Futo Journal Series (FUTOJNLS)
e-ISSN :2476-8456 p-ISSN : 2467-8325
Volume-2, Issue-1, pp- 255 - 264
www.futojnls.org

Research Paper July 2016

# Effects of Boiling on Concentration Gradients and Equilibrium Potentials of Minerals in Egg-Edible Portions of Free Range *Gallus Domesticus*

**Ibegbulem, C.O.*, Alisi, C.S., Nwaogu, L.A., Iheanacho, K.M.E., Peters, G.O. and Oguegbu, I.F.**

Department of Biochemistry, School of Biological Sciences, Federal University of Technology, Owerri, Nigeria.

*Corresponding author: E-mail: ibemog@yahoo.com; ibemog@futo.edu.ng

## Abstract

*Effects of boiling eggs of free range Gallus domesticus (chicken) in deionised water for 30 minutes on concentration gradients and equilibrium potentials of K, Na, Mg, Ca and Zn in their edible portions were investigated. Results indicate that boiling changed the mineral profile of albumen from [K] > [Na] > [Mg] > [Ca] > [Zn] to [Na] > [K] > [Mg] > [Ca] > [Zn] and that of yolk from [K] > [Ca] > [Mg] > [Na] > [Zn] to [K] > [Na] > [Ca] > [Mg] > [Zn], thereby increasing ($p < 0.05$) their [Na]. Concentration gradients of Zn, Ca, Na and K across the vitelline membrane reduced, while that of Mg increased. Equilibrium potentials of Zn, Ca and Mg increased but those of Na and K reduced. In conclusion, boiling enhanced the extents to which albumen can meet the recommended daily allowances for Zn, Ca, Mg and Na.*

**Keywords:** *Albumen, boiling, concentration gradient, equilibrium potential, Gallus domesticus, mineral, yolk*

## 1.0 Introduction

### 1.1 Egg values

Families in rural communities of Iboland have poultries that are predominantly free range scavenging *Gallus domesticus* (chickens). These chickens serve as sources of meat and eggs for most rural dwellers in Africa. Breeds of these village chickens include the Normal Feathered Indigenous chicken (with different shades of brown and black feathers) and Feathered Shank hen (with black and white patched feathers). These breeds have successfully mix-bred with New Hampshire (with light brown feathers), Light Sussex (white bird with black strip neck feathers and black tail) and Rhode Island Red (with dark brown feathers). Eggs of chickens (locally called *Akwa-okuko* in Igbo) and guinea fowls (locally called *Akwa-ogazi* in Igbo) are the most commonly consumed as food in Nigeria, and are normally taken raw, hard-boiled, or fried. Goose and duck eggs are consumed to lesser extents. Egg white (also called albumen) and yolk are the main edible portions and are consumed together or separately for different health and nutritional reasons. These main edible portions are separated by a vitelline membrane (Mann, 2008) which presumably maintains their compositional differences. Conflicting results have been obtained in studies that tried linking egg consumption with coronary heart disease (CHD), cardiovascular disease (CVD), stroke and Type 2 diabetes (Schärer and

Schulthess, 2005; Qureshi *et al.*, 2007; Djoussé *et al.*, 2009); because of the cholesterol in yolk. Food allergies in infants and food intolerance have been linked to the consumption of egg whites (Wardlaw and Kessel, 2002; Cantani, 2008). Biotin deficiency due to avidin develops when there is a regular daily consumption of 12 to 24 raw eggs (Wardlaw and Kessel, 2002). Beaten whole egg and raw egg white foams are leavening agents in baking (Jaworski, 1997; LaBau, 2008). Raw egg white foams are also used in the production of egg white ice creams (LaBau, 2008). Raw yolk is used as thickener in the production of custard powder and the foams used in making Custard ice cream (Clay, 2008; Gyngell, 2013). Raw eggs are consumed mainly because of food faddism. Wardlaw and Kessel (2002) reported that *Salmonella* infection is the only risk associated with the consumption of raw eggs but such risk is reduced by proper cooking.

### 1.2 Effects of cooking on foods

Boiling is one of the most common and simplest methods of cooking. It was reported to have reduced the mineral compositions of oyster and beef (Wardlaw and Kessel, 2002), potatoes (Bethke and Jansky, 2008) and *Dioscorea rotundata* Poir (white yam) (Adepoju, 2012) by leaching. Parboiling reduced the ash contents of processed *Manihot esculenta* Crantz (cassava) chip relative to the sundried ones (Chijindu and Boateng, 2008). However, boiling increased the potassium content in whole eggs (Wardlaw and Kessel, 2002). The P, Zn and Mg contents of Table hen eggs also have been influenced by organic and conventional housing systems (Küçükyilmaz *et al*., 2012). Cooking solidifies egg edible portions, and increases the bioavailability of egg protein from 51% to 91% (Evenepoel *et al.*, 1998). Fresh vitelline membrane can be seen holding the yolk in place until disrupted. However, this membrane becomes ‘brittle’ and disintegrates easily when egg is boiled.

