)

t = soaking time (min)

k_1 = Peleg's rate constant (min^{-1} , d. b)

k_2 = Peleg's capacity constant ($\%^{-1}$ d. b)

The equilibrium moisture content is given by:

$$M_e = M_o + 1 / k_2 \quad (2)$$

where;

M_e = equilibrium moisture content

A plot of $t / (M_t - M_o)$ against time t gives a straight line with k_1 and k_2 representing the ordinate-intercept and gradient of the line.

The effect of soaking temperature on the hydration rate was determined using the Arrhenius equation given by:

$$\ln k = \ln k_0 - E_a / RT \quad (3)$$

where:

- k = hydration constant (min^{-1})
 E_a = activation energy (kJ mol^{-1})
 R = universal gas constant ($8.318 \text{ kJ mol}^{-1} \text{ } ^\circ\text{K}^{-1}$)
 T = absolute temperature ($^\circ\text{K}$)
 k_0 = constants having the same units as the hydration constant

Statistical Analysis

Linear regression analysis was carried out on data obtained using Minitab 17.3.1.

Results and Discussion

Physical Properties

The physical properties of hyacinth beans studied are presented in Table 1. The average length of the seeds was 6.50 mm, with a width of 5.85 mm and a thickness of 4.62 mm. These findings show that hyacinth seeds are shorter than the reported values for bambara which has a length of 11.48 mm (Mpotokwane *et al.*, 2008), chickpea: 10.2 mm (Tabatabaefar *et al.*, 2003) and jack bean: 18.66 mm (Eke *et al.*, 2007). It is also wider than reported values for African breadfruit (Omobuwajo *et al.*, 1999). However, it has the same range of thickness reported for African breadfruit (Omobuwajo *et al.*, 1999).

Table 1. Physical Properties of Hyacinth beans

Parameter	Values
Length (mm)	6.50 ± 0.81
Width (mm)	5.85 ± 0.47
Thickness (mm)	4.62 ± 0.37
True density (g/ml)	0.83 ± 0.46
Bulk density (g/ml)	0.80 ± 0.12
Porosity	0.04 ± 0.23
Sphericity	0.86 ± 0.05
Volume (mm ³)	24.99 ± 0.2
Surface area (mm ²)	148.80 ± 1.22
Aspect ratio	0.96 ± 0.07
Geometric mean diameter (mm)	5.44 ± 0.20
100g seed weight (g)	11.93 ± 0.44
Moisture content (%w. b)	10.27 ± 0.04

The bulk and true densities were found to be 0.80 g/ml and 0.83 g/ml respectively. The value obtained for true density suggests that the seed is less heavy than water and this characteristic can be exploited in the design of the separation and

cleaning processes. Similar trends of bulk and true density have also been reported for African bread fruit (Omobuwajo *et al.*, 1999). The usefulness of bulk density is found in the determination of the capacity of storage as well as transport systems (Kumar *et al.*, 2016).

The porosity and sphericity of the seeds were found to be 0.035 and 0.86 respectively. Porosity depends on geometry and surface properties of the material (Mohsenin, 1986). Bambara and jack bean had higher porosity 0.227 and 0.326 respectively as a result of their higher geometric dimensions (Eke *et al.*, 2007; Mpotokwane *et al.*, 2008). This property allows fluid to pass through the bulk. Information on the porosity of materials is useful in the calculation of the rate of aeration and cooling, drying and heating and the design of heat exchangers (Asoegwu *et al.*, 2006). The value for sphericity indicates that hyacinth bean is spherical in shape. A sphericity higher than 70% tells of how close the shape of a seed is to that of sphere (Eke *et al.*, 2007). Such higher sphericity allows the bean seeds to roll rather than slide which is a property required in the design of chutes, hoppers and other storage facilities (Mpotokwane *et al.*, 2008). A similar trend has been reported for bambara groundnut and jack bean.

The aspect ratio was found to be 0.96, which further confirmed that hyacinth bean seed is more spherical in shape. A value higher than 0.7 indicates that the seeds are more likely to roll rather than slide during handling and processing (Eke *et al.*, 2007).

The surface area and volume of hyacinth bean seeds were found to be 148.8 mm² and 24.99 mm³ respectively. The surface area affects the velocity of air stream that can be used in order to separate the seed from unwanted materials in pneumatic separator or to convey seed in pneumatic conveying (Asoiro and Ani, 2011).

