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Changes induced by soaking period on the physical properties of maize in the production of Ogi

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Abstract: This study was aimed at investigating the effect of soaking method and period on some selected physical properties on maize varieties. Five varieties of maize (A4W, C3Y, D8W, B2Y and E9W) were soaked for 12–96 h at ambient temperature of 28 and average hot temperature of 65°C as generally praciticed in the production of Ogi from cereals. Some selected physical properties were evaluated based on a 5 × 2 × 9 factorial design (varieties × soaking methods × soaking periods). The reseult revealed that the linear dimensions of the five varieties of soaked maize increased with increase in linear dimensions up to about 36th hour of soaking. The percentage increase in width was in the range of 5.482–9.67%, 4.064–8.25%, 3.76–6.81% and 0.88–1.81%, for C3Y, B2Y, D8W, A4W and E9W for both soaking conditions, respectively. Significant difference ($p < 0.05$) existed between the maize varieties for surface area and the volume. These increased with increase in moisture content and soaking period with the highest surface area recorded for maize variety E9W at 36th hours of 65°C. There were significant differences ($p < 0.05$) between unsoaked and soaked maize varieties for all the samples. Values obtained for sphericity increased with increase in soaking period. There was no significant difference ($p > 0.05$) in the values obtained for sphericity at soaking condition of 65°C compared with soaking at 28°C. This study showed that the period

ABOUT THE AUTHOR

O.T. Bolaji (PhD) is a lecturer and researcher with strong passion for Process and Post Harvest of Agricultural products, food process modelling, and engineering design. Research areas of focus are: upgrading indigenous technology to a modern application, design process equipment, Optimization of food processing conditions and equipment, modelling of engineering properties of food and Food system, Rheological studies of food materials, Information communication and technology application in food process, development of food engineering models and Functionality investigation and utilisation of underutilized indigenous crops. These are attended to, by effectively collaborating with experts in various relevant fields to solve problems.

PUBLIC INTEREST STATEMENT

Soaking is a significant processing condition often employed in the production of ogi, a food derived from cereals. Between seventy-two (72) and one hundred and twenty (120) hours are often committed to it at ambient condition or initial use of boiled water. This is often attempted with an intention to reduce the hardness of cereal. Several reports in this regards were without focus on the effect of soaking duration and methods on the physical properties. This work evaluated the effect of soaking duration and methods on some relevant physical properties of maize grains in the production of "Ogi". The information obtained are of concern for design of equipment useful in handling and processing of these maize grains. This work provided an estabilished information that should assist during commercial production with the use of equipment . Also, this work suggested possible maize's moisture kinetics during the common soaking duration and methods which will help in taking appropriate decision where and when necessary.

of soaking had significant effect ($p < 0.05$) in increasing the overall dimensions of maize grains up to 36th hour and thereafter witnessed an irregular pattern.

Subjects: Food Science & Technology; Food Engineering; Biomaterials

Keywords: maize; soaking; change; rate; physical properties; ogi

1. Introduction

The significance of maize as an important cereals crops used in the human diet are well reported (Adegbite, 2011; McDonald & Nicol, 2005). Ogi is one of the many foods derived from maize and some other cereal. Ogi production as reported by many researchers is characterized with Soaking between 1 and 3 days (Akingbala, Onochie, Adeyemi, & Oguntimein, 1987; FAO, 1999; Odunfa & Adeyele, 1985; Onyekwere, Akinrele, & Koleoso, 1989; Teniola & Odunfa, 2001). Some resarches reported some slight modification to this widely reported method. Nago, Hounhouigan, Akissoe, Zanou, and Mestres (1998) reported mild boiling at 95–100°C preceeding soaking for 12–48 h at ambient temperature (25–35°C). Teniola and Odunfa (2002) reported room temeprature soaking between 72 and 120 h. The primary reason for saoking in the production of ogi is to reduce the hardness of maize. Moisture have been reported by many researchers to have significant effect on the physical propertties of some agricultural producem (Deshpande, Bal, & Ojha, 1993; Mohsenin, 1986; Oje, 1994; Oje & Ugbor, 1991; Omobuwajo, Akande, & Sanni, 1999; Olalusi & Bolaji, 2009). Physical parameters like shape, size and surface area were reported important in separation of seeds and grains from undesirable materials (Aviara, Gwandzang, & Haque, 1999; Mohsenin, 1986; Oje, 1994; Oje & Ugbor, 1991; Omobuwajo et al., 1999; Shepherd & Bhardwaj, 1986), designing of handling equipment, (Deshpande et al., 1993; Omobuwajo et al., 1999), handling and processing materials (Deshpande et al., 1993; Dutta, Nema, & Bhardwaj, 1988; Joshi, Das, & Mukherjee, 1993; Sreenarayanan, Visvanathan, & Subramaniyan, 1988). Some researchers (Aviara & Haque, 2000; Çarman, 1996; Deshpande et al., 1993; Joshi et al., 1993; Oje & Ugbor, 1991; Olalusi & Bolaji, 2009, 2010, 2011; Omobuwajo et al., 1999; Suthar & Das, 1996) determined the size of seeds by measuring their principal axi. Aviara et al. (1999), Deshpande et al. (1993) and Kaleemullah (1992) reported the variations in dimensions as affected by moisture content of Guna seed, soybean and groundnut kernel, respectively. The volume of Gram and Guna seeds were computed by empolying arithmetic mean of the three principal dimensions, geometric average and effective diameter (Aviara et al., 1999; Dutta et al., 1988). Bolaji, Awonorin, Shittu, and Sanni (2009) worked on the Rate of changes in some physical properties of a maize variety. According to Kocabiyik, Aktas, and Kayisoglu (2004), porosity and density are useful in designing postharvest operations systems. These parameters are also relevant in affecting grain hardness, breakage susceptibility, milling, drying rate and resistance to fungal development (Barbosa-Cánovas, Juliano, & Peleg, 2010; Kocabiyik et al., 2004).

This work focus on determining the effect of long soaking period and method on some physical properties of maize in the production of “Ogi”. This is necessary in the equipment design and handling of these soaked grains at a commercial level. This work also have a potential to obtained an established information on the effect of length of soaking on the physical properties of maize grain in the production of ogi. Most of the research work on physical and engineering properties of agricultural materials did not attempt the evaluation of these paramerters at such long soaking period as done for maize grains during the production of Ogi, most especially, considering the moisture kinetics during the process.

