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Physical properties and rehydration kinetics of two varieties of cowpea (*Vigna unguiculata*) and bambara groundnuts (*Voandzeia subterranea*) seeds

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Abstract

The water absorption kinetics of the cowpea (varieties CW and CG) and bambara seeds (varieties BB and WB) were studied following the first order, Peleg with a proposed sigmoid model. Significant intra and inter varietal variations were observed on the physical characteristics of the seeds. In general the saturation water content was higher for the cowpea varieties (1.39–1.50 g g^{-1}) and lower for the bambara varieties (0.88–1.00 g g^{-1}). The proposed sigmoid model was shown to significantly describe the kinetic of absorption irrespective of the variety and temperature. The effective diffusivity of the seeds were shown to vary in the order GC > WB > BB > WC and increased as the soaking temperature increased from 35 to 45 °C. The variation in the effective diffusivity at 25 and 35 °C was observed to be linearly correlated ($R^2 > 0.82$; $p < 0.05$) to the percent seed coat, suggesting its role in the process of mass exchange. In addition the effective diffusivity varied with temperature according to the Arrhenius equation and the resulting activation energy varied from 78.8 kJ mol^{-1} for GC variety to 11.20 kJ mol^{-1} for WB variety.
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1. Introduction

Cowpea (*Vigna unguiculata*) and bambara groundnuts (*Voandzeia subterranea*) seeds are important plant foods that are widely produced and consumed in many parts of Africa. On dry weight basis, these foods contain mostly proteins 17–28%, fats 3.0%, carbohydrates 50–53%, ash 3% and fibre 6% (Amarteifio, Sawula, & Gibbons, 1997; Mbofung, Njintang, & Waldrom, 2002; Phillips et al., 2003; Mbofung, Rigby, & Waldrom, 1999). The grains are generally sun dried after harvesting to a water content of about 12%.

Recent studies on these plant food sources have mostly been focused on their conversion into food powders for use as ingredients in food processes (Njintang, Mbofung, & Waldrom, 2001; Phillips et al., 2003). In the powder production processes, soaking, drying and decortication of seeds have systematically figured as important steps. Although the soaking step is important as it facilitates decortication, it normally last for as long as 12 h. In some cases this lag time could be detrimental to the quality of the resulting product. Indeed the rehydration process of these seeds tends to be accompanied by loss in soluble compounds through leaching (Garcua-Pascual, Sanjua'n, Ricardo Melis, & Mulet, 2006).

The physical characteristics of the bambara and cowpea seeds are essential determinants for the behaviour of the

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seeds during rehydration. In fact the water absorption kinetics of grains have been shown to be influenced by their intrinsic (physical and chemical) and extrinsic (temperature, soaking solutions, etc.) factors (Baryeh, 2001). Meanwhile mathematical modelling of hydration processes is known to be important for the design and optimization of food process operations. In this respect, empirical models are widely used because they require considerably less effort (Saguy, Marabi, & Wallach, 2005). The most commonly used models in this case includes: the exponential model (Misra & Brooker, 1980), the Peleg's model (Abu-Ghannam & McKenna, 1997; Peleg, 1988; Turhan, Sayar, & Gunasekaran, 2002), first-order kinetics (Krokida & Marinos-Kouris, 2003); Becker's model (Becker, 1960; Lu, Siebenmorgen, & Archer, 1994), the Weibull distribution function (Sacchetti, Pittia, Biserni, Pinnavaia, & Rosa, 2003), and the Normalized Weibull distribution function (Marabi & Saguy, 2004). Of these, the Peleg (1988) model and the first-order kinetics stand out as the most used in the rehydration of legumes seeds (Abu-Ghannam, 1998; Hung, Liu, Black, & Trewhella, 1993; Ibarz, Gonzalez, & Barbosa-Canovas, 2004; Sopade & Obekpa, 1990). As of now not much work has been carried out on the physical characteristics and rehydration modelling of bambara and cowpea seeds.

The present study was carried out to evaluate the physical properties of two varieties of bambara groundnut and cowpea seeds, and to determine the diffusivity of liquid water in the seeds during soaking at different temperatures as well as their required energy of activation.

2. Material and methods

2.1. Seeds samples

Samples of two varieties of cowpeas (coded GC and WC) and two varieties of bambara groundnuts (coded WB and BB) were purchased from local markets in Ngaoundere (for WB and BB), Garoua (for GC) and Bafoussam (for WC) and used in all experiments. Individual samples were cleaned of infected seeds and foreign materials sealed in polyethylene bags and stored at 4 °C in a refrigerator until required for use. The proximate composition of the seeds samples, analysed according to AOAC (1990), is summarized in Table 1.

2.2. Determination of the physical characteristics of seeds

The physical characteristics of the legumes seeds were evaluated essentially according to Baryeh (2001) with minor modifications where necessary. For each grain sample, 100 grains were selected at random and their individual length (L), width (W) and thickness (T) were measured from the three principal dimensions which are in three mutually perpendicular directions using a micrometer gauge reading to 0.01 mm. L was defined as the distance from the eye's seed to the opposite end, while W and T taking in the two opposite perpendicular direction of eye seed represented the major and the minor seed diameters. Using the different readings, the sphericity, ϕ, was calculated using the equation

$$\phi = \frac{(LWT)^{1/3}}{L},$$

while the geometric mean diameter (cm), D_g, was calculated using the equation

$$D_g = (LWT)^{1/3}.$$

The surface area, S (cm^2), was also calculated using the equation

$$S = \pi \cdot D_g^2.$$

While the volume, V_g, was evaluated using the equation

$$V_g = \frac{\pi \cdot WT \cdot L^2}{6[2L - (WT)^{0.5}]}.$$

The seed mean mass was determined on 100 seeds using an electronic balance of 0.001 g sensitivity. The mean true volume of the seed was determined according to the water displacement method of Karababa (2006). The seed true density, ρ_g, expressed as g/ml was calculated as the ratio of weight of seeds to the true volume while the bulk density, ρ_b, also expressed as g/ml, was determined according to Okezie and Bello (1988).

Following this the porosity, ε, of the seeds which is the fraction of the space in the bulk seed which is not occupied by the grain was computed from the values of seed true density and bulk density using the relationship as follows (Baryeh, 2001):

$$\varepsilon = \frac{(\rho_g - \rho_b) \cdot 100}{\rho_g}.$$

Table 1
Proximate composition of cowpea and bambara groundnut seeds (g/100 g dry weight)

	Varieties[A]			
	GC	WC	WB	BB
Moisture content (% dry basis)	9.41 ± 0.06^b	9.24 ± 0.11^b	11.3 ± 0.24^a	11.6 ± 0.29^a
Ash	3.35 ± 0.04^b	3.24 ± 0.02^b	3.80 ± 0.07^a	3.61 ± 0.06^a
Proteins	23.58 ± 0.12^b	26.59 ± 0.36^a	17.8 ± 0.23^d	19.7 ± 0.17^c
Available carbohydrate	57.67 ± 1.74^b	55.83 ± 1.92^b	61.7 ± 0.44^a	57.9 ± 1.0^b
Fat	3.17 ± 0.17^c	2.07 ± 0.14^d	6.12 ± 0.02^a	5.90 ± 0.18^b

[A] Mean in a line not followed by the same letter in superscript are significantly different at $P < 0.05$.

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