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External and Internal Quality Characteristics of Eggs Sourced in Supermarkets, General Dealers, and Vendors in Gaborone, Botswana

John Cassius Moreki *, Boineelo Katie Motiki, Shame Bhawa, and Freddy Manyeula

Department of Animal Science, Faculty of Animal and Veterinary Sciences, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana

*Corresponding author's E-mail: jmoreki@buan.ac.bw

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ABSTRACT

Egg quality characteristics influence consumer acceptance and preference of one egg over another. Several factors that impact egg quality include storage before and after dispatch, rearing conditions, temperature, handling, diseases, and the age of the eggs. The present study evaluated internal and external quality traits of eggs sourced from supermarkets, general dealers, and vendors in Gaborone, Botswana. One hundred and twenty eggs (24 eggs per location) were sourced from four supermarkets, seven general dealers, and 10 vendors in Gaborone. Parameters measured were egg weight (g), length (mm), width (mm), average shell thickness (mm), shell weight (g), surface area (cm^2), volume (cm^3), shape index, Haugh unit (HU), and shell weight per unit surface area (SWUSA, mg/cm^2) of the eggs. The current results indicated that egg weight and surface area were the highest for eggs sourced from supermarkets. Heavier eggs correlated with better HU scores, indicating richer and denser yolk, while surface area plays a role in moisture loss and potential shell strength. Eggs purchased from supermarkets and general dealers had noticeably greater egg weights, egg volumes, shell percentages, and SWUSA. Eggs from supermarkets had the greatest egg content weight, whereas those purchased from vendors had the lowest. The HU was highest for supermarket eggs compared to other egg sources. It was observed that eggs bought from supermarkets had superior internal and external quality traits compared to those from general dealers and vendors. It was concluded that eggs from vendors had lower quality due to inadequate storage and cooling facilities compared to supermarkets and general dealers.

Keywords: External quality, Haugh unit, Internal quality, Supermarket, Vendor

INTRODUCTION

The functional properties of eggs are intriguing, and nutritionally fortified eggs, also referred to as nutrition-enriched or functional eggs, are one of the products that have experienced phenomenal growth worldwide in recent years (Mesías et al., 2011). Functional foods increase the quality of the human diet, lower the risk of developing certain chronic illnesses, and effectively and affordably promote public health, all of which support current health efforts (Tian et al., 2022). The demand for functional foods has increased over the years due to their ability to reduce the risk of certain diseases and address socio-demographic factors, such as the rise in life expectancy. The rising demand for functional foods among health-conscious consumers has motivated an innovation in the production of omega-3 eggs (Miranda et al., 2015).

When presented with new products that lack sufficient evidence to support their purchasing decisions, consumers typically adopt a conservative, risk-averse stance, although they are sensitive to new information regarding such products (McFadden and Huffman, 2017). Information is crucial in influencing how consumers perceive innovative products, as it raises awareness, disseminates knowledge, and shapes or alters a person's pre-existing attitude and ways of thinking (Rondoni et al., 2020).

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Over the past few decades, the egg industry has faced several challenges that have impacted the financial viability of eggs. Increased animal breeding and husbandry practices are raising societal concerns, as they are perceived to compromise animal well-being (Malone and Lusk, 2016; Montossi et al., 2018). For instance, most eggs produced globally come from cage-based systems, which present significant animal welfare concerns as hens are confined to facilities with little room to move around (Buller and Roe, 2014). Consumer preferences and real egg consumption are impacted by the growing number of human health conditions linked to the nutritional components of eggs, such as allergies (Loh and Tang, 2018) and excessive cholesterol (Zhu et al., 2018).

Consequently, the egg industry has responded to the critical issues and challenges, as well as the complex and growing consumer demand for sustainable and healthy food products (Grunert et al., 2014). These responses include among others bringing a wide range of new eggs to the market that differ in intrinsic and extrinsic attributes, such as organic, free-range, enriched eggs (Barnkob et al., 2020), and to create new ways to improve animal welfare criterion in egg farms, such as eliminating the practice of beak trimming (Hester and Shea-Moore, 2005) or avoiding male culling by employing the novel dual-purpose poultry system (Krautwald-Junghanns et al., 2018). Heng et al. (2013) reported that consumer polls indicated that environmental concerns are less important than animal welfare issues. Some studies have suggested a desire for more natural and animal-friendly egg production methods (Texeira et al., 2018).