2. Material and methods

Five varieties of maize (A4W, C3Y, D8W, B2Y and E9W) were selected and obtained based on availability from Internation Institute of Tropical Agriculture (IITA) for this study. These maize varieties were soaked for varying soaking period of 12, 24, 36, 48, 60, 72, 84 and 96 h, within the range reported in the liteatures for the production of ogi (Odunfa & Adeyele, 1985; Onyekwere et al., 1989) and soaking methods at ambient Tempearture (28°C) and boiled water Tempearture of (100°C). This equilibirate with the environment after 4 h. The average temperature taken at interval of 20 mintues was 65°C. Some physical properties were determined (mass, volume, density, width, thickness, geometric mean diameter, poorostity, 1,000th weight). General relationship in analysis of physical properties are as given in Equations (1)–(8).

Code	Breed name
A4W	TZL COM4
C3Y	ACR9931DMRSRY
D8W	ACR89DMR W
B2Y	BR 9928DMRSRY
E9W	ACR97COM1

2.1. Determination of linear dimensions

One thousand whole seeds (1,000) maize were randomly selected and divided into 2 slots and 100 seeds of each variety were selected at random for determining the physical properties. These grains were subjected to two soaking method, cold (28°C) and average soaking temperature of 65°C, respectively. The seed size, in terms of the three principal axial dimensions, Length (*L*), breadth (*W*) and thickness (*T*) were measured using the Micrometer screw guage (0.01) at 12 h interval (12–96 h). The geometric mean diameter and the Rate of changes in the linear dimension were evaluated applying the Equations (1)–(7) and divided by effective time of soaking.

$$D_g = LWT^{0.333} \tag{1}$$

$$A_g = \frac{(L + W + T)}{3} \tag{2}$$

$$\emptyset = \left[\frac{B(2L - B)}{L^2}\right]^{1/3} \tag{3}$$

$$V = \frac{\pi B^2 L^2}{6(2L - B)} \tag{4}$$

$$S = \frac{\pi B L^2}{2L - B} \tag{5}$$

where,

$$B = (WT)^{0.5}. \tag{6}$$

The surface area, *S*,

$$s = \pi\left(D_g\right)^2 \tag{7}$$

length (*L*), width (*W*) and thickness (*T*) were measured using Micro meter screw gauge (0.01), D_g Geometric mean diameter, A_g Arithmetic diameter mean, ∅. sphericity (%), *S* is surface area, *V* is the volume were subsequently computed Baryeh (2001) determined the porosity using Equation (8); thus,

$$\in = \frac{\left[(\rho_t - \rho_b) \times 100\right]}{\rho_t} \tag{8}$$

$$\rho_b = \frac{W}{V_s} \tag{9}$$

where, the ρ_b is the bulk density in kg m^{-3}; W_s is the weight of the sample in kg; and V_s is the volume occupied by the samples, ρ_t is true density and $\in$ is the porosity (Mohsenin, 1986).

2.2. Mass and volume determination of individual seed

The mass of individual seeds were determined using electronic balance model (0.01 g). One hundred (100) randomly selected seeds were weighed individually. A capacity measuring cylinder containing 50 ml of distilled water of net volumetric water displacement by the seeds was recorded. One thousand seed mass ($W_{1,000}$) was also obtained with the help of an electronic balance weighing (0.01 g). This were carried out at the varying soaking period of 12, 24, 36, 48, 60, 72, 84 and 96 h for all the maize varieties. This were conducted four times and mean result recorded.

2.3. Bulk density (test weight)

About 100 grains of known average weight was dropped into a container filled with water. The grains were not coated due to the short duration of experiment. There was significant increase in mass within the time of experiment as reported by Tunde-Akintunde and Akintunde (2007) and more so, the rate of water absoption were relatively low from preliminary studies. The true density was determined from mass and volume of 100 grains. The 50 ml cylinder was filled with a known weight grain from the height 0.15 m striking the top level. The bulk density was determined from the measured mass and volume (Dutta et al.,1988; Shepherd & Bhardwaj, 1986) equation is as presented in Equation (9).

2.4. Porosity

Porosity indicates the volume fraction of void space or air space inside a material. The porosity was calculated from the measured values of bulk density (ρ_b) and true densit (ρ_t) using the relationship given by Mohsenin (1986). This relationship is presented in Equation (8).

2.5. Data analysis

The data obtained in this experiment were analysed using SPSS version 17. Analysis of variance was determined, where significant difference existed, Ducun multiple range test were conducted to separate the means.

3. Results and discussion

3.1. Some physical properties of soaked maize

The linear dimensions of the five varieties of soaked maize subjected to range of popularly practiced methods in the production of Ogi is as shown in Tables 1 and 2. The maize kernels increased in linear dimensions: length, width, thickness, Arithmetic diameter and geometric diameter for all the maize varieties used in this experiment up to 36th hour of soaking. The percentage increase in width was in the range of 5.48–9.67%, 4.06–8.25%, 3.76–6.81% and 0.88–1.81%, for C3Y, B2Y, D8W, A4W and E9W for both soaking conditions, respectively. The increase in thickness was linear throughout the soaking period. The value ranged from 4.44–4.97 to 4.64–4.90 mm for A4W, 4.32–4.63 and 4.37–4.67 mm for E9W, 4.42–4.85 and 4.32–4.82 mm for C3Y, 4.31–4.66 mm and 4.42–4.86 mm B2Y for soaking at hot (65°C) and ambient temperature (28°C), respectively. The values obtained for length, thickness and Sphericity for all the varieties of maize were higher than the values obtained for pop corn (Erşan, 2006) and vetch seed (Yalçın & Özarslan, 2004). Similar results were reported by some researchers (Aviara et al., 1999; Baryeh, 2001, 2002; Deshpande et al., 1993). However, the thickness was in the same range reported for Okro (Sedat, Musa, Haydar, & Uğur, 2005; Tarighi, Mahmoudi, & Alavi, 2011). This was contrary to report of length, width and thickness of cocoa at moisture range between 5 and 24% which though increased with increase in moisture content, but values were higher compared with the value obtained for maize varieties in this work when soaked (Bart-Plange and Baryeh, 2003). The length and thickness were within the range reported for length of breadfruit seed and gram (Dutta et al., 1988; Omobuwajo et al., 1999). All the linear dimensions of the maize varieties were higher than values reported for millet (Jain & Bal, 1997) however, lower than the values obtained for oil bean (Oje & Ugbor, 1991), sunflower seeds (Gupta & Das, 1997), pigeon peas

