Evaluation of quality and nutrient contents of table eggs from different sources in the retail market

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Abstract

Table egg quality and nutrient contents from four sources in the retail market in Jeddah city, Saudi Arabia were evaluated using straight run experimental design and compared with the recommended daily allowance (RDA, 2002/2005) profiles. Egg source had a noticeable effect (P<0.05) on shell weight per unit of surface area, albumen percentage, Haugh unit, yolk percentage, index and colour. Differences in dry matter, protein, and lipid profiles of eggs were significant (P<0.05) among various sources, while variability in egg cholesterol and low density lipoprotein reached 51 and 17.6% (P<0.05), respectively. Egg sources had an effect (P<0.05) on total antioxidant capacity and lipid malonaldehyde. Mineral contents (mg/egg) of the whole edible parts of eggs showed a significant difference (P<0.05) among different egg sources in most of the minerals except for potassium. In conclusion, eggs in the retail market had variable quality and nutrition contents that may affect the fulfillment of the RDA for human and may possibly improve the quality of eggs and their nutritional values. Such diversity indicates the need for uniform of production and husbandry practice, the enforcement of quality control regulations based on egg quality and nutrient profiles by the authorities in the market, and the impact this may have on the health of the consumer.

Introduction

Eggs have been considered as a principle food item for human consumption over the history as they provide most of the nutrition as suggested by the recommended daily allowance (RDA) (Vila, 1999; Bradley and King, 2000; Basmacioglu and Ergul, 2005). There is general acceptance that eggs in the retail market have similar quality. The variability in the quality and nutritional values of eggs has a significant impact on consumers’ health; simultaneously, welfare and many other factors can affect egg quality. These factors include the breed and strain of layers (Cook and Briggs, 1977; Kiiskinen and Helander, 1998; Elkin, 2004; Zita et al., 2009; Kucukyilmaz et al., 2012), dietary composition (Calislar and Kirik, 2009; wiatkiewicz et al., 2010; Goldberg et al., 2012), birds’ health, environmental condition and storage, processing and handling of eggs (Ryu et al., 2011; Zhang et al., 2011; Khan et al., 2013).

Lipids and antioxidants of eggs are essential components for humans from a health and consumption perspective and therefore they have considerable impact on egg consumption and health implications. Lipids of eggs are influenced by genotype (Kucukyilmaz et al., 2012), the level and type of dietary fats (Rezaei et al., 2008; Attia et al., 2009; Belitz et al., 2009; Ahmadi and Rahimi, 2011; King et al., 2012), and husbandry practice (Kucukyilmaz et al., 2012). Mineral contents of eggs such as Ca, P, Cu, Fe, Mn and Zn, belong to the most influential and basic microelements that are essential for human and chickens nutrition. Consequently, they often are supplemented in poultry diet (National Research Council, 1994; Hashish et al., 2012). As such, there is a relationship between doses and sources of these elements for poultry, accumulation in tissues and products, excretion from the organism and their accumulation in soil and plants (Hashish et al., 2012).

In literature, there are rare studies about mineral content in different parts of eggs. Egg mineral contents have a considerable health implications and nowadays there is increasing interest in supplementing eggs with several minerals such as Se, Fe, Cr and Zn for human health benefits (Attia et al., 2010). Moreover, the mineral contents in eggs and eggshells show quite different concentrations, depending on the dose and form of element and other factors such as physiological reasons, husbandry practice, geographic area (Giannenas et al., 2009; Attia et al., 2010; Hashish et al., 2012), as well as supplemented feed additives (Bäckermann and Ternes, 2008).

The present research was conducted to monitor the variability in the quality of the eggs from four sources in the retail market in terms of external and internal quality, nutrient and mineral contents, cholesterols, antioxidant status, and peroxidation biomarkers.

Materials and methods

Egg sources

Four hundred and eighty eggs were randomly collected from four sources named A, B, C and D, chosen from retail stores. The sample represented different sources of eggs, in the Hyper Panda retail market, in Jeddah, Saudi Arabia from May to September 2013. The sample size was 30 eggs per source per time and was replicated four times, resulting in 120 eggs per source.