Water Absorption Curves of Blanched and Unblanched Hyacinth Beans

The effects of soaking time and temperature on water absorption of blanched and unblanched hyacinth beans are shown in Figures 1 and 2. For all the four temperatures, it was observed that there was an initial high rate of water absorption (within the first 60 min of soaking). This was later followed by a slower rate of water absorption as the equilibrium moisture content (EMC) was being approached. Similar trends have been observed for various grains such as pigeon peas (Okpala, 2010), maize (Agarry *et al.*, 2014), sorghum (Kashiri *et al.*, 2010) and red kidney beans (Abu-Ghannam and McKenna, 1997). It was observed that for both blanched and unblanched seeds, it took a longer time for seeds soaked at 27°C to reach EMC than those soaked at

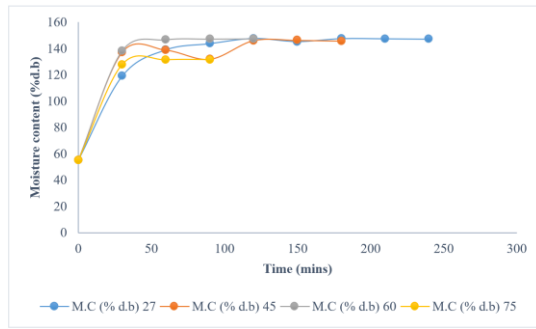


Figure 1. Water absorption characteristics of blanched hyacinth beans

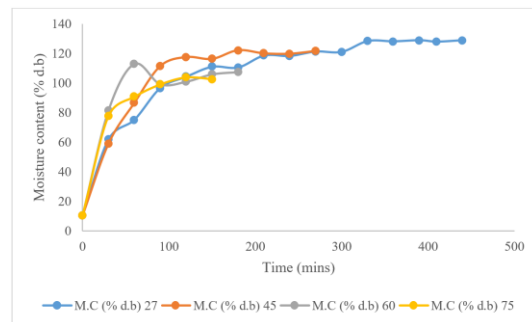


Figure 2. Water absorption characteristics of unblanched hyacinth beans

higher temperatures. In other words, increased temperatures led to shorter time in reaching the EMC. It was also observed that the blanching before soaking enhanced the rates of water absorption; seeds reached EMC at a faster rate than unblanched seeds regardless of the soaking temperature. Olatinjo and Omomowo (2019) observed that blanching had a similar effect on water absorption of sword beans. Urga *et al.* (2006) reported that the increase in water absorption by blanched seeds could be due to a change in the integrity of the seed coat resulting from the heat treatment used during blanching, leading to a change in the anatomical barriers of the hilum thereby resulting in water penetrating at a faster rate.

Table 2. Equilibrium moisture content of unblanched and blanched hyacinth beans

Treatment	Temperature (°C)	Equilibrium moisture content (% d. b)
Unblanched	27	128±1.50
	45	126±2.75
	60	106±1.09
	75	104±2.11
Blanched	27	149±1.65
	45	148±1.27
	60	148±1.25
	75	147±2.60

% d. b = % dry basis

The equilibrium moisture contents of blanched and unblanched hyacinth beans is presented in Table 2. It was observed that the blanched samples had higher EMC than the unblanched samples. Maximum EMC for unblanched beans was 128% at 27°C while it was 149% for blanched beans at the same soaking temperature. This could be because the temperature used in blanching the beans resulted in the pores and spaces inside the grain to expand, thereby enabling more water to be held (Miano and Augusto, 2018). It was also observed that for the blanched hyacinth beans, regardless of the soaking temperature, there was no significant difference in the EMC of the beans. Abu-Ghannam and McKenna (1997) observed a similar trend with blanched kidney beans where the EMC was not significantly affected by soaking at temperatures between 20°C and 60°C.

Model Fitting

Presented in Table 3 are estimated values for Peleg's constants (k_1 and k_2), initial hydration rate, coefficients of determination (R^2) and sum of squares error (SSE) which were obtained from fitting data of water absorption into Peleg's model. The Peleg's rate constant (k_1) was observed to be inversely proportional to temperature for both blanched and unblanched beans. As soaking temperatures increased, values for k_1 decreased.