Table 1. Dimenson of maize grains at varying soaking conditions (length and thickness)

Maize/ Soaking methods	0 (hr)	12 (hrs)	24 (hrs)	36 (hrs)	48 (hrs)	60 (hrs)	72 (hrs)	84 (hrs)	96 (hrs)
Length									
E9W 65°C	10.84^{b}	10.88^{b}	10.91^{a}	10.93^{ab}	10.93^{ab}	10.91^{ab}	10.87^{a}	10.98^{abc}	10.91^{ab}
E9W28°C	10.84b	10.87^{a}	10.96^{ab}	10.95^{ab}	10.91a^{b}	10.97^{abe}	10.93^{ab}	10.93^{ab}	10.9^{ab}
A4W 65°C	10.91^{b}	10.96^{a}	10.97^{a}	10.53^{b}	10.46^{b}	10.44^{b}	10.35^{b}	10.29^{b}	10.27^{b}
A4W 28°C	10.91^{b}	10.95^{ab}	10.94^{ab}	10.94^{ab}	10.95^{ab}	10.93	10.91^{ab}	10.91^{b}	10.92^{b}
C3Y 65°C	9.65^{c}	9.69^{c}	9.68^{c}	9.69^{c}	9.68^{c}	9.69^{c}	9.79^{c}	9.69^{c}	9.67^{c}
C3Y 28°C	9.65^{c}	9.69^{c}	9.69^{c}	9.63^{c}	9.69^{c}	9.69^{c}	9.69^{c}	9.67^{c}	9.66^{c}
D8W 65°C	10.45^{bc}	10.46^{bc}	10.46^{bc}	10.47^{bc}	10.44^{b}	10.49^{bc}	10.59^{bc}	10.44^{bc}	10.49^{bc}
D8W 28°C	10.45^{bc}	10.57^{bc}	10.45^{bc}	10.32^{bc}	10.47^{b}	10.43^{bc}	10.14^{bc}	10.17^{bc}	9.93^{c}
B2Y 65°C	10.74^{b}	10.79^{b}	10.77^{bc}	10.76^{a}	10.82^{ab}	10.47^{ab}	10.78^{a}	10.83^{ab}	10.79^{ab}
B2Y 28°C	10.74^{b}	10.47^{bc}	10.76^{bc}	10.75^{bc}	10.75^{a}	10.76^{ab}	10.75^{ab}	10.75^{ab}	10.76^{ab}
Thickness									
E9W 65°C	4.32c	4.56^{a}	4.60^{a}	4.62^{a}	4.61^{b}	4.69^{ab}	4.59^{b}	4.72^{abc}	4.586^{b}
E9W28°C	4.37c	4.64^{ab}	4.67^{a}	4.61^{b}	4.61^{b}	4.66^{b}	4.65^{bc}	4.64^{b}	4.83^{ab}
A4W 65°C	4.44^{c}	4.78^{a}	4.83^{a}	4.84^{b}	4.97^{ac}	5.02^{a}	4.89^{abc}	4.95^{abc}	4.88^{ab}
A4W 28°C	4.64^{ab}	4.83^{ab}	4.87^{a}	4.84^{b}	4.89^{bc}	4.92^{ab}	5.01^{a}	4.89^{abc}	4.94^{ab}
C3Y 65°C	4.42^{c}	4.50^{a}	4.66^{b}	4.70^{b}	4.83^{bc}	4.70^{ab}	4.76^{abc}	4.76^{abc}	4.76^{b}
C3Y 28°C	4.32^{c}	4.67^{ab}	4.82^{a}	4.57^{b}	4.62^{bc}	4.64^{b}	4.67^{bc}	4.74^{ab}	4.78^{b}
D8W 65°C	4.69^{b}	4.98^{ab}	5.41^{a}	5.21^{a}	5.26^{a}	5.02^{a}	5.053^{a}	5.099^{a}	5.17^{a}
D8W 28°C	4.69^{b}	4.62^{ab}	4.52^{b}	4.59^{b}	4.66^{ab}	4.69^{ab}	4.74^{abc}	4.72	4.73^{b}
B2Y 65°C	4.44^{c}	4.97^{a}	4.87^{b}	4.78^{b}	4.79^{bc}	4.77^{ab}	4.79	4.88^{abc}	4.75^{b}
B2Y 28°C	4.41^{c}	4.69^{ab}	4.79^{b}	4.83^{b}	4.86^{bc}	4.88^{ab}	4.95^{ac}	4.99^{ac}	4.93^{ab}

Notes: Values are mean of 100 seeds of five varieties of maize. Values bearing the different superscripts are significantly different ($p < 0.05$). Hot-Soaking at 65°C. Cold-Soaking at ambient temperature 28°C.

(Shepherd & Bhardwaj, 1986) but comparable coffee and Amaranth (Abalone, Cassinera, Gastón, & Lara, 2004; Chandrasekar & Viswanathan, 1999).

3.2. Surface area and volume

As shown in Table 3 significant difference ($p < 0.05$) existed between the maize varieties for surface area and the volume. The value of E9W was significantly different ($p < 0.05$) from A4W, C3Y and D8W for unsoaked maize. There were significant differences ($p < 0.05$) between unsoaked and soaked maize varieties. The volume for C3Y were in the range 151.09–163.14 mm^3 (highest at the 36th hour of soaking). A4W (ambient temperature and 65°C hour of soaking) were in the range 168.33–217 mm^3 (highest at 60th hour of soaking) and 166.33–187.16 mm^3, (this increased steadily till 72th hour of soaking. Similar observation were reported for other maize varieties. The surface areas also increased with increase in moisture content and soaking period with the highest surface area recorded for maize variety E9W at 36th hours of 65°C.