Laying hens in A, B, C and D groups were fed commercial layer diets, which expected to meet dietary nutrient requirements of laying hens according to their breeder guide of each strain. Eggs were laid by white eggshell layers, which had similar genetic makeup, e.g. White leghorn. Hens were housed in environmental controlled houses (25°C and 50% relative humidity). Hens were submitted to 14:10 light dark cycle, fed mash diets and supplied with fresh water ad libitum. Layers were reared under commercial operation condition and managed using common husbandry practice for layers. Egg collections was manual in A farm and automatic in the others. Egg sources had similar dates of production and expired when collected from the retail markets.
Measurements

External egg quality

Egg cleanliness was determined using a scale of 5 points: 5=excellent (absent of signs of faecal and/or bedding material), 4=remarkably clean (remarkably clean and no sign of faecal and/or bedding material not apparent), 3=good (the eggs are clean with acceptable appearance), 2=fair (eggs are not clean, but faecal and/or bedding material are absent) and 1=dirty (eggs are not clean, and there was a faecal and/or bedding material on the eggs). Broken egg percentage was calculated by counting the number of broken eggs in each source and dividing by the total number of eggs. Egg shape index and quality included shell weight, percentage shell, shell thickness and shell weight per unit of surface area (SWUSA); these parameters were recorded according to Attia et al. (1994) and Alsaffar et al. (2013).

Internal egg quality

Eggs were weighed and external quality was measured according to Alsaffar et al. (2013). Then, the eggs were broken and internal egg quality included yolk weight and percentage, yolk index, yolk colour, albumen weight and percentage, Haugh unit score and blood and meat spots; these parameters were determined according to Abd El-Rahman and Attia (2002). Blood and meat spots were evaluated using a 6 points score: 0=no blood or meat spot; 1=1 blood or meat spot, 2=2 blood or meat spots or 1 blood and 1 meat spots; 3=3 blood or meat spots or their sums; 4=4 blood or meat spots or their sums; and 5=5 blood or meat spots or their sums.

Nutrient contents of eggs

The chemical composition of eggs (dry matter, method number 934.01; protein, method number 954.01; lipid, method number 920.39; and ash, method number 942.05) was determined according to AOAC (2004) after mixing yolk and albumen according to Di Meo et al. (2003). The sample size was 5 pooled samples per source over time. The data of chemical composition of eggs was used for calculation of nutrient contents in the eggs by multiplying nutrient concentration by mean egg weight of each treatment. This was done to correct the difference in egg weight among different egg sources.

Lipids and antioxidant status of yolk

Yolk samples were collected (n=5 of pooled samples per source over time), cleaned from albumen and immediately stored at -70°C until analysis. Egg and yolk lipids were extracted (AOAC, 2004) to determine yolk total lipids, triglyceride, cholesterol, high (HDL) and low density lipoprotein (LDL) according to Zollner and Krich (1962), Fossati and Precnipe (1982), Al lain et al. (1974), Lopez-Virella et al. (1977) and Wieland and Seidel (1983), respectively. The determinations were done using commercial kits (Diamond Diagnostics, Holliston, MA, USA). Total antioxidant capacity (TAC, µmol/L) and lipid peroxidation biomarker such as malonyldialdehyde (MDA, µmol/L) and malondialdehyde (MA, µmol/L) were determined according to Koracevic et al. (2001) and Ohkawa et al. (1979), respectively. The data of lipid compositions of eggs were used for calculation of lipid contents in the eggs by multiplying lipid concentrations by mean yolk weight of each treatment. This was done to correct for difference in the weight of yolk among different egg sources.