### 1.3 Biological membranes

Like other biological membranes, the shell and vitelline membranes regulate transport of substances into the albumen and yolk, respectively, from their exteriors. These exchanges would definitely affect the compositions of these egg-edible portions. Exchange of ions and water between the albumen and yolk occur through the vitelline membrane (Latter & Baggot, 1996) while exchanges of oxygen and carbon dioxide between the albumen and the egg’s environment occur through the shell membranes (Visschedijk *et al.*, 1988). Fluidity of biological membranes is increased by heat, transforming them into fluid crystalline structures (Garrett and Grisham, 1999; Devlin, 2006; Nelson and Cox, 2008). This increases the surface area per lipid and decreases bilayer thickness by 10 to 15% (Garrett and Grisham, 1999). It is thought that increase in fluidity may compromise the normal functions of membranes. The fluidity of the vitelline membrane may also increase when heated, leading to loss of its functions. Boiling eggs may alter the mineral contents of albumen and yolk thereby affecting their concentration gradients and equilibrium potentials.

### 1.4 Aim of the study

The aim of the study was to determine the effects of boiling of eggs of free range hens on the concentration gradients and equilibrium potentials of potassium (K), sodium (Na), magnesium Mg), calcium (Ca) and zinc (Zn) across the vitelline membrane.

## 2.0 MATERIALS AND METHODS

### 2.1 Eggs

Two eggs each were randomly collected from ten (10) free-range Normal Feathered Indigenous hens in Ibele, Njaba Local Government Area of Imo State, Nigeria. The birds were authenticated by Mr.

Emeka Iheme of the Department of Animal and Environmental Biology, Imo State University, Owerri, Nigeria. Each egg was one to three days old and weighed 52.99 ± 2.53 g.

2.2 Treatment of sample

The 20 eggs that were obtained were randomly assigned to two groups of 10 eggs each by putting an egg from each hen into each group. The eggs were washed with deionised water. One group of eggs (the test group) was put in 3000 ml of deionised water. The water was brought to boil and allowed to simmer for 30 min. The eggs were brought out and cooled to room temperature (28.6 ± 1.0$^{o}$C). Their shells were cracked, peeled off and their albumen and yolk separated manually. For the control groups, the eggs were left uncooked. Their shells were cracked open and the fluids poured into 100.0 ml capacity beakers (one beaker for each egg). Their albumen and yolk were carefully separated from the vitelline membrane by aspiration using Pasteur pipettes.

2.3 Mineral contents

The mineral (Zn, Mg, Ca, Na and K) contents of the samples were determined using the methods of Allen *et al*. (1996) and AOAC (2006).

2.4 Concentration gradient

The concentration gradient for a mineral was calculated by subtracting its concentration in the albumen from that in the egg yolk.

2.5 Equilibrium potentials

The minerals were assumed to be ions and their equilibrium potentials calculated using the Nernst equation, $E = -(RT/ZF)\ln(C_1/C_2)$ as described by Nelson and Cox (2008); where $E$ = equilibrium potential, $R$ = gas constant (8.315 J/mol·K), $Z$ = charge on the ion, $F$ = Faraday's constant (96, 500 J/V·mol), ln = natural logarithm, $C_1$ = albumen and $C_2$ = egg yolk.

2.6 Statistical Analysis

Data generated were analyzed using the Student's *t*-test and percentage coefficient of variation (CV %). The probability was set at $P \leq 0.05$.