3.3. Sphericity

The result indicating sphericity in this work is as shown in Table 4. The values obtained for sphericity increased with increase in soaking period. However, there was no significant difference ($p > 0.05$) in the values obtained for sphericity at soaking condition of 65°C compared with soaking at 28°C. The values increased with increase in moisture content and mass of the soaked maize. Similar results were reported by Deshpande et al. (1993) for Soyabeans. The sphericity in all the soaking period and soaking method were in the range of 0.74–0.79 (E9W), 0.77–0.82 (A4W), 0.80–0.86 (C3Y), 0.75–0.79

Table 2. Dimenson of maize grains at varying soaking conditions width and geometric diameter mean

Maize grains/ Soaking methods	0 (hr)	12 (hrs)	24 (hrs)	36 (hrs)	48 (hrs)	60 (hrs)	72 (hrs)	84 (hrs)	96 (hrs)
Width									
E9W 65°C	8.80	8.98^{bc}	8.90^{bc}	8.91^{bc}	8.84^{bcd}	8.85^{b}	8.91^{b}	8.91	8.78^{bc}
E9W28°C	8.59^{b}	8.99^{bc}	8.85^{b}	8.63^{b}	8.66^{bcd}	8.70^{b}	8.72^{b}	8.59^{b}	8.53^{b}
A4W 65°C	9.63^{ab}	9.94^{a}	10.27^{a}	10.11^{a}	10.22^{a}	10.24^{a}	10.03^{a}	10.12^{a}	10.00^{a}
A4W 28°C	8.57^{b}	9.27^{bcd}	9.42^{d}	9.19^{bdc}	9.22^{de}	9.19^{ab}	9.33^{ab}	9.26^{de}	9.24^{de}
C3Y 65°C	9.04^{c}	9.18^{bcd}	9.25^{bcd}	9.04^{bc}	9.28^{de}	10.90^{a}	10.86^{a}	9.13^{cde}	9.22^{de}
C3Y 28°C	8.56^{b}	9.05^{bc}	8.92^{bc}	8.94^{bc}	8.78^{bc}	8.92^{ab}	8.92^{b}	8.78^{bc}	8.79^{bc}
D8W 65°C	8.99^{c}	9.4°C^{d}	9.22^{bcd}	9.21^{bdc}	9.20^{de}	9.36^{ab}	9.43^{ab}	9.44^{e}	9.54^{e}
D8W 28°C	8.82^{bc}	9.56^{ad}	9.38^{d}	9.48^{d}	9.36^{e}	9.30^{ab}	9.25^{ab}	9.26^{de}	8.89^{cde}
B2Y 65°C	8.79^{bc}	8.89^{b}	9.11^{bcd}	9.13^{bdc}	9.07^{cde}	9.08^{ab}	9.02^{ab}	8.89^{bcd}	8.94 ^{cd}
B2Y 28°C	8.76^{bc}	9.09^{bc}	9.32^{d}	9.12^{bdc}	9.21^{de}	9.33^{ab}	9.17^{ab}	9.26^{bd}	9.19^{de}
Geomtric diameter mean									
E9W 65°C	7.44^{b}	7.43^{b}	7.48^{b}	7.49^{b}	7.44^{b}	7.47^{b}	7.42^{b}	7.46^{b}	7.32^{b}
E9W28°C	7.38^{c}	7.56^{bcd}	7.51^{c}	7.36^{bc}	7.34^{b}	7.42^{b}	7.41^{ab}	7.31^{b}	7.39^{b}
A4W 65°C	7.73^{a}	7.948^{a}	8.11^{a}	7.99^{a}	8.07^{a}	8.08^{a}	7.78^{a}	7.99^{a}	7.92^{a}
A4W 28°C	7.24^{cd}	7.67^{acd}	7.72^{ac}	7.59^{cd}	7.61^{cde}	7.65^{cd}	7.69^{ac}	7.41^{b}	7.61^{ab}
C3Y 65°C	7.24^{c}	7.21^{b}	7.29^{b}	7.23^{b}	7.31^{bcd}	7.41^{bcd}	7.41	7.199^{a}	7.21^{bc}
C3Y 28°C	6.91^{b}	7.29^{ab}	7.32^{b}	7.23^{b}	7.22^{bc}	7.25^{bc}	7.26^{bc}	7.18^{ab}	7.23^{bcd}
D8W 65°C	7.67^{a}	7.71^{ab}	7.79^{ab}	7.64^{ab}	7.70^{ab}	7.69^{ab}	7.75^{ab}	7.75^{ab}	8.38^{a}
D8W 28°C	7.31^{cd}	7.37^{bcd}	7.270^{b}	7.28^{bc}	7.12^{b}	7.15^{b}	7.09^{a}	7.29^{b}	6.94^{b}
B2Y 65°C	7.47^{d}	7.41^{bcd}	7.49^{bc}	7.42^{bcd}	7.39^{bcd}	7.4^{bcd}	7.36^{abc}	7.34^{b}	7.29^{b}
B2Y 28°C	7.44^{d}	7.62^{a}	7.80^{ac}	7.72^{ad}	7.79^{ae}	7.78^{ad}	7.79^{a}	7.82^{ab}	7.71^{ab}

Notes: Values are mean of 100 seeds of five varieties of maize. Values bearing the different superscripts are significantly different ($p < 0.05$). Hot- Soaking at 65°C. Cold-Soaking at ambient temperature 28°C.

(D8W), 0.74–0.809 (B2Y) for all the soaking period and contrary to the value obtained for Okro 0.89–0.91 (Sedat et al., 2005). These however fall within the range of the value obtained for Bambara groundnuts at the 5 and 35% moisture content (Baryeh, 2001), Pearl millet (Jain & Bal, 1997), Pigeon Pea seed (Baryeh & Mangope, 2003), cowpea seed (Yalcın, 2007). Ackee apple (Omobuwajo, Sanni, & Olajide, 2000). The sphericity were higher compared with the value reported by Bart-Plange and Baryeh (2003) for category B cocoa which ranged from 0.57 at 8.6% (wb) moisture content to 0.58 at 24.0% (wb) moisture, calabash nut meg 0.67 (Omobuwajo, Omobuwajo, & Sanni, 2003). The sphericity obtained were lower compared with values reported for the vetch seed, 0.837–0.859 (Yalçın & Özarslan, 2004), Turkey okra, 0.897–0.905 (Sedat et al., 2005), Jatropha fruit (Sirisomboon, Kitchaiya, Pholpho, & Mahuttanyavanitch, 2007). The sphericty of cocoa bean was less than the values obtained in this work (0.55–0.58) also were reported lesser than the value obtained in popcorn kernels (Erşan, 2006), Sunflower (Gupta & Das, 1997), cowpea seed (Olapade, Okafor, Ozumba, & Olatunji, 2002).