Egg mineral concentrations

Mineral composition of eggs was determined on 5 samples per source over 4 times on albumen, yolk or a mixture yolk+albumen. The samples were subjected to chemical extraction using a 1:3 mixture of concentrated hydrochloric and nitric acid (AOAC, 2004). The clear digested solutions were made of 50 mL using double-distilled water, and stored in plastic bottles. The concentration of Ca, Cu, Mn, Mg, K, Na, Zn and Fe in the final solutions was determined utilizing flame spectrophotometric techniques using the method of Haraguchi and Fuwa (1976). The data for mineral concentrations of eggs were used for calculation of mineral contents in the eggs by multiplying element concentration by mean egg weight of each treatment. This was done to correct for difference in egg weight among different egg sources.

Statistical analyses

Analysis of variance was performed using straight run experimental design (one-way analyses of variance) of SAS software computer programme (SAS, 2009) using the following model:

\[ Y_{ij} = \mu + A_{i} + e_{ij} \]

where \( \mu \) is general mean, \( A_{i} \) is the effect of egg source, and \( e_{ij} \) is a random error. All percentages were transformed into their corresponding logarithmic values to a normalise data distribution before conducting the analysis. Student Newman Keuls test was employed to compare mean differences at \( P<0.05 \). Correlation analyses were also done to obtain the relationship among different egg quality traits.

Results

External egg quality

Table 1 presents the effect of different egg sources on the external egg quality. Eggs from source A had significantly bigger egg weight than the other sources; eggs from source B had a higher (\( P<0.05 \)) weight than source C, while no differences were among B vs D and C vs D source. Eggs from source B had significantly better egg clearness followed by source D and, together, sources A and C. Source B and D had significantly the highest broken egg percentage followed by C and the last was A. Shell weight (g and %), shell thickness and SWUSA were significantly different for each egg source, but shape index was not. These last parameters were significantly greater for eggs from source C than those of other sources. Eggshell quality from source A had the lowest values except for shell weight, g, while source D had eggs with the lowest shell thickness.

Internal egg quality

Table 2 shows the effect of different egg sources on the internal egg quality. Albumen weight (g) was significantly greater of eggs from source A than that of the other sources. Albumen weight from source D was the smallest and that of source B and C was intermediate. Albumen percentage was significantly greater of eggs from source A, C and D than that from source B. Albumen height was significantly higher of eggs from source A than that of the other source followed by sources B and D and C sources. Differences between the latter groups were significant in favor of eggs from source D. Eggs from source D had significantly higher Haugh unit score than that of the other
sources. Haugh unit score of eggs from source A and B exhibited similar value and were greater than that of source C.

Eggs from source A had significantly bigger yolk weight (g) than the other sources, whereas source D had a smaller yolk weight (g) than that of source B and C. The latter source exhibited also significantly lower value than source B. Differences in yolk weight (%) and yolk/albumen ratio were apparent, showing that source B had significantly greater values than those from source C or D, whereas those of source A was bigger than that of source C only.

Yolk index was significantly greater of eggs from source B than from other sources, and that from source D was smaller than that of source A and C, the latter group had bigger value that that of source A. Yolk colour was significantly influenced by source of eggs, showing darker yolks of eggs from source C and D than those of A and B sources, with B source exhibited darker one than that of the source A. Meat and blood spots were significantly higher of eggs from source A and C than those of eggs from B and D sources.

**Correlation between egg quality traits**

Table 3 shows Pearson correlation coefficient analyses among egg quality traits. The results indicated that egg weight had the highest correlation with albumen weight (r=0.912; P=0.0001) and the lowest correlation with shell thickness (r=-0.042; P=0.376). Yolk weight had the strongest correlation with yolk percent (r=0.717; P=0.0001), and the weakest one with shell thickness (r=-0.057; P=0.231). The corresponding values for yolk index was with albumen height (r=0.468; P=0.001) and shell weight (r=0.057; P=0.227). Yolk colour showed significant negative correlations with yolk weight (r=0.449; P=0.0001) and the yolk percent (r=-0.301; P=0.0001).