Egg external and internal quality characteristics influence consumer behavior, such as the acceptance and preference for one egg over another (Venkatesh et al., 2019). Egg quality characteristics are crucial for the egg industry, as they influence grading, price, hatchability, chick weight, and consumer preferences, all of which are affected by the configuration of eggs (Kumar et al., 2022). Indicators of the exterior quality of eggs include egg size, shell color, breaking strength, shell deformation, shell weight, shell percentage, shell thickness, and ultrastructure (Roberts, 2004). Recently, Silva Neto et al. (2024) reported that the most used conventional parameters to evaluate egg quality include the Haugh unit (HU), the yolk color index, yolk and albumen ratios, and shell thickness and resistance. Several factors influence egg quality, including storage before and after dispatch, rearing conditions, temperature, handling, diseases, and egg age. Additionally, egg quality may be influenced by factors such as the hen's age, breed, induced molting, production system, nutritional status, and stressors, including heat stress. Other factors that influence egg quality are genetics, lighting, medications, diseases, and management practices (Ahmadi and Rahimi, 2011).

Storage conditions and ambient temperature can affect egg quality. Tabidi (2011) recommended that eggs can be preserved by refrigeration for a maximum of 30 days or storage at room temperature for no more than 15 days. According to the FAO (2003), the ideal temperature for storing eggs in the tropics is 13°C or lower, typically between 10°C and 13°C. Information about egg quality from different market segments in Botswana has not been documented. Egg quality challenges are common in summer due to elevated temperatures, which cause egg spoilage. Therefore, the present study evaluated the internal and external quality characteristics of eggs sourced from supermarkets, general dealers, and vendors in Gaborone, the capital city of Botswana, to ascertain if there was variation in egg quality from these egg segments.

MATERIALS AND METHODS

Ethical approval

No ethical approval was required as no animals were used in the experiment.

Study area

The study was conducted at the Meat Science Laboratory of the Department of Animal Science, Botswana University of Agriculture and Natural Resources (BUAN), Gaborone, Botswana. A total of 120 eggs (24 eggs per location) were purchased from vendors, general dealers, and supermarkets at five sites in Gaborone from January to February 2024 (two months). After purchase, eggs were stored at room temperature overnight, and measurements were performed the following day. Thereafter, eggs were individually evaluated using non-destructive and destructive methods.

Sample preparation

A total of 120 eggs were purchased from supermarkets, general dealers, and vendors in Gaborone (Table 1) and assessed for egg quality traits in the Meat Science Laboratory at BUAN. After purchase, eggs were stored at room temperature overnight until measurements including egg weight (g), shell thickness (mm), egg width (mm), egg length, egg contents weight (g), shell percentage and egg surface area (cm^2), egg volume (cm^3), egg shape index (%), shell weight per unit surface area (SWUSA, mg/cm²), and HU were performed the following day.

Table 1. The number of supermarkets, retailers, and vendors in Gaborone, Botswana, from which eggs were purchased

Category	Number
Supermarket	4
General Dealers	7
Vendors	10
Total	21

Data collection

External egg quality traits

Eggs were individually weighed using Adam's electronic scale sensitive to 0.01 g (Adam scale Pty Ltd, Gaborone, Botswana), and their weights were recorded. Thereafter, individual egg weights were combined, and the means computed. Egg length (mm) and width (mm) were measured using an electronic digital Vernier Caliper (Ingco, South Africa), sensitive to 0.01 mm. These measurements were used to calculate the egg shape index (ESI) and the egg volume (cm³). The ESI was estimated using the following equation.

ESI = egg width/egg length × 100 (Gwaza and Elkanah, 2017; Alkan, 2023).

Egg volume (EV) was calculated using Formula 1.

$EV = 0.51 \times L \times B^2$. (Formula 1)

L is the egg length, and b is the breadth (width) of the egg (Hoyt, 1979).

Internal egg quality traits

After measuring the external characteristics of each egg, the eggs were carefully broken individually using a scalpel to allow the passage of the albumen and the yolk without mixing their contents. Thereafter, the Vernier callipers and an electronic scale sensitive to 0.01 mm were used to determine shell thickness (mm) and weight (g) with intact membranes (Monira et al., 2003). The egg yolk and albumen were carefully separated and placed in separate Petri dishes and then individually weighed. After weighing each parameter, the Petri dishes were washed with clean water and wiped dry with a paper towel before the subsequent weighings.

The yolk diameter and height, albumen height and albumen diameter were measured using electronic callipers sensitive to 0.001 mm (Reddy et al., 1979). The yolk ratio, albumen ratio, and eggshell ratio were expressed as yolk weight/egg weight × 100, albumen weight/egg weight × 100, and eggshell weight /egg weight × 100, respectively (Yang and Luu, 2009; Alkan, 2023). Haugh unit was calculated using Formula 2.