3.4. 1,000th weight and true density

The reault for the 1,000th weight, bulk and true density and porosity are shown in Tables 5 and 6. The 1,000th seed mass was found to range from 0.225–0.311 and 0.223–0.306 kg for variety C3Y for 65°Cand soaking at 28°C, respectively. The variety A4W had 0.314–0.446 and 0.293.5–0.434, B2Y 0.272–0.390 and 0.251–0.362 and D8W, 0.237–0.362 kg. These values increased linearly with

Table 3. The volume (mm^3) and surface area (mm^2) of maize grains at varying soaking conditions

Maize grains/Soaking methods	0 (hr)	12 (hrs)	24 (hrs)	36 (hrs)	48 (hrs)	60 (hrs)	72 (hrs)	84 (hrs)	96 (hrs)
Volume									
C3Y 28°C	151.29^{b}	158.29^{a}	161.16^{a}	162.52^{a}	160.29^{ab}	163.14^{ab}	159.16^{a}	164.62^{a}	154.87^{a}
C3Y 65°C	151.29^{b}	165.68^{ab}	161.01^{a}	153.66^{a}	153.85^{a}	157.93^{a}	157.21^{a}	152.95^{a}	160.72^{ab}
A4W 28°C	171.31^{c}	198.01^{d}	205.43^{c}	203.58^{d}	213.03^{e}	217.14^{f}	199.88^{d}	208.74^{f}	200.91^{d}
A4W 65°C	171.33^{c}	189.74^{c}	189.97^{b}	186.12^{b}	187.96	190.52^{de}	197.16^{d}	190.01^{cde}	190.69^{cd}
E9W 28°C	143.87^{a}	153.77^{a}	161.45^{a}	161.47^{a}	170.73^{bc}	161.04^{ab}	169.55^{ab}	160.27	161.75^{ab}
E9W 65°C	143.81^{a}	159.24^{a}	170.73^{b}	152.31^{a}	151.83^{a}	156.27^{a}	158.99^{a}	157.88^{a}	155.66^{a}
B2Y 28°C	172.34^{c}	193.44^{d}	203.66^{c}	188.98c	195.81^{d}	193.28^{de}	197.32^{d}	197.97^{de}	209.16^{d}
B2Y 65°C	173.94^{c}	189.36^{c}	181.58^{b}	185.08^{c}	184.57^{d}	185.90^{de}	183.57^{c}	175.53^{bcd}	163.76^{ab}
D8W 28°C	155.77^{b}	169.83^{ab}	177.03^{ab}	174.08	170.79^{ab}	168.69^{abcd}	168.62^{ab}	172.21^{bcd}	164.11^{ab}
D9W 65°C	153.72^{b}	170.49^{a}	182.69^{b}	178.29^{c}	183.27b^{cd}	185.19^{de}	185.22^{d}	189.49^{de}	183.08^{cd}
Surface area									
E9W 65°C	147.78^{bc}	147.49^{bcd}	149.98^{bc}	151.02^{bc}	149.41^{bcd}	150.89^{d}	148.49^{bc}	151.09^{bcd}	145.22^{bc}
E9W28°C	145.22^{c}	153.53^{cd}	150.02^{bc}	145.70^{b}	145.75^{bc}	148.19^{bc}	147.73^{bc}	144.65^{b}	148.32^{bc}
A4W 65°C	160.28^{a}	171.14^{a}	177.97^{a}	173.49^{a}	178.17^{a}	179.34^{a}	170.06^{a}	175.77^{a}	171.36^{a}
A4W 28°C	148.8°C	160.31	161.4°C^{d}	157.62^{bc}	158.43^{ef}	160.06^{de}	163.07^{ed}	155.82^{cd}	159.15^{abc}
C3Y 65°C	139.61^{bc}	143.32^{b}	143.89^{b}	145.17^{b}	152.04^{cde}	148.42^{bc}	149.78^{bc}	145.46^{b}	145.12^{bc}
C3Y 28°C	131.79^{b}	146.24^{bc}	152.37^{bc}	142.51^{b}	142.34^{b}	144.27^{b}	144.74^{b}	146.39^{bc}	143.73^{b}
D8W 65°C	158.34^{a}	168.22^{af}	169.56^{ae}	165.29^{a}	168.87^{g}	167.82^{e}	170.09^{a}	170.24^{af}	160.91^{abc}
D8W 28°C	143.93^{c}	160.67^{ef}	156.6°C	158.02^{c}	157.39^{efg}	158.27^{de}	156.53^{cd}	157.61^{de}	150.32^{bc}
B2Y 65°C	148.95^{c}	154.85^{cde}	158.56^{c}	157.29^{bc}	154.37^{cde}	153.23^{d}	153.09^{cd}	154.09^{cd}	150.42^{bc}
B2Y 28°C	147.61^{c}	156.14^{ce}	160.31^{cd}	160.53^{d}	163.35^{fg}	163.69^{e}	164.03^{e}	165.78^{ef}	161.72^{ac}

Notes: Values are mean of 100 seeds of five varieties of maize. Values bearing the different superscripts are significantly different ($p < 0.05$). Hot-soaking at 65°C. Cold-soaking at ambient temperature 28°C.

Table 4. The sphericity of maize grains at varying soaking conditions

Maize/ Soaking methods	0 (hr)	12 (hrs)	24 (hrs)	36 (hrs)	48 (hrs)	60 (hrs)	72 (hrs)	84 (hrs)	96 (hrs)
E9W 65°C	0.738^{b}	0.804^{abc}	0.777^{bc}	0.773^{b}	0.775^{b}	0.779^{b}	0.782^{b}	0.792^{b}	0.785^{b}
E9W28°C	0.735^{b}	0.771^{b}	0.771^{bc}	0.772^{b}	0.782^{b}	0.7748^{b}	0.776^{b}	0.783^{b}	0.784^{b}
A4W 65°C	0.766^{bc}	0.795^{abc}	0.799 ^{cd}	0.809^{d}	0.821^{d}	0.823^{b}	0.821^{c}	0.828^{d}	0.819^{cde}
A4W 28°C	0.793c	0.799^{abc}	0.808^{d}	0.807^{d}	0.8142	0.809^{b}	0.823^{c}	0.831^{c}	0.823^{de}
C3Y 65°C	0.801^{ad}	0.831^{ac}	0.8478^{a}	0.850^{a}	0.8724^{a}	0.916^{a}	0.858^{a}	0.870^{a}	0.862^{a}
C3Y 28°C	0.822^{a}	0.829^{ac}	0.8400^{a}	0.818^{d}	0.812 ^{cd}	0.823^{b}	0.824c	0.848	0.833^{d}
D8W 65°C	0.754^{b}	0.787^{bc}	0.799^{cd}	0.800^{cd}	0.798 ^{cbd}	0.793^{b}	0.791^{b}	0.803	0.807^{bcd}
D8W 28°C	0.756^{b}	0.784^{b}	0.777^{bc}	0.797^{bcd}	0.790^{bc}	0.787^{b}	0.798^{bc}	0.795^{b}	0.7926
B2Y 65°C	0.744^{b}	0.789^{abc}	0.794^{bcd}	0.804^{d}	0.801^{bcd}	0.8031^{b}	0.802^{bc}	0.804	0.802^{bcd}
B2Y 28°C	0.745^{b}	0.774^{b}	0.772^{bc}	0.776$_{bc}$	0.777^{b}	0.790^{b}	0.7845^{b}	0.791^{b}	0.796^{bc}