Shell quality traits exhibited positive correlation with each other with the strongest between shell weight and SWUSA (r=0.631; P=0.0001) and the smallest between shell weight and shell percent (r=0.356; P=0.0001). The correlations between albumen quality traits was high between albumen height and Haugh unit score (r=0.878; P=0.0001); moderate between albumen weight and albumen percent (r=0.609; P=0.0001) and weak between albumen weight and albumen height (r=0.104; P=0.029) and Haugh unit score (r=0.181; P=0.0001). On the other hand, blood and meat spots were not correlated with any other egg quality traits.

**Nutrient contents of eggs**

Table 4 displays data for the influence of different egg sources on nutrient contents of eggs. Dry matter, protein, lipid and ash content showed a significant effect of egg source. Eggs from source D had higher dry matter content than that of eggs from sources A, B and C. The latter group had lower dry matter content than that of A and B sources. On the other hand, dry matter content from source A was significantly higher than that of source B only.

Eggs from source A showed greater protein

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### Table 1. Effect of different egg sources on the external egg quality.

| Parameters           | Source of eggs | Statistical analyses |
|----------------------|----------------|----------------------|
|                      | A              | B                    | C                    | D                    | RSME   | P        |
| Egg cleanliness      | 2.933b         | 3.967a               | 2.892c               | 3.42b                | 0.718   | 0.0001   |
| Broken eggs, %       | 0.034c         | 0.083b               | 0.042b               | 0.083b               | 0.148   | 0.0001   |
| Egg weight, g        | 61.38c         | 57.14b               | 55.41b               | 56.49c               | 4.383   | 0.0001   |
| Shape index, %       | 74.7           | 75.0                 | 75.7                 | 75.7                 | 3.534   | 0.0002   |
| Shell weight, g      | 5.720b         | 5.638b               | 5.924a               | 5.303c               | 0.542   | 0.0001   |
| Shell weight, %      | 9.062c         | 9.748b               | 10.398a              | 9.958b               | 0.903   | 0.0001   |
| Shell thickness, µm  | 36.00c         | 36.82b               | 39.28d               | 35.78c               | 2.742   | 0.0008   |
| SWUSA, mg/cm²        | 78.79c         | 82.56a               | 87.54d               | 82.31c               | 7.198   | 0.0052   |

RMSE, root mean square error; SWUSA, shell weight per unit of surface area. *Different letters in the same column denote significant differences (P<0.05).*

### Table 2. Effect of different egg sources on the internal egg quality.

| Parameters            | Source of eggs | Statistical analyses |
|-----------------------|----------------|----------------------|
|                      | A              | B                    | C                    | D                    | RSME   | P        |
| Albumen quality       |                |                      |                      |                      |        |          |
| Albumen weight, g     | 39.27a         | 35.37b               | 35.92b               | 33.29c               | 4.415   | 0.0001   |
| Albumen, %            | 62.14c         | 60.61b               | 62.44a               | 62.09a               | 3.883   | 0.0001   |
| Albumen height, mm    | 5.074b         | 4.215c               | 3.28a                | 4.78b                | 0.972   | 0.0001   |
| Haugh unit score      | 60.73c         | 60.35b               | 50.23c               | 68.21b               | 12.22   | 0.0001   |
| Yolk quality          |                |                      |                      |                      |        |          |
| Yolk weight, g        | 18.04a         | 17.15b               | 15.71c               | 14.94d               | 2.055   | 0.0001   |
| Yolk weight, %        | 28.79c         | 29.65a               | 27.19c               | 27.94b               | 3.708   | 0.0001   |
| Yolk/albumen ratio    | 45.94a         | 48.48b               | 43.74a               | 44.88b               | 0.845   | 0.0001   |
| Yolk index            | 29.86c         | 33.30b               | 32.18a               | 28.89c               | 3.058   | 0.0001   |
| Yolk colour score     | 2.867c         | 4.168b               | 4.955a               | 4.941b               | 0.538   | 0.0001   |
| Blood and meat spots, %| 1.00b         | 0.00b                | 1.00b                | 0.00b                | 0.000   | 0.0001   |

RMSE, root mean square error. *Different letters in the same column denote significant differences (P<0.05).*
and lipid content than those of eggs from sources B, C and D. The latter groups had lower protein content than that of the B source. On the other hand, differences in protein contents between C and D sources were not significant. In addition, lipid contents of sources B, C and D were similar.