## 3.0 RESULTS AND DISCUSSION

3.1 Mineral contents of raw egg edible portions

The concentrations of Na and K were significantly higher ($p < 0.05$) in the raw albumen while those of Zn, Ca and Mg were significantly higher ($p < 0.05$) in the raw yolk (Table 1). These suggested that the albumen was richer in those monovalent minerals, whereas the yolk was richer in those divalent minerals. The higher content of Mg in albumen reported in this study contrasted sharply with the report of USDA (2013a and 2013b) which said that yolks contain more Mg than albumens. USDA (2013a and 2013b) reported that the minerals with the highest concentrations in albumens and yolks relative to this study were Na and Ca, respectively. Zinc was the least occurring mineral evaluated in the two edible portions studied. This was in agreement with the reports of USDA (2013a and 2013b). The two raw egg-edible portions contained far less the amounts of these minerals that can meet their minimum Recommended Daily Allowances (RDAs) requirements for health (Table 1). Different husbandry systems have been reported to affect trace mineral elements in eggs (Giannenas *et al*., 2009). Feeds and forages consumed by livestock provide most of their minerals, whereas factors like climate, plant genotype, stage of maturity and soil environment determine the mineral contents of plants and seeds and influence the mineral intakes of these livestock (Suttle, 2010). The vitelline membrane which separates albumen from yolk may constitute a barrier to the equilibration of minerals in these egg-edible portions. This may explain the concentration gradients of the minerals in the raw eggs (Table 1). The richness of the raw albumen in Na and K seems to suggest that the vitelline membrane may contain another type of $Na^{+}/K^{+}$ ATPase that is quite different from that found in plasma membranes which makes $K^{+}$ a major intracellular ion.

Table 1. Mineral contents of raw albumen and yolk, their concentration gradients and Recommended Daily Allowance (RDA).

| Mineral | Albumen (mg/50 ml)* | Yolk (mg/50 ml)* | Conc. Gradient (mg/50 ml) | RDA (mg/day)† |
|---|---|---|---|---|
| Zn | $4.25 \pm 0.02^{b}$ | $6.99 \pm 0.00^{d}$ | + 2.74 ± 0.05 | 11 (M); 8 (F) |
| Ca | $5.96 \pm 0.04^{b}$ | $55.83 \pm 0.01^{d}$ | + 49.87 ± 0.07 | 1000 to 1300 (M & F) |
| Mg | $20.74 \pm 0.00^{b}$ | $30.54 \pm 0.10^{d}$ | + 9.80 ± 0.01 | 420 (M); 350 (F) |
| Na | $126.23 \pm 0.15^{b}$ | $21.93 \pm 0.11^{d}$ | − 104.30 ± 0.09 | 500 (M & F) |
| K | $199.43 \pm 0.10^{b}$ | $86.35 \pm 0.07^{d}$ | − 113.08 ± 0.12 | 2000 (M & F) |

* Values are mean ± SD of 10 determinations. Values on the same row with different superscript letters are significantly different ($p < 0.05$). † Wardlaw and Kessel (2002). Conc. = concentration; (M) = for males, (F) = for females, (M & F) = for males and females.

3.2 Mineral contents of boiled egg edible portions

The boiled albumen contained more ($p < 0.05$) Mg (Table 2) than the uncooked one (Table 1). This seemed to suggest that boiling increased the concentration of Mg in albumen initially by the Mg transporter in vitelline membrane and later by 'forced' diffusion due to loss of the regulatory function of the transporter. There exists an ATP-dependent Na/Mg exchanger in biological membranes (Beyenbach, 1990; Nelson and Cox, 2008). If it is assumed that minerals like Na can be leached from the egg shell into the albumen, it can be stated that the Na/Mg exchanger in the vitelline membrane was active when heating commenced thereby decreasing the [Mg] in yolk, increasing [Mg] in albumen and increasing [Na] in egg yolk (compare [Mg] and [Na] in Tables 1 and 2). The concentration gradients of Zn, Ca and K across the vitelline membranes were reduced when the eggs were boiled (Table 2). The concentration gradient of Mg was increased by more than 23% after boiling while that of Na was not significantly reduced ($p > 0.05$). Zinc, Ca, Mg and Na seemed to have diffused down their concentration gradients, whereas K seemed to have diffused against its concentration gradient. Since transport of minerals across biological membranes is mediated by proteins like the ATPases, the diffusion of these minerals in eggs while they were being boiled may not have been mediated only by active transport or facilitated diffusion. ATPases are proteins and like other proteins can be denatured by heat. The transporters in the vitelline membrane may have lost their abilities to maintain the compositional differences in the mineral contents of the albumen and yolk when the eggs were heat-treated. This presumably later permitted the 'forced' diffusion of these minerals in different directions. The concentrations of K in the albumens of the raw and boiled eggs suggest that selective leaching of some minerals into the boiling water may have occurred (compare Table 1 with Table 2). Boiling has been reported to leach minerals from food materials (Adepoju, 2012). Boiling the eggs reduced the concentration gradients of Zn, Ca, Na and K by 96.07, 55.89, 0.84 and 57.78 %, respectively, but increased that of Mg by 23.91% (compare Table 1 with Table 2). The boiled albumen and yolk contained far less the quantities of Zn, Ca, Mg, Na and K that are required to meet their RDAs for males and females.