HU = 100 log (H + 7.57-1.7W0.37) (Formula 2)

where H means albumen height (mm) while W means egg weight in grams (Altan et al., 1998).

Eggshells were washed under gentle running water to remove adhering albumen (Kul and Seker, 2004) and wiped with a paper towel to remove excessive moisture. Thereafter, shell thickness was measured using Vernier callipers sensitive to 0.01 mm (Carter, 1975). Two measurements from each of three regions (i.e., sharp end, equator, and broad/blunt end) were averaged to give three eggshell thickness values (Ehtesham and Chowdhury, 2002). The shell weight (mm) with intact membranes was carefully obtained and weighed using an electronic scale. The egg content weight (ECW) was obtained by subtracting the eggshell weight from the egg weight (Moreki, 2005; Phitsane, 2006). The egg surface area (cm^2) of each egg was calculated using the formula $3.9782W^{0.7056}$, where W is the egg weight in grams (Carter, 1975).

Statistical analysis

Data collected for the egg quality traits were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedures of SAS (version 9.2) (SAS, 2008). Duncan's multiple range test was used to test significant differences among the means.

RESULTS AND DISCUSSION

Data on egg quality characteristics (egg weight, shell percentage, shell thickness, ECW, egg volume, HU, albumen ratio, yolk ratio, ESI, ESA, and SWUSA) from supermarkets, general dealers, and vendors are presented in Table 2. The egg quality traits of supermarkets, general dealers, and vendors differed significantly ($p < 0.05$). Egg weight significantly differed ($p < 0.05$) among egg sources or marketing outlets (Table 2). Eggs from supermarkets were heavier ($p < 0.05$) than those from other sources, with vendors' eggs being lighter. The weight of eggs from supermarkets, general dealers, and vendors was 61.58 ± 0.70 g, 59.51 ± 0.54 g, and 56.97 ± 0.44 g, respectively.

Table 2. A comparison of least squares means and standard errors of egg quality traits from three retail levels in Gaborone, Botswana

Egg quality trait	Supermarket	General dealer	Vendors	P-value
Egg weight (g)	61.58 ± 0.70[a]	59.51 ± 0.54[b]	56.97 ± 0.44[c]	< 0.05
Egg shape index (%)	74.00 ± 1.18[b]	76.30 ± 0.90[a]	73.55 ± 0.75[b]	< 0.05
Shell weight (g)	8.33 ± 0.35[a]	8.00 ± 0.27[a]	5.96 ± 0.22[b]	< 0.05
AST (mm)	1.68 ± 0.59[b]	1.79 ± 0.45[a]	1.22 ± 0.37[c]	< 0.05
SHPCT (%)	13.51 ± 0.68[a]	13.48 ± 0.52[a]	10.64 ± 0.43[b]	< 0.05
Egg content weight (g)	53.25 ± 0.87[a]	51.51 ± 0.67[ab]	51.00 ± 0.55[b]	< 0.05
Egg volume (cm^3)	1060.05 ± 18.95[a]	1090.25 ± 14.50[a]	969.48 ± 11.99[b]	< 0.05
ESA (cm^2)	72.83 ± 0.60[a]	71.08 ± 0.46[b]	68.89 ± 0.38[c]	< 0.05
SWUSA (mg/cm^2)	114.30 ± 5.4[a]	112.75 ± 4.19[a]	87.50 ± 3.46[b]	< 0.05
Haugh unit	85.90 ± 1.37[a]	77.94 ± 1.16[b]	74.52 ± 0.96[b]	< 0.05
Albumen ratio (%)	56.10 ± 1.05[b]	53.60- ± 0.06[a]	51.79 ± 1.86[ab]	< 0.05
Yolk ratio (%)	32.33 ± 1.42[b]	34.20 ± 1.09[b]	41.02 ± 0.90[a]	< 0.05

[abc]Means that within a row that do not share common superscript letters differ significantly ($p < 0.05$). The ESA: Egg surface area, SHPCT: Shell percentage, SWUSA: Shell weight per unit surface area, AST: Average shell thickness.