Lipid profiles and antioxidant status

Table 4 summarises the impact of different egg sources on lipid profiles of egg yolk and antioxidant status. Triglycerides were the highest in eggs from A source. Source B also had higher triglycerides content than source C, while D source was not different from B and C. The amount of cholesterol of eggs from source D was lower than that of the other sources. Source D showed lower (P<0.05) values of LDL than A and B, while had the highest (P<0.05) values of HDL and HDL/LDL ratio.

Total antioxidant capacity was significantly higher of eggs from sources C and D than that of eggs from sources A and B. Eggs from C source had a higher (P<0.05) MA values than sources A and D.

Egg mineral contents

Table 5 summarises the effect of different egg sources on mineral contents of eggs. Most of mineral contents in the egg were significantly affected by source of eggs in the retail market except for K content. The Ca, Zn and Mg contents of source A were significantly greater than those of the other sources. In addition, Ca content of B and D sources were significantly higher than those of source C. Zinc content of source D was significantly greater than that of B and C. Difference between the latter groups was also significant in favour of group C. The iron content was the highest in eggs from source B, followed by sources A, D and C. Eggs from source A showed significantly greater Cu contents than those of eggs from sources C and D. The P content of sources A and D was significantly higher than that of sources B and C. Differences between A and D or B and C were not significant.

The Na content of eggs from source A was higher (P<0.05) than those of the other source except D. In addition, source D had higher (P<0.05) Na content than that of source C that displayed the lowest Na concentration.

**Discussion**

Eggs were found to have different levels of cleanliness which could be due to differences in storage and handling condition, sanitation and...
hygienic condition, method of collection and handling of the eggs. However, correlation analysis indicated lack of significance between egg cleanliness and important internal egg quality such as albumen height, Haugh unit score and yolk colour (P>0.05). It should be mentioned that laying hens produced the eggs used in this study were kept in cages in environmental control houses, however, the age of facility and housing are different among different sources of eggs.

Variability in egg weight (10.8%) among different sources can affect different parts of eggs and quality of eggs as well as the consumer desire for eggs as consumer typically prefers larger eggs (USDA, 2000). Difference in eggs weight, on the other hand, could be attributed to age and strain of hens (Zita et al., 2009; Alsaffar et al., 2013), dietary protein/amino acids, energy and fat/fatty acids, housing density and housing condition (cages vs floor), health status, environmental stress and feed intake (Attia et al., 1994; Ahmadi and Rahimi, 2011; Goldberg et al., 2012; Bovera et al., 2014).

It should be mentioned that hens in A, B, C and D groups were kept under similar common management and husbandry practice for laying hens under commercial table egg production.

Increasing broken eggs percentage can be detrimental to selling and consumption. This can result in increased microbial contamination of eggs after harvest (Zhang et al., 2011) and was found to be positively affected by egg weight (r=0.129, P=0.005), showing that bigger eggs are more likely to be broken during handling and transportation than small ones. In addition, eggshell quality is one of the critical factors affecting overall egg quality before and after harvest. The higher weight, broken eggs (%) and lower eggshell quality of eggs from source A could be attributed to older hens’ age of this group as the hens was on production for 18 months when eggs were collected from the market than that of the other groups 6-10 months in production. On the other hand, the values of eggshell quality criteria found herein are within the range of those retrieved by several authors (Kiiskinen and Helander, 1998; USDA, 2000; Ahmadi and Rahimi, 2011; Al-Harthi and El-Deek, 2011; Alsaffar et al., 2013). Differences in eggshell quality of laying hens could be expected due to concentrations of dietary calcium, phosphorus and vitamin D3, Mn, strain, age, husbandry and management of hens (Attia et al., 1994; Zita et al., 2009), water quality, dietary protein levels,