Table 5. One thousand weights (g) and True density maize grains at varying soaking conditions

Maizes/ Soaking methods	0 (hr)	12 (hrs)	24 (hrs)	36 (hrs)	48 (hrs)	60 (hrs)	72 (hrs)	84 (hrs)	96 (hrs)
1,000th Weight									
C3Y 28°C	224.50	290.00	323.5	324.33	362.67	338.33	332.67	327.83	311.33
C3Y 65°C	223.33	291.67	325.83	327.00	328.67	344.66	321.83	324.32	306.33
A4W 28°C	314.33	420.01	454.04	459.08	469.06	473.33	473.50	473.23	446.83
A4W 65°C	293.50	409.83	444.83	457.33	432.50	438.33	440.50	440.83	434.00
E9W 28°C	247.17	327.50	361.50	406.50	388.50	366.67	367.33	370.67	363.00
E9W 65°C	246.67	326.67	344.83	389.83	371.83	353.33	351.14	353.33	339.00
B2Y 28°C	272.00	353.33	387.83	394.00	388.50	393.03	390.50	389.50	369.50
B2Y 65°C	274.67	363.17	396.33	414.67	395.17	315.33	318.33	319.33	309.50
D8W 28°C	251.33	320.00	354.83	360.83	388.50	362.00	362.67	358.83	350.67
D9W 65°C	237.67	306.67	341.50	362.10	345.33	351.33	345.67	344.50	309.50
True density									
C3Y 28°C	1,136.99	1,532.09	1,685.66	1,669.01	1,945.96	1,784.07	1,773.37	1,704.57	1,701.69
C3Y 65°C	1,181.49	1,450.37	1,749.63	1,847.58	1,844.99	1,852.73	1,735.55	1,792.18	1,628.85
A4W 28°C	1,465.19	1,821.07	1,890.57	1,959.53	1,906.27	1,864.48	2,051.42	1,951.64	1,939.75
A4W 65°C	1,557.37	1,981.09	2,144.83	2,311.83	2,116.30	2,137.29	2,050.93	2,144.32	2,079.82
E9W 28°C	1,357.07	1,846.07	1,929.88	2,239.22	1,984.26	1,997.56	1,882.23	2,008.57	1,925.72
E9W 65°C	1,568.32	1,772.29	1,691.49	2,260.60	2,136.89	1,939.74	1,901.31	1,916.82	1,884.03
B2Y 28°C	1,266.67	1,509.37	1,614.95	1,763.66	1,691.70	1,717.76	1,676.46	1,669.98	1,468.96
B2Y 65°C	1,512.83	1,707.07	2,031.32	2,041.81	1,991.39	1,519.17	1,543.59	1,523.09	1,592.96
D8W 28°C	1,304.94	1,584.27	1,677.10	1,768.05	1,983.45	1,834.02	1,835.00	1,790.50	1,832.69
D9W 65°C	1,261.32	1,518.24	1,561.06	1,719.24	1,609.80	1,590.01	1,589.69	1,494.28	1,393.30

increase in soaking period. There was increase in the 1,000th weight with increase in moisture content. A similar result was reported by some reseachers (Aviara et al., 1999; Baryeh, 2001, 2002; Baryeh & Mangope, 2003; Chandrasekar & Viswanathan, 1999; Deshpande et al., 1993; Erşan, 2006; Öğüt, 1998; Visvanathan, Palanisamy, Gothandapani, & Sreenarayanan, 1996) for soybean, cumin seeds, neem nut, white lupin, coffee, guna seeds bambara nuts, millet, and pigeon pea, respectively. Values obtained in this work were higher than the value reported for locust bean by Ogunjimi, Aviara, and Aregbesola (2002), Vetch seed by Yalçın and Özarslan (2004).

The 1,000th grain mass were lower for all the soaking period and the varieties of maize compared with the value obtained for bambara ground and category B cocoa, respectively. (Baryeh, 2001; Bart-Plange & Baryeh, 2003). The 1,000th may find application in determining the effective diameter which can be used in the theoretical estimation of seed volume.

The True density increased with increase in moisture content as well. The C3Y Variety soaked with cold water at room temperature increased from 1,181.49 to 1,852.73 kg/m^{3}at 60th hour of soaking while for A4W, 1,136.99–1,955.3 kg/m^3 at 48th hour of soaking, respectively. At 65°C, the true density for E9W and C3Y increased from 1,465.19–2,350.95 kg/m^3 at 72nd hour of soaking and 1,557.37–2,137.29 kg/m^3 at 60 h of soaking, respectively. Varities E9W and B2Y followed a similar trend increasing from 1,357.07–2,108.57 kg/m^3 at soaking period of 60th hours of soaking, and 1,868.32–2,436.89 kg/m^3 for 48th hour of soaking and 1,266.67–1,763 kg/m^3 at soaking period of 36th hours and 1,512.83–2,041.81 at 36th hours soaking period for cold and hot soaking,respectively. Samples D8W also increased to 1,983.45 and 1,719.24 kg/m^3 for respetive cold and hot soaking.