Table 2 demonstrated that vendors had lower ($p < 0.05$) egg weights, probably due to moisture loss during storage and transportation to the market, resulting from a lack of a cold chain. The current results were not in line with those of Brito et al. (2020), who reported that open street market eggs had a higher egg weight ($p < 0.05$, 60.48 g) and the lowest shell percentage (9.23%) compared to supermarket eggs. The differences in egg weights might be related to the genetic make-up of the hens, age, management practices, and poor storage conditions (Vlčková et al., 2019). The current findings did not align with those of Tebesi et al. (2012), who observed an average egg weight of 42.03 g due to prolonged storage time. Previous studies by Brake et al. (1997) and Jones and Musgrove (2005) reported that prolonged storage of eggs led to decreases in egg weight. Tůmová et al. (2016) evaluated the interactions in performance and eggshell quality of Lohmann (LSL) and a traditional breed (the Czech hen), housed in conventional cages and reared on litter, and fed two levels of dietary calcium (3.5% *vs.* 3.0%). The authors found that an increase in dietary Ca resulted in an increase in egg weight in Czech hens housed in cages and LSL hens housed on the floor. Increased calcium intake leads to an increase in egg weight, shell thickness, and ESA. On the contrary, Roland and Bruant (1994) and An et al. (2016) found that dietary calcium had no significant effect on egg weight.

The ESI for the general dealers statistically differed ($p < 0.05$) from that of supermarkets and vendors. However, ESI for supermarkets and vendors was similar. Contrary to the present results, Venkatesh et al. (2019) indicated no significant ($p > 0.05$) differences in the ESI of eggs from wholesale, retailers, and interior vendors. Jayasena et al. (2012) assessed egg quality traits from the wholesale market in Sri Lanka and obtained an average ESI of 75.03, indicating that eggs had a normal shape. According to Duman et al. (2016), eggs with ESIs of <72, 72-76, and >76 are sharp, normal, and round, respectively. For Alkan (2023), the ESI of a standard egg ranges between 72 and 76, with an average of 74. The present results indicated that the eggs from wholesale, retailers, and interior vendors had similar normal shapes (ESI = 72-76).

The shell weight of eggs from supermarkets and general dealers was heavier ($p < 0.05$) than that of vendors. However, the shell weight for eggs sourced from supermarkets and general dealers was not significantly different ($p > 0.05$) from one another. The lower shell weight observed in vendors' eggs correlated with the smaller eggs sold in this market segment. The current result disagreed with Hussain et al. (2013), who indicated that the shell weight of indigenous chicken eggs was five to six grams. Farhad and Fariba (2011) observed that eggshell quality decreases as the hen ages, due to increased egg weight without a corresponding increase in calcium carbonate deposition on the shell. Shell thickness was statistically affected ($p < 0.05$) by egg sources. The shell thickness values for eggs from supermarkets, general dealers, and vendors were 1.68 ± 0.59 mm, 1.78 ± 0.45 mm, and 1.22 ± 0.37 mm, respectively. The present finding on shell thickness disagreed with Castilla et al. (2009), who reported eggshell thickness of 0.25 to 0.338 mm in the red-legged partridge. The difference could be ascribed to the species difference. In agreement with the current results, Venkatesh et al. (2019) observed that the shell thickness values of chicken eggs obtained from interior vendors were significantly lower ($p < 0.05$) than those from grocery shops.

In this study, shell percentage for eggs sourced from supermarkets and general dealers was higher ($p < 0.05$) than that of vendors (Table 2). However, the shell percentage for supermarkets and general dealers' eggs was not statistically significant ($p > 0.05$). The shell percentage for vendors, supermarkets, and general dealers' eggs was 10.64 ± 0.43%, 13.51 ± 0.68%, and 13.48 ± 0.51%, respectively. The lower shell percentage for eggs from vendors suggests that eggs sold in this market segment originated from older hens or hens fed diets deficient in certain nutrients, such as calcium and phosphorus. Peebles and Brake (1987) and Mayeula et al. (2021) stated that shell percentage decreases with the increasing age of the hen. Furthermore, as hens age, the quality of their shells declines, becoming thinner, thus impacting the eggs' ability to withstand breaking. Bovera et al. (2014) posited that this decrease in shell quality happens due to an increase in egg weight with the hen's age, and the shell weight failing to keep up with this growth. Several factors contribute to thinner shells, including high temperatures, age, poor nutrition, high water salinity, and diseases. The present results indicated that eggs sourced from vendors had poor shell quality ($p < 0.05$).

Sources of eggs significantly affected ECW ($p < 0.05$). The ECW for the supermarkets was significantly higher ($p < 0.05$) than that of vendors. However, the ECW for supermarkets and general dealers was similar. The ECW for eggs obtained from the supermarket, general dealers, and vendors was 53.25 ± 0.8 g, 51.51 ± 0.67 g, and 51.00 ± 0.55 g, respectively. The present findings disagreed with the study of Hussain et al. (2013), who reported an average ECW of 47.9 g. The egg volume values for the supermarket, general dealer, and vendor eggs were 1060.05 ± 18.95 cm^3, 1090.25 ± 14.50 cm^3, and 969.48 ± 11.99 cm^3, respectively. A significantly lower ($p < 0.05$) egg volume was observed from the vendors, whereas the highest was observed from supermarkets and general dealer sources. However, the egg volume for supermarkets and general dealers was similar. These results suggest that supermarkets and general dealers sold larger eggs, while vendors sold smaller eggs, due to their limited financial resources. Sedghia and Ghaderi (2023) reported that egg volume is a more reliable predictor of egg size.