Table 3. Equilibrium moisture content of unblanched and blanched hyacinth beans

Treatment	Temp (°C)	k_1 (min ⁻¹ %)	$1/k_1$ (% min ⁻¹)	k_2 (% ⁻¹)	P	R^2	SSE
Unblanched	27	6.0×10^{-1}	1.666	6.95×10^{-3}	0.000	86.0	2.70
	45	6.2×10^{-1}	1.614	5.96×10^{-3}	0.025	48.4	2.68
	60	6.0×10^{-2}	16.667	1.01×10^{-2}	0.000	99.6	0.01
	75	7.5×10^{-2}	73.376	1.04×10^{-2}	0.000	99.2	0.01
Blanched	27	7.0×10^{-2}	14.24	1.05×10^{-2}	0.000	99.8	0.01
	45	3.5×10^{-2}	28.868	1.09×10^{-2}	0.000	99.9	0.00
	60	1.8×10^{-2}	55.556	1.07×10^{-2}	0.000	99.9	0.00
	75	7.0×10^{-3}	140.857	1.31×10^{-2}	0.000	100	0.00

The reciprocal of the Peleg's rate constant ($1/k_1$) is known as the initial hydration rate. Blanched beans had higher initial hydration rates than unblanched beans for all of the soaking temperatures. Okpala and Ekechi (2014) observed a similar trend with blanched and unblanched West African pepper leaves and they concluded that the blanching process actually improves initial hydration rates.

The Peleg's constant k_2 has been reported to be a constant which defines the equilibrium moisture content (Abu-Ghannam and McKenna, 1997). Turhan *et al.* (2002) reported that k_2 is inversely related to the water absorption capacity. In other words, the higher the water absorption capacity, the lower the k_2 . This trend was observed in this work. The coefficients of determination (R^2) ranged from 99.8 to 100 % for the blanched beans with $P \leq 0.000$ and 48.4% to 99.6% with $P \leq 0.05$ at 45°C for unblanched beans indicating a good fit to the experimental data especially for the blanched beans. With the exception of unblanched seeds soaked at 27°C and 45°C, values obtained for sum of squares error (SSE) ranged between 0.00 and 0.01; also indicating a good fit to the experimental data. It was observed that the blanched beans had higher values of k_2 than the unblanched beans at all the soaking temperatures. Abu-Ghannam and McKenna (1997) observed that k_2 did not vary largely with temperature for blanched kidney beans. A similar observation was made in this study with the blanched beans.

Effect of Soaking Temperature on Peleg's Rate Constant (k_1)

The temperature dependence on hydration rates of hyacinth bean was illustrated by the linearized Arrhenius equation (Equation 3). Table 4 shows the energy of activation (E_a), the coefficient of determination (R^2) for blanched and unblanched beans as derived by regression. The low coefficient of determination (R^2) for the unblanched beans showed that K_1 was not temperature dependent ($p > 0.05$; $R^2 = 75.3\%$) while the blanched beans, on the other hand, was temperature dependent ($p < 0.05$ and $R^2 = 98.1\%$). Activation energies for the blanched and unblanched beans were 9.92 and 11.32 Kcal/mole respectively. The blanched beans had lower

activation energy than unblanched grains. The blanching step produced a reduction of more than 10% in activation energy of soaking.

Conclusions

The study has shown that Peleg's model can be used to describe the water absorption of both blanched and unblanched hyacinth beans at temperatures ranging between 27°C and 75°C. The use of a blanching step prior to soaking not only reduces soaking time of the grains but also increases the hydration rate.