**Table 4. Nutrient contents of whole edible parts of different egg sources compared with the recommended daily allowance.**

| Parameters                           | Source of eggs | Statistical analyses | RDA/day |
|--------------------------------------|----------------|----------------------|---------|
|                                     | A              | B        | C       | D     | RSME | P       |         |
| Whole edible eggs, g/egg             |                |          |         |       |      |         |         |
| Dry matter                           | 14.35<sup>a</sup> | 13.13<sup>b</sup> | 12.82<sup>c</sup> | 15.00<sup>c</sup> | 0.202 | 0.001   | nr      |
| Crude protein                        | 8.64<sup>a</sup>  | 7.98<sup>b</sup>   | 7.60<sup>c</sup>  | 7.78<sup>c</sup>  | 0.118 | 0.001   | 56 g    |
| Ash                                  | 0.656<sup>a</sup> | 0.569<sup>b</sup> | 0.571<sup>c</sup> | 0.702<sup>c</sup> | 0.020 | 0.001   | nr      |
| Yolk lipid profile                   |                |          |         |       |      |         |         |
| Total lipid, g/egg                   | 7.02<sup>a</sup>  | 6.44<sup>b</sup>   | 6.40<sup>b</sup>  | 6.63<sup>c</sup>  | 0.149 | 0.001   | 30-31 g |
| Triglycerides, g/egg                 | 3.193<sup>a</sup> | 2.957<sup>b</sup> | 2.696<sup>c</sup> | 2.846<sup>c</sup> | 3.06  | 0.006   | nr      |
| Cholesterol, mg/egg                  | 295.5<sup>a</sup> | 270.1<sup>b</sup> | 256.1<sup>a</sup> | 195.7<sup>b</sup> | 3.34  | 0.001   | 300 mg  |
| LDL, mg/egg                          | 159.7<sup>a</sup> | 157.4<sup>b</sup> | 145.6<sup>a</sup> | 136.1<sup>b</sup> | 6.81  | 0.002   | nr      |
| HDL, mg/egg                          | 70.39<sup>b</sup> | 68.77<sup>b</sup> | 60.33<sup>b</sup> | 89.94<sup>a</sup> | 2.24  | 0.001   | nr      |
| HDL/LDL ratio                        | 0.441<sup>b</sup> | 0.437<sup>b</sup> | 0.414<sup>b</sup> | 0.661<sup>b</sup> | 0.0543| 0.001   | nr      |
| Antioxidant and lipid per oxidation biomarker |         |          |         |       |      |         |         |
| Total antioxidants capacity, µmol/L  | 407.6<sup>a</sup> | 407.1<sup>b</sup> | 412.4<sup>a</sup> | 412.2<sup>a</sup> | 4.79  | 0.033   | nr      |
| Malondialdehyde, µmol/L              | 10.78<sup>a</sup> | 9.89<sup>b</sup>   | 10.33<sup>b</sup> | 10.44<sup>b</sup> | 1.24  | 0.516   | nr      |
| Malonaldehyde, µmol/L                | 0.600<sup>b</sup> | 0.789<sup>b</sup> | 0.889<sup>b</sup> | 0.644<sup>b</sup> | 0.634 | 0.020   | nr      |

RMSE, root mean square error; RDA, recommended daily allowance, 2002/2005; nr, not reported; LDL, low density lipoprotein; HDL, high density lipoprotein. *Different letters in the same column denote significant differences (P<0.05).