Egg surface area differed significantly ($p < 0.05$) between egg sources. The ESA mean values for supermarkets, general dealers, and vendors' eggs were 72.83 ± 0.60 cm^2, 71.08 ± 0.46 cm^2, and 68.89 ± 0.38 cm^2, respectively. The supermarket eggs had a higher ESA ($p < 0.05$) than those from general dealers and vendors. Eggs from vendors had lower ESA. The ESA values in this study were similar to those reported by Rodríguez et al. (2016), who found ESA values ranging from 64.23 cm^2 to 71.71 cm^2. The SWUSA differed significantly ($p < 0.05$) among egg sources. The SWUSA values for supermarkets, general dealers, and vendors were 114.30 ± 5.48 mg/cm^2, 112.75 ± 4.19 mg/cm^2, and 87.50 ± 3.4 mg/cm^2, respectively. However, the highest ($p < 0.05$) SWUSA was observed in eggs sourced from vendors, while the lowest was observed in eggs from supermarkets and general dealers. An increase in egg weight could have contributed to a decrease in SWUSA. According to Alsobayel and Albadry (2011), the storage period causes significant increases ($p < 0.05$) in SWUSA.

In the present study, HU significantly ($p < 0.05$) differed among marketing outlets. The HU values for eggs from supermarkets, general dealers, and vendors were 85.90, 77.94, and 74.52, respectively. The higher HU value (85.90) indicated that supermarket eggs had superior quality to general dealer and vendor eggs, while the lowest quality was observed in the eggs sold by the vendors. Leandro et al. (2005) also indicated a lower HU value (44.91) for eggs sold in open street markets. USDA (2020) stated that an HU of 72 or higher indicates superior egg quality, suggesting that the eggs in the three market outlets in this study had good quality. The lower HU value observed in the eggs from general dealers and the vendors could be due to eggs being exposed to long storage and unfavorable storage conditions, or a lack of a cold chain. Cağlayan et al. (2009) reported that HU declines with lengthened storage time. Similarly, Moreki et al. (2023) observed that the HU for ostrich eggs decreased with the prolonged storage time. The current result disagreed with Bell et al. (2001), who indicated that the albumen quality of the brown shell eggs ranged from 62.8 to 71.5 HU. The findings of the present study demonstrated that an increase in egg weight results in an increase in HU.

Albumen ratio differed significantly ($p < 0.05$) between egg sources. The albumen ratio for eggs from supermarkets, general dealers, and vendors was 56.10 ± 1.05%, 53.60 ± 0.86%, and 51.79 ± 1.37%, respectively. The supermarkets' eggs had significantly higher ($p < 0.05$) albumen ratios than the general dealers' eggs. However, eggs sourced from vendors did not differ significantly ($p > 0.05$) from those sourced from supermarkets and general dealers in terms of albumen ratio. These results suggested that eggs sourced from supermarkets had better quality.

The present results were consistent with those of Brito et al. (2020), who observed that supermarket-sold eggs had higher albumen percentage levels than those sold in grocery stores. Conversely, Leandro et al. (2005) found no noteworthy variations in the albumen percentage among any facilities they assessed. Higher albumen values for supermarket eggs in the present study might be due to improved storage conditions.

The yolk ratio differed significantly ($p < 0.05$) between egg sources. The yolk ratios for supermarkets, general dealers, and vendors were 32.33 ± 1.42, 34.20 ± 1.09, and 41.02 ± 0.90, respectively. Eggs sourced from vendors had the highest yolk ratio ($p < 0.05$) compared to those from general dealers and supermarkets. The yolk ratio of chicken eggs in the present study was slightly lower than that reported by Cağlayan et al. (2009) for partridge eggs, which ranged from 34.01 to 36.82. However, the current results were inconsistent with Kgwatalala et al. (2013), who reported an average yolk ratio of 44.94 in helmeted Guinea fowl. The difference in yolk ratio values could be attributed to the fact that guinea fowl eggs were used in the study by Kgwatalala et al. (2013), whereas the present study used chicken eggs. The present study had higher yolk and albumen ratios, indicating the freshness of eggs. A lower yolk ratio might be due to high ambient temperatures and egg shaking during transportation from the farm to the market, thus causing deterioration of yolk quality. King'