Table 2: Mineral contents of boiled albumen and yolk, their concentration gradients and Recommended Daily Allowances (RDAs).

| Mineral | Albumen (mg/50 g)* | Yolk (mg/50 g)* | Conc. gradient (mg/50 g) | RDA (mg/day)[†] |
|---|---|---|---|---|
| Zn | 5.17 ± 0.02[a] | 5.22 ± 0.01[b] | + 0.05 ± 0.01 | 11 (M); 8 (F) |
| Ca | 11.62 ± 0.10[a] | 25.73 ± 0.06[b] | + 14.11 ± 0.03 | 1000 to 1300 (M & F) |
| Mg | 25.09 ± 0.05[a] | 9.13 ± 0.01[b] | − 15.96 ± 0.05 | 420 (M); 350 (F) |
| Na | 130.08 ± 0.11[a] | 27.52 ± 0.03[b] | − 102.56 ± 0.11 | 500 (M & F) |
| K | 74.06 ± 0.07[a] | 43.80 ± 0.11[b] | − 30.26 ± 0.07 | 2000 (M & F) |

*Values are mean ± SD of 10 determinations. Values on the same row with different superscript letter are significantly different ($p < 0.05$). [†] Wardlaw and Kessel (2002). Conc. = concentration; (M) = for males, (F) = for females, (M & F) = for male and females.

The raw and boiled albumens (Tables 1 and 2) can supply more Na than a 250 ml capacity cup of milk which contains 120 mg Na (Wardlaw & Kessel, 2002). However, the abilities of the raw and boiled albumen and yolk samples, and their combined consumptions, to meet the RDAs for Zn would be reduced if the body's 40% absorptive capability of intakes (Wardlaw & Kessel, 2002) is considered. The [Mg]/[Ca] ratios of raw and boiled albumens (3.48:1.00 and 2.16:1.00, respectively) suggested that Mg would be the more absorbed of these divalent minerals from the stomach and intestines when their absorptive antagonisms for each other (Watts, 1990; Wardlaw & Kessel, 2002) are considered on the basis of 1:1. On the other hand, their ratios in raw and boiled yolks (0.55:1.00 and 0.35:1.00, respectively) suggested that Ca would be the more absorbed of the two minerals. Deficient intakes of Zn and Ca can lead to Cd and Pb toxicities, respectively (Watts, 1990; Wardlaw & Kessel, 2002). However, Watts (1990) reported synergisms between Zn, K, Mg, Mn, Cr and P; Ca, Mg, P, Cu, Na, K and Se; Mg, Ca, K, Zn, Mn, P and Cr; K, Na, Mg, $B_{10}$, Mn, Zn, P and Fe, and Na, K, Se, Co, Ca, Fe, Cu and P at the metabolic level.

### 3.3 Mineral profiles

The mineral profiles in order of decreasing concentrations of raw albumen and yolk were [K] > [Na] > [Mg] > [Ca] > [Zn] and [K] > [Ca] > [Mg] > [Na] > [Zn], respectively. The former was akin to what is obtained in normal human cells (Nelson and Cox, 2008). The mineral profile of the raw albumen portrayed maintenance of conserved evolutionary biochemical system, whereas that of the yolk portrayed unity in diversity as a central biological principle due to increases in [Ca] and [Mg]. Those of their boiled counterparts were [Na] > [K] > [Mg] > [Ca] > [Zn] and [K] > [Na] > [Ca] > [Mg] > [Zn], respectively, suggestive of increases of the [Na] in the two egg-edible portions (see Tables 1 and 2). However, mineral profiles of [Na] > [K] > [Mg] > [Ca] > [Zn] for raw albumen and [Ca] > [K] > [Na] > [Mg] > [Zn] for raw yolk have been reported (USDA, 2011a and 2013b). The USDA (2013a and 2013b) reports seemed to suggest that the concentration of Na is normally higher than that of K in raw albumen while their positions are reversed in raw yolk; unlike the results presented in this study. The reports also suggested that the concentrations of Ca and Na were higher than those of K and Mg, respectively, in raw yolk unlike the results presented in this study where there was reversal of positions for these minerals. The differences in mineral profiles noticed in this study and those of USDA (2013a and 2013b) for raw albumen and yolk may be due to differences in breeds, diets and housing systems. Dietary compositions and housing systems have been reported to affect the mineral compositions of eggs (Naber, 1979; Matt *et al*., 2009; Yair and Uni, 2011; Küçükyilmaz *et al*., 2012; Bologa *et al*., 2013). While whitish eggs laid by free-range scavenging local hens were used in this study, those of New Hampshire, Light Sussex, Rhode Island Red, White Leghorn or other non-indigenous breeds to Nigeria, may have been used in the study conducted by USDA (2013a and 2013b).