Table 6. Bulk density (kg/m³) and Porosity(%) maize varieties at varying soaking conditions

Maize varieties	0 (hr)	12 (hrs)	24 (hrs)	36 (hrs)	48 (hrs)	60 (hrs)	72 (hrs)	84 (hrs)	96 (hrs)
C3Y 28°C	683.19	721.97	760.76	763.41	766.44	764.49	761.95	826.64	890.37
C3Y 65°C	683.19	721.97	760.79	762.44	765.04	764.49	762.96	826.64	890.36
A4W 28°C	685.14	733.46	781.78	791.65	801.51	806.78	812.00	817.72	823.45
A4W 65°C	683.18	721.97	760.75	763.41	767.49	764.88	762.98	826.67	890.37
E9W 28°C	712.06	744.40	776.74	775.84	774.94	785.24	795.41	804.33	813.21
E9W 65°C	683.18	721.97	760.76	763.40	766.09	764.81	762.98	826.46	890.38
B2Y 28°C	670.28	711.09	751.89	753.99	756.07	754.79	753.94	753.73	753.97
B2Y 65°C	683.19	721.97	760.75	763.45	766.04	764.48	762.68	826.66	890.37
D8W 28°C	690.99	729.54	768.12	779.81	791.49	794.91	798.84	798.48	798.47
D9W 65°C	690.99	729.51	768.12	779.88	791.49	794.99	798.48	798.49	798.47
Porosity									
C3Y 28°C	39.92	52.87	54.87	54.26	60.63	57.15	56.98	51.50	47.68
C3Y 65°C	42.18	50.22	56.52	58.68	58.48	58.74	56.04	53.87	45.34
A4W 28°C	53.25	59.72	58.65	59.60	57.95	56.73	60.42	58.10	57.55
A4W 65°C	56.13	63.56	64.53	66.98	63.80	64.23	62.80	61.45	57.19
E9W 28°C	47.53	59.68	59.75	65.35	60.95	60.69	57.73	59.66	57.77
E9W 65°C	56.4	59.26	55.02	66.23	64.15	60.58	59.87	56.87	52.74
B2Y 28°C	47.08	52.89	53.44	57.25	55.31	56.06	55.05	54.87	48.67
B2Y 65°C	54.84	57.71	62.55	62.61	61.53	49.68	50.58	45.73	44.11
D8W 28°C	47.055	53.95	54.19	55.89	60.09	56.65	56.49	55.41	56.43
D9W 65°C	45.22	51.95	50.79	54.64	50.83	50.00	49.77	46.56	42.69

Notes: Values are mean of 100 seeds of five varieties of maize. Values bearing the different superscripts are significantly different ($p < 0.05$). Hot-Soaking at 65°C. Cold-soaking at ambient temperature 28°C.

This observation was in contrary to the report by Erşan (2006) where the true density decreased linearly from 1.309 to 1.224 g/cm³ as the kernel moisture content increased which was due to high rate of increase in seed volume. It was also contrary to the trend observed by Deshpande et al. (1993) for soy bean, Suthar and Das (1996) for karinga seeds, Sahoo and Srivastava (2002) for okra seed, Kaleemullah and Gunasekar (2002) canut kernels. The true density of maize and soaked maize varieties were found to be higher than the value obtained by Ogunjimi et al. (2002) for locust bean seed, breadfruit seed (Omobuwajo et al., 1999) and Vetch seed (Yalçın & Özarslan, 2004) but lower than that of Gram (Dutta et al., 1988), and millet (Jain & Bal, 1997). The true density of all the five varieties of maize at all the soaking period and method were greater than the value obtained for category B which in the range 946–991 for category B (Bart-Plange & Baryeh, 2003), ackee nut (Omobuwajo et al., 2000), vetch seed (Yalçın & Özarslan, 2004), calabash nutmeg (Omobuwajo et al., 2003), Amaranth seed (Abalone et al., 2004). The porosity of C3Y increased from 39.91–60.63% to 42.17–58.48% at 48 and 60th hours of soaking, respectively. A similar trend was recorded for A4W 53.23–60.41% and 56.13–66.97% for both soaking methods, E9W 47.52–65.35% and 56.43–66.23%, B2Y 47.08–55.05% and 54.84–61.53% for soaking, respectively.

3.5. The rate of changes in physical parameters

The rate of changes of both soaking condition (28°C) and at 65°C) of maize are as presented in Figure 1. The result revealed that the Rate of changes in the linear dimension decreased with increase in the period of soaking. There was a general reduction in the rate of increase in linear dimensions however, the rate of changes of Miaze soaked at Ambinet temperture were not significantly different ($p > 0.05$) from soaking condition of 65°C. The rate of C3Y reduced from $9.0–0.55 \times 10^{-3}$ %/hr and $23.9–0.82 \times 10^{-3}$ %/hr for hot (65°C) and soaking at 28°C while D8W were $15.8–0.47 \times 10^{-3}$ %/hr and

2.36–0.54 × 10^{-3} %/hr B2Y during hot (65°C) and soaking at 28°C 2.50–1.00 × 10^{-3} %/hr. A4W had 0.18–0.66 × 10^{-3} %/hr and 2.0–0.9 × 10^{-3} %/hr for both soaking conditions. The tthickness of maize showed the highest rate of increase compared with changes noticed in other linear dimensions. The rate of changes of linear dimension of all maize materials cannot be unconnected with the water absorption behavior, nature and structure of the maize varieties. There was general decrease in the rate of increase in length, thickness, width, mass, sphericity, volume and surface area of all the soaked maize grains. The rate of changes in the linear dimensions was found to depend on the moisture/water interaction with maize structure. This was probably dependent on the nature of the seed, the moisture permeability of the aulorene layer of the seed, the moisture gradient and the internal pores spaces of the maize seed. The reduction in the rate of increase in the physical parameter cannot be unconnected with possible moisture migration across in the layer of the maize grains with possible changes in the pH of the soaking medium with increase in soaking period. Rate of changes may also be connected with cell arrangements (Kerdpiboon, Kerr, and Devahastin (2006). The rate of changes was found to depend on the moisture/water interaction of maize structure. This is probably dependent on the nature of the seed, the moisture permeability of the outer layer of maize grains, the moisture gradient, the internal pores of the maize grains (Aguilera & Stanley, 1999; Fito, LeMaguer, Betoret, & Fito, 2007).

The statistical parameters of the exponential decrease equation with a higher coefficient of determination, lower χ^2 and RSME values as presented in Equations (10)–(14) will be useful in predicting the rate of change in physical properties. This may help fulfill some of the basic concept of studying the engineering properties in food materials and process. It is imperative to ensure that processes and equipment are designed inorder to control quality and standardise process without compromising safety, at reduced time and energy (Tarighi et al., 2011).