**Table 5. Minerals of whole edible parts of different egg sources compared with the recommended daily allowance.**

| Parameters | Source of eggs | Statistical analyses | RDA/day |
|------------|----------------|----------------------|---------|
|            | A              | B        | C       | D     | RSME | P       |         |
| Ca         | 33.9<sup>a</sup> | 31.5<sup>b</sup> | 29.6<sup>c</sup> | 32.0<sup>d</sup> | 0.847 | 0.001   | 1000 mg |
| P 110.1a   | 92.6<sup>a</sup> | 93.6<sup>b</sup> | 103.5<sup>c</sup> | 6.40  | 0.002 | 700 mg  |
| Zn         | 0.573<sup>a</sup> | 0.403<sup>b</sup> | 0.449<sup>c</sup> | 0.488<sup>c</sup> | 0.024 | 0.001   | 11 mg   |
| Mn         | 0.004<sup>a</sup> | 0.000<sup>b</sup> | 0.004<sup>c</sup> | 0.002<sup>a</sup> | 0.002 | 0.006   | 2.3 mg  |
| Mg         | 0.51<sup>b</sup> | 4.46<sup>a</sup>   | 4.48<sup>a</sup>  | 3.90<sup>b</sup>  | 0.406 | 0.001   | 400 mg  |
| K 94.0     | 83.1           | 81.1     | 81.8    | 14.2  | 0.438 | 4.7 g   |
| Fe         | 0.691<sup>b</sup> | 0.795<sup>c</sup> | 0.478<sup>b</sup> | 0.591<sup>c</sup> | 0.060 | 0.001   | 8 mg    |
| Cu         | 0.034<sup>a</sup> | 0.039<sup>b</sup> | 0.014<sup>b</sup> | 0.020<sup>b</sup> | 0.014 | 0.039   | 0.9 mg  |
| Na         | 109.9<sup>a</sup> | 99.7<sup>b</sup> | 97.1<sup>c</sup>  | 104.9<sup>b</sup> | 4.46  | 0.002   | 1.5 g   |

RMSE, root mean square error; RDA, recommended daily allowance, 2002/2005; Ca, calcium; P, phosphorus; Zn, zinc; Mn, manganese; Mg, magnesium; K, potassium; Fe, iron; Cu, copper; Na, sodium. *Different letters in the same column denote significant differences (P<0.05).
fat/fatty acid contents, health status and environmental stress of layers (Attia et al., 2009; Ahmadi and Rahimi, 2011; Alsaffar et al., 2013). Minerals such as Ca, P and vitamin D are the primary factors affecting eggshell quality of layers (Attia et al., 1994, 2009). Even hens were fed commercial layer diets which expected to meet dietary nutrient requirements of laying hens according to guide of each strain and layers had similar genetic makeup (white eggshell layers which had White leghorn blood), variability in eggshell quality e.g. SWUSA reached 11.1%, showing the potential of improving eggshell quality through uniform of production condition and husbandry practice.

On the other hand, correlation between egg weight and eggshell quality (shell weight; shell percentage and SWUSA) was (r=0.561; P=0.0001; r=0.565, P=0.0001, r=-0.282, P=0.0001, respectively), which is moderate to low depends on the eggshell quality criteria. The correlation between eggshell quality traits (shell weight and shell percentage, shell thickness and SWUSA) was significant (r=0.356, 0.380 and 0.631, P=0.0001, respectively), and ranged from moderate to high, indicated that one of these criteria is adequate principally those of high r value.

Interior egg quality reflects the quality of eggs before and after harvesting with colour and firmness of yolk and albumen, which had a significant influence on consumer desire. Difference among various egg sources in albumen percentage (3.02%), Haugh unit (35.80%), yolk percentage (9.1%), yolk index (15.30%) and yolk colour (72.8) was high. Lower albumen quality (%) and (%), albumen height and Haugh unit score) of eggs of A source could be attributed particularly to older age of hens, strain, husbandry and management of hens (Zita et al., 2009), water quality, contents of dietary crude protein/amino acids, health status of layers, environmental stress, condition and length of storage of eggs (Ahmadi and Rahimi, 2011; Al-Harthi and El-Deek, 2011; Khan et al., 2013). This suggests the importance of quality control during marketing and the potential of improving these traits by manipulating husbandry and storage condition.