3.4 Thermodynamic considerations

In thermodynamics parlance, boiling converts eggs from open systems to closed systems that are relatively rich in potential energies like fat, protein and carbohydrate. It reduced the equilibrium potentials of Na and K, but increased those of Zn, Ca and Mg (Table 3). The changes in their equilibrium potentials were due to changes in their concentration gradients (Tables 1 and 2). If the raw eggs are further considered as thermodynamic entities and their minerals as ions, the free energy of transport ($\Delta G_t$) for the translocation of the $Zn^{2+}$, $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ into the egg yolk (calculated using the equation $\Delta G_t = RT \ln (C_2/C_1) + ZFV$; where V = transmembrane potential of – 65 mV and other terms are as described earlier) would be + 11.26, + 6.75, + 11.54, − 10.76 and – 8.44 kJ/mol, respectively. Though boiled eggs are closed systems, boiling changed the concentration gradients of the minerals (Table 2) and their $\Delta G_t$ to + 12.52, + 10.50, − 15.15, − 10.28 and – 4.75 kJ/mol, respectively. These represented changes of 11.19, 55.55, 231.28, 4.46 and 43.72 per cent, respectively, for their $\Delta G_t$ and 98.40, 64.48, 361.08, 11.26 and 37.26 per cent, respectively, for their *E* values. The $\Delta G_t$ demands for translocation of Zn and Ca into the yolk were increased while the $\Delta G_t$ released was reduced. That of Mg was changed from a $\Delta G_t$ demanding entity to a $\Delta G_t$ releasing entity.

Table 3: Equilibrium potentials (*E*) of the mineral ions across the vitelline membrane in raw and boiled eggs

| **Mineral ion** | ***E* (mV)*** | |
|---|---|---|
| | **Raw egg** | **Boiled egg** |
| $Zn^{2+}$ | − 8.14 ± 0.01[a] | − 0.13 ± 0.01[b] |
| $Ca^{2+}$ | − 29.98 ± 0.02[a] | − 10.65 ± 0.04[b] |
| $Mg^{2+}$ | − 5.19 ± 0.03[a] | + 13.55 ± 0.03[b] |
| $Na^{+}$ | + 47.26 ± 0.05[a] | + 41.94 ± 0.05[b] |
| $K^{+}$ | + 22.60 ± 0.04[a] | + 14.18 ± 0.06[b] |

* Calculated from TABLES 1 and 2, values are mean ± SD of 10 determinations. Values on the same row with different superscript letter are significantly different ($p < 0.05$).

3.5 Mineral ratios and protein synthesis

The [K]/[Na] ratio in the albumen and yolk decreased ($p < 0.05$) after boiling ( 4). The mineral ratios of [K]/[Ca], [Na]/[Mg] and [Na]/[Ca] significantly reduced ($p < 0.05$) in the albumen after boiling, whereas those of [K]/[Ca], [Na]/[Mg] and [Na]/[Ca] increased in the yolk.

Table 4: Protein contents and some mineral ratios of raw and boiled albumen and yolk*

| Mineral ratio | Raw albumen | Raw yolk | Boiled albumen | Boiled yolk |
|---|---|---|---|---|
| [K]/[Na] | 1.58 ± 0.01[a] | 3.94 ± 0.02[b] | 0.57 ± 0.00[c] | 1.59 ± 0.01[a] |
| [K]/[Ca] | 33.39 ± 0.14[a] | 1.55 ± 0.00[b] | 6.37 ± 0.07[c] | 1.70 ± 0.01[d] |
| [Na]/[Mg] | 6.09 ± 0.00[a] | 0.72 ± 0.01[b] | 5.18 ± 0.01[c] | 3.01 ± 0.00[d] |
| [Na]/[Ca] | 21.18 ± 0.12[a] | 0.39 ± 0.01[b] | 11.19 ± 0.08[c] | 1.07 ± 0.01[d] |

*Values are mean ± SD of 10 determinations. Values on the same row with different superscript letter are significantly different ($p < 0.05$).