References

- Abu-Ghannam, N., and McKenna, B. (1997). Hydration kinetics of kidney beans. *J. Food Sci.*, 62:520-523.
- Agarry, S.E., Afolabi, T.J., and Akintunde, T.T.Y. (2014). Modelling the water absorption characteristics of different maize (*Zea Mays L.*) types during soaking. *J. Food Proc. Technol.*, 5:326. doi:10.4172/2157-7110.1000326
- AOAC. (2016). Official Methods of Analysis. 20th ed. Association of Official Analytical Chemists, Washington D.C.
- Asoegwu, S.N., Ohanyere, S.O., Kanu, O.P., and Iwueke, C.N. (2006). Physical properties of African oil bean seed. *Agric Eng International: the CIGR E-Journal*, 8(5-6).
- Asoiro, F.U. and Ani, A.O. (2011). Determination of some physical properties of African yam beans. *Pacific Journal of Science and Technology* 12(1), 374-380.
- Eke, C.N.U., Asoegwu, S.N., and Nwandikom, G.I. (2007). Some physical properties of Jackbean seed (*Canavalia ensiformis*). *Agric. Eng. Int.: CIGR.*, 9:7-14.
- Hossain, S., Ahmed, R., Bhowmick, S., Al Mamun A., and Hashimoto, M. (2016). Proximate composition and fatty acid analysis of *Lablab purpureus* (L.) legume seed: implicates to both protein and essential fatty acid supplementation. *Springer Plus*, 5:1.899
- Kashiri, M., Kashaninejad, M., and Aghajani, N. (2010). Modelling water absorption of sorghum during soaking. *Latin American Applied Research* 40, 383-388
- Kumar, M.M., Prasad, K., Chandra, T.S., and Debnath, S. (2016). Evaluation of physical properties and hydration kinetics of red lentil (*Lens culinaris*) at different processed levels and soaking temperatures. *J. Saudi Soc. Agri. Sci.*, 17. doi.org/10.1016/j.jssas.2016.07.004
- Miano, A.C. and Augusto, P.E.D. (2018). The hydration of grains: A critical review from description of phenomena to process improvements. *Compre. Rev. Food Sci. Food Safe.*, 17:352-370.
- Mohsenin, N.N. (1986). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York.
- Mpotokwane, S.N., Gadithathelwe, E., Sebaka, A., and Jideani, V.A. (2008). Physical properties of Bambara Groundnut from Botswana. *J. Food Eng.*, 6:89-105.
- Okpala, L.C. (2010). Hydration kinetics and textural properties of pigeon pea (*Cajanus cajan*). *Nigerian Food J.*, 28(2): 349-356.
- Okpala, L.C. and Ekechi C.A. (2014). Rehydration characteristics of West African pepper (*Piper guineense*) leaves. *Food Sci. Nutri.*, 2(6):664-668.

Table 4. Arrhenius equation parameters for water absorption during hydration of unblanched and blanched hyacinth beans

Treatment	Temperature (°C)	E_a (kJ/mol)	R^2	P
Unblanched	27-75	11.31	0.753	0.132
Blanched	27-75	9.92	0.981	0.009

- Olabinjo, O.O. and Omomowo, O.O. (2019). Hydration kinetics of blanched and unblanched sword beans. *Int. J. Horticult. Agri. Food Sci.*, 3(5):243-253.
- Omobuwajo, T.O., Akande, E. A., and Sanni L. A. (1999). Selected physical, mechanical and aerodynamic properties of African breadfruit (*Treculia africana*) seeds. *J. Food Eng.*, 40(4):241-244.
- Peleg, M. (1988). An empirical model for the description of moisture sorption curves. *J. Food Sci.*, 53:1,216-1,219.
- Sopade, P.A. and Obekpa, J.A. (1990). Modelling water absorption in soybean, cowpea and peanuts at three temperatures using Peleg's equation. *J. Food Sci.*, 55:1,084-1,087.
- Tabatabaeefar, A., Aghagoolzadeh, H., and Mobli, H. (2003). Design and development of an auxiliary chickpea second sieving and grading machine. *Agri. Eng. Int.: CIGR J. Sci. Res. Dev. Manus. FP.*, 03:005.
- Taiwo, K.A., Akanbi, T., and Ajibo, O.O. (1994). Effect of soaking conditions on water absorption and texture of two cowpea varieties. *Nigerian Food J.*, 12:11-18.
- Turhan, M., Sayar, S., and Gunasekarar, S. (2002). Application of Peleg Model to study water absorption in chickpea during soaking. *J. Food Eng.*, 53(2):153-159.
- Urga, K., Fufa, H., Biratu, E., and Gebretsadik, M. (2006). Effects of blanching and soaking on some physical characteristics of grass pea (*Lathyrus sativa*). *African J. Food Agri. Nutri.*, 6(1):1-17.
- Vasudeva, S. and Vishwanathan, K.H. (2010). Hydration behaviour of food grains and modelling their moisture pick up as per Peleg's equation: Part II. Legumes. *J. Food Sci. Technol.*, 47(1):42-46.