The value of Haugh Unit score practically for source D was in agreement with what was cited by (USDA, 2000; Alsaffar et al., 2013). In addition, a portion of the differences in albumen quality could be explained by the effect of egg weight on albumen weight (r=0.912, P=0.0001), albumen percentage (r=0.238, P=0.0001), albumen height (r=0.128, P=0.006) and Haugh unit score (r=-0.192, P=0.0001). Furthermore, the correlation between albumen height and Haugh unit score was high and positive (r=0.878, P=0.0001), showing that one of them is adequate for prediction of albumen quality. It should be mentioned, however, that correlation analyses between time of egg collections and egg quality indicated a significant negative correlation between duration of collection and egg quality traits such as shell percent, shell thickness, SWUSA, yolk colour, albumen height and Haugh unit score.

Due to differences in egg weight among various sources, nutrient contents of eggs were expressed per egg rather than percentage as hens deposited nutrients as a sum in egg. The results indicated that protein and lipid of the whole edible eggs can fulfill about 14 and 22% of RDA for adults of protein and lipids with the yolk is the significant source of lipids and cholesterol. Difference in nutrient contents of eggs was obvious in dry matter (14.5%), protein (12%), lipid (8.8%) and ash (18.9%). Difference in nutrient contents of eggs could be explained in part by the influence of absolute weight and chemical composition of eggs.

Yolk index increased with increasing egg weight, age of hens, storage time and poor storage condition. Increasing yolk index reflected undesirable changes in interior egg quality due to increase in permeability of vitelline membrane for water from albumen to yolk (Attia et al., 1994; Alsaffar et al., 2013). Egg weight had a negative effect on yolk colour (r=-0.336, P=0.0001). This negative correlation could be attributed to spread in the amount of pigmentation (lutein and zeaxanthin) over the surface area of yolk which increased with increasing egg weight and age of hens. Differences in yolk colour could be expected practically due to dietary pigmentation such as zeaxanthin and lutein, and age of hens (Attia et al., 1994; Ahmadi and Rahimi, 2011; Al-Harthi and El-Deek, 2011; Alsaffar et al., 2013).

Differences among different egg sources in mineral contents of eggs reflected the nutrition and health status of laying hens. For example, Ca, P, Zn, Mn, Mg, Fe, Cu and Na contents were affected by source of eggs and differences were 12.7, 15.9, 29.5, 100, 25.1, 39.9, 64.1, 11.6%, respectively. On the other hand, difference observed in Ca (6.6%), Mn (100%), and Zn (34.6%) content of the eggs was little to big depending on the element. The mineral of the whole edible parts of eggs was found to fulfill 3.2, 14.3, 4.3, 0.11, 1.1, 8.0, 3.0, 1.8 and 21% of the RDA for Ca, P, Zn, Mn, Mg, Fe, Cu, K, and Na, respectively. The mineral contents of eggs found herein were in line with those reported by Hashish (2012) and Roe et al. (2013). This suggested that minerals with high variability could be enriched particularly those with health implications such as Zn, Cr and Fe (Vila, 1999). Differences in mineral contents of eggs could be attributed to dietary mineral contents and sources, husbandry systems (floor vs cages) (Giannenas et al., 2009; Attia et al., 2010), feed additives (Bäckermann and Ternes, 2008), organic and conventional rearing system (Kucukyilmaz et al., 2012) and different geographic area (Hashish et al., 2012).

**Conclusions**

Variability in egg quality in the retail market was found to be of considerable importance for different quality parameters and nutritional profiles and thus had a considerable effect on fulfilling RDA for humans, and the potential for
improving quality of eggs and their nutritional value. This suggested that eggs’ consumers can improve their intake of the nutrition by being more selective when shopping. Also, such diversity indicates the need for uniform production and husbandry practice, the enforcement of quality control regulations and new quality control aspects based on internal egg quality, e.g. Haugh unit and nutrient profiles, by the authorities in the market, and the influence this may have on the health of the consumer.

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