Reductions in ratios that involved K after boiling were as a result of the reduction in its concentration gradient by more than 57 %. Ratios like [K]/[Na], [K]/[Ca], [Na]/[Mg] and [Na]/[Ca] have been correlated with protein contents of foods (Ibegbulem and Abanobi, 2014). Increase in [K]/[Na] ratio and decreases in those of [Na]/[Mg] and [Na]/[Ca] correlated with high protein contents; with the [K]/[Na] ratio being the most important of them. Ibegbulem and Abanobi (2014) reported that such ratios engendered protein synthesis in cells because K promotes it while Na antagonises it. The ratios enumerated in this study support the higher protein content of raw egg yolk (15.86 g/100 g) relative to that of raw albumen (10.90 g/100 g) as reported by USDA (2013a and 2013b). The lower [K]/[Ca] ratio in the raw yolk was due to its high [Ca]. However, the much higher [K]/[Ca] ratio reported for raw albumen in this study did not support its reported lower protein content relative to the protein content of raw egg yolk. This seems to suggest that high [Ca] in yolk may not have antagonised the activity of K downstream. The high [Ca] in yolk may be as a result of the need to form the skeleton of the embryo and to make its muscles function properly during embryogenesis.

3.6 Nutritional considerations

Tables 5 and 6 further explain the results presented in Tables 1 and 2. The Tables suggested that boiling increased the concentrations of Zn, Ca, Mg and Na from their mean values by more than 1.49 to 32.00 % and reduced that of K by more than 45 % in the albumen (Table 5). Boiling also reduced the concentrations of Zn, Ca, Mg and K by more than 14 to 53 % and increased that of Na by more than 11 % in the yolk (Table 6).

Table 5: Change in mineral contents of albumen after boiling*

| Mineral | Raw albumen (mg/50 ml) | Boiled albumen (mg/50 g) | Mean | SD | CV% |
|---|---|---|---|---|---|
| Zn | 4.25 ± 0.02 | 5.17 ± 0.02 | 4.71 | 0.46 | 9.77 |
| Ca | 5.96 ± 0.04 | 11.62 ± 0.10 | 8.79 | 2.83 | 32.20 |
| Mg | 20.74 ± 0.00 | 25.09 ± 0.05 | 22.92 | 2.18 | 9.49 |
| Na | 126.23 ± 0.15 | 130.08 ± 0.11 | 128.16 | 1.93 | 1.50 |
| K | 199.43 ± 0.10 | 74.06 ± 0.07 | 136.75 | 62.69 | 45.84 |

* Based on Tables 1 and 2; values are mean ± SD of 10 determinations.

Table 6: Change in mineral contents of yolk after boiling*

| Mineral | Raw yolk (mg/50 ml) | Boiled yolk (mg/50 g) | Mean | SD | CV% |
|---|---|---|---|---|---|
| Zn | 6.99 ± 0.00 | 5.22 ± 0.01 | 6.11 | 0.89 | 14.48 |
| Ca | 55.83 ± 0.01 | 25.73 ± 0.06 | 40.78 | 15.05 | 36.91 |
| Mg | 30.54 ± 0.10 | 9.13 ± 0.01 | 19.84 | 10.71 | 53.96 |
| Na | 21.93 ± 0.11 | 27.52 ± 0.03 | 24.73 | 2.80 | 11.30 |
| K | 86.35 ± 0.07 | 43.80 ± 0.11 | 65.08 | 21.28 | 32.69 |

* Based on Tables 1 and 2; values are mean ± SD of 10 determinations.