Rate of change in area, volume and geometric diameter means of maize grain,

$$R_a = a \times e^{\frac{t}{a}} + c \quad R^2 = 0.8447 - 0.98567 \tag{10}$$

$$R_v = a \times e^{\frac{t}{a}} + c \quad R^2 = 0.88437 - 0.99468 \tag{11}$$

$$R_g = a \times e^{\frac{t}{a}} + c \quad R^2 = 0.92437 - 0.9968 \tag{12}$$

Where R_a and R_v and rate of changes in surface area and volume and R_g is the rate of change in geometric mean diameter. The rate of change in sphericity (R_s) and rate of change in mass (R_m).

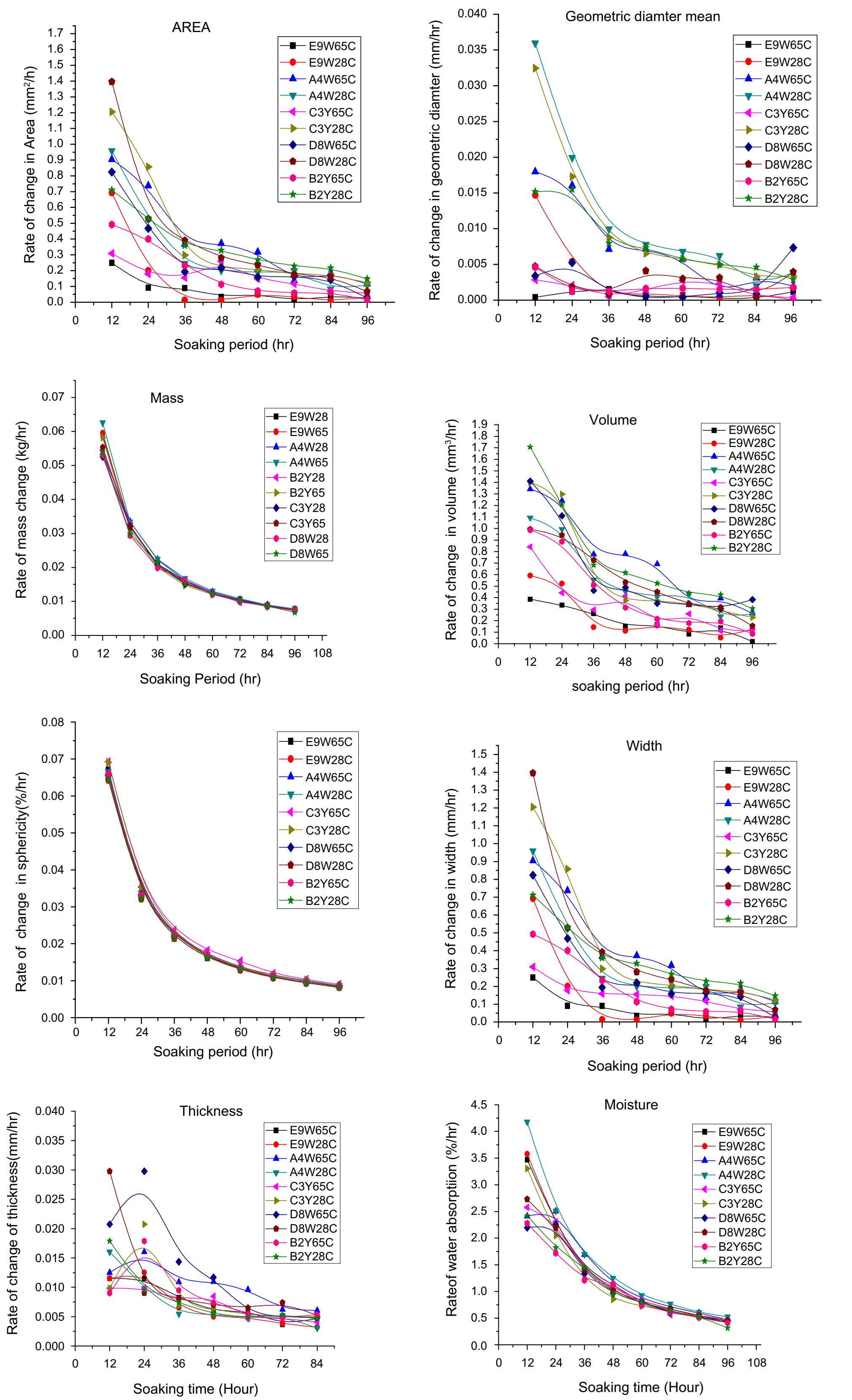
$$R_s = a \times e^{(-bt)} \, R^2 = 0.9921 - 0.99584 \tag{13}$$

$$R_m = a \times e^{(-bt)} \, R^2 = 0.9951 - 0.9984 \tag{14}$$

where *r* is the rate of change, *a* and *b* are constants and *t* is the time of soaking.

The changes observed in the surface area cannot but be connected with moisture absorption behaviour of the maize grains. The rate of changes of mositure content substantially reduced as it probably equilibrate with the soaking environment and alteration in the balance result into osmotic pull causing moisture maigration across the maize grains outer layers. The true density behaviour in this work may be attributed to varying rate of increase in seed volume to massof maize varieties (Barbosa-Cánovas et al., 2010; Koocheki et al., 2007). The influence of moisture content on bulk density and porosity were were however dependent on the maize grains mass. The bulk density was noted to increase non-linearly with increase in moisture content. There may have been some level of moisture migration from the maize back to soaking medium after the moment of equiplibrium was attained in the internal structure of the maize seeds for all the varieties with soaking medium. This may be due to the obvious changes in pH of soaking medium The period of soaking cannot but be implicated in all the behaviour of physical properties of maize.The mass-volume ratio, interaction

Figure 1. The rate of change of physical parameters at varying soaking conditions.



of maize grains components and formation or collapse of air or void phase during water absorption may be responble for the changes in physical properties (Barbosa-Cánovas et al., 2010).

4. Conclusion

This study showed that the period of soaking had significant effect ($p < 0.05$) in increasing the overall dimensions of maize grains such as length, width and thickness. The sphericity, true density and bulk density all increased in all the varieties with increase in the soaking period. The mositure content of maize soaked for long period increased up to about 24th hrs and in some cases, 36 h for all the maize varieties and thereafter witnessed an irregular decline which showed there may be moisture migration across the aleurone layer (hull) membrane of the maize seed to the soaking medium as the concentration of the soaking water changes. Also, the method of hot water soaking at 65°C only caused an insignificant changes

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