The most variable mineral in the albumen was K while Mg was the most variable mineral in the yolk. While boiling improved the ability of the albumen to meet the RDAs for Mg, it reduced the ability of the yolk to meet its RDAs for the sexes. The RDAs for Mg for adults of between 19 to 30 years of age can be met by the raw and boiled albumens by 6.28 and 7.60 %, respectively, for males and 8.13 and 9.84 %, respectively, for females; at RDA levels of 330 mg/day for males and 255 mg/day for females for the age brackets (Wardlaw & Kessel, 2002). In the same light, the raw and boiled yolks can meet the RDAs for Mg for the same age bracket by 9.25 and 2.77%, respectively, for males and 11.98 and 3.59 %, respectively, for females. Boiling increased the extent to which Zn can meet the RDAs from 38.64 % (for males) and 53.13 % (for females) in the raw albumen to 47.00 % (for males) and 64.63 % (for females). The extents to which Ca, Mg and Na can meet their RDAs after boiling were increased from 0.46 - 0.60 % (for males and females) for Ca; 4.94 % (for males) and 5.93 % (for females) for Mg, and 25.25 % (for males and females) for Na in the raw albumen to 0.89 - 1.16 % (for males and females) for Ca; 6.27 % (for males) and 8.09 % (for females) for Mg, and 26.02 % (for males and females) for Na. The extent to which the albumen can meet the RDA for K was reduced from 9.97 % (for males and females) to 3.70 %. Whereas boiling increased the extent to which the yolk can meet the RDA of Na from 4.39 % to 5.50 % for both sexes, it reduced those of Zn (from 63.55 to 47.45 % for males and 87.34 to 65.25 % for females), Ca (from between 4.29 to 5.58 % to between 1.97 to 2.57 % for both sexes), Mg (from 7.27 to 2.28 % for males and 9.85 to 2.95 % for females) and K (from 4.32 to 2.19 % for both sexes). These extents would improve when the albumen and yolk are consumed together. For instance, combined consumption of the raw albumen and yolk would improve the RDAs for Zn by 102.18 % for males and 140.50 % for females; Ca by 4.75 to 6.18 % for both sexes; Mg by 12.21 % for males and 14.65 % for females; Na by 35.63 % for both sexes and K by 14.29 % for both sexes. Consumption of the boiled albumen and yolk together would improve the RDAs for Zn by 94.45 % for males and 129.88 % for females; Ca by 2.87 to 3.74 % for both sexes; Mg by 8.56 % for males and 11.04 % for females; Na by 31.52 % for both sexes and that of K by 5.89 % for both sexes.

## 4.0 CONCLUSION

Boiling 'forced' the diffusion of some minerals to the compartment where their concentrations were lower. These improved the ability of the albumen to meet the recommended daily allowances of some of these minerals.

## 5.0 Acknowledgement

We gratefully acknowledge the technical assistance of Mr. J. Onwuegbu.

## References

Adepoju, O.T. (2012). Effects of processing methods on nutrient retention and contribution of white yam (*Dioscorea rotundata*) products to nutritional intake of Nigerians. *African Journal of Food Science, 6*(6), 163-167.

Allen, S.E., Parinson, J.A. & Quarmry, C. (1996). *Chemical analysis of ecological materials*. Oxford, UK: Blackwell.

AOAC. (2006). *Official Methods of Analysis* (18th ed.). Washington DC: Association of Official Analytical Chemists.

Banerjee, P. & Keener, K.M. (2012). Maximizing carbon dioxide content of shell eggs by rapid cooling treatment and its effect on shell egg quality. *Poultry Science, 91*(6), 1444-1453.

Bethke, P.C. & Jansky, S.H. (2008). The effects of boiling and leaching on the content of potassium and other minerals in potatoes. *Journal of Food Science, 73*(5), H80-H85.

Beyenbach, K.W. (1990). Transport of magnesium across biological membranes. *Magnesium and Trace Elements, 9*(5), 233-254.

Bologa, M., Pop, I.M. & Albu, A. (2013). Research on chemical composition of chicken egg from different systems of production (conventional and organic). *Lucrări Ştiinţifice-Seria Zootehnie, 59*, 80-85.

Cantani , A. (2008). *Pediatric Allergy, Asthma and Immunology*. Berlin: Springer.

Chijindu, E.N. & Boateng, B.A. (2008). Effect of nutritional content of processed cassava chips on development of *Prostephanus truncatus* (Horn). *World Journal of Agricultural Sciences, 4*(3), 404-408.

Clay, X. (2008). *Home-made ice cream recipes: ice and easy does it every time*. Retrieved from http://www.telegraph.co.uk/foodanddrink/recipes/3344644/Home-made-ice-cream-recipes-Ice-and-easy-does-it-every-time.html

Devlin, T.M. (Ed). (2006). Biological membrane: structure and membrane structure. In *Textbook of Biochemistry with Clinical Correlation*, 6th ed. (pp. 443-487) New Jersey, NJ: John Wiley and Sons Inc.

Djoussé, L., Gaziano, J.M., Buring, J.E. & Lee, I.M. (2009). Egg Consumption and Risk of Type 2 Diabetes in Men and Women. *Diabetes Care (Biowizard.com), 32*(2), 295–300.

Evenepoel, P., Geypens, B., Luypaerts, A., Hiele, M., Ghoos, Y. & Rutgeerts, P. (1998). Digestibility of cooked and raw egg protein in humans as assessed by sTable isotope technique. *The Journal of Nutrition, 128*(10), 1716-1722.

Garrett, R. H., & Grisham, C. M. (Eds). (1999). *Biochemistry*, 2nd ed. Pacific Groove, California, CA: Brooks/Cole – Thomson Learning.

Giannenas, I., Nisianakis, P., Gavriil, A., Kontopidis, G. & Kyriazakis, I. (2009). Trace mineral content of conventional, organic and courtyard eggs analysed by inductively coupled plasma mass spectrometry (ICP-MS). *Food Chemistry, 114*(2), 706–711.

Gyngell, S. (2013). *Custard base for ice cream recipe*. Retrieved from http://www.telegraph.co.uk/ foodanddrink/recipes/9948393/Custard-base-for-ice-cream-recipe.html

Ibegbulem, C.O. & Abanobi, S.E. (2014). Possible correlation between mineral profile and protein contents of foods. *Turkish Journal of Biochemistry, 39*(1), 45-50.

Ibegbulem, C.O., Agha, N.C., Mgbaja, C.H. & Emeka-Nwabunnia, I. (2012). Amino acid profiles and characteristics of proteins of intramural and subserous uterine fibroid tissues. *Journal of Research in Biochemistry, 1*(1), 059-064.

Jaworski, S. (1997). *Eggs*. Retrieved from http://www.joyofbaking.com/eggs.html

Keener, K.M., LaCrosse, J.D. & Babson, J.K. (2001). Chemical method for determination of carbon dioxide content in egg yolk and albumen. *Poultry Science, 80*(7), 983-987.

Küçükyılmaz, K., Bozkurt, M., Yamaner, Ç., Çınar, M., Çatlı, A. U. & Konak, R. (2012). Effect of an organic and conventional rearing system on the mineral content of hen eggs. *Food Chemistry, 132*(2), 989-992.

LaBau, E. (2008). *Nougat ice cream*. Retrieved from http://www.candy.about.com/b/2008/10/03/nougat-ice-cream.htm

Latter, G.V. & Baggot, G.K. (1996). The effect of egg turning and fertility upon the sodium concentration of the Japanese quail. *British Poultry Science, 37*(2), 301-308.

Mann, K. (2008). Proteomic analysis of the chicken egg vitelline membrane. *Proteomics, 8*(11), 2322-2332.

Matt, D., Veromann, E. & Luik, A. (2009). Effect of housing systems on biochemical composition of chicken eggs. *Agronomy Research, 7*(Special issue II), 662–667.

Naber, E.C. (1979). The effect of nutrition on the composition of eggs. *Poultry Science, 58*(3), 518-528.

Nelson, D.L. & Cox, M.M. (Eds). (2008). *Lehninger Principles of Biochemistry*, 6th ed. New York, NY: W.H. Freeman and Company.

Qureshi, A.I., Suri, F.K., Ahmed, S., Nasar, A., Divani, A.A. & Kirmani, J.F. (2007). Regular egg consumption does not increase the risk of stroke and cardiovascular diseases. *Medical Science Monitor, 13*(1), CR1–8.

Schärer, M. & Schulthess, G. (2005). [Egg intake and cardiovascular risk]. *Therapeutische Umschau, 62* (9), 611–613.

Suttle, N.F. (2010). *Mineral Nutrition of Livestock*, 4th ed. Oxfordshire, UK: CABI.

USDA (2013a). *National nutrient database for standard reference, release 26*. Agricultural Research Service of the United States Department of Agriculture. Retrieved from http://ndb.nal.usda.gov/ndb/foods/show/152?fg=&man=&lfacet=&format=&count=&max=25&offset=&sort=&qlookup=egg+white

USDA (2013b). *National nutrient database for standard reference, release 26*. Agricultural Research Service of the United States Department of Agriculture. Retrieved from http://ndb.nal.usda.gov/ndb/foods/show/152?fg=&man=&lfacet=&format=&count=&max=25&offset=&sort=&qlookup=egg+yolk

Visschedijk, A.H.J., Girard, H. & Ar, A. (1988). Gas diffusion in the shell membranes of the hen's egg: lateral diffusion in situ. *Journal of Comparative Physiology B, 158*(5), 567-574.

Wardlaw, G. M. & Kessel, M. W. (Eds). (2002). *Perspective in Nutrition*, 5th ed. (pp. 420, 681, A-18). Boston, MA: McGraw-Hill.

Watts, D.L. (1990). Nutritional interrelationships: minerals, vitamins, endocrines. *Journal of Orthomolecular Medicine, 5*(1), 11-19.

Yair, R., & Uni, Z. (2011). Content and uptake of minerals in the yolk of broiler embrayos during incubation and effect of nutrient environment. *Poultry Science, 90*, 1523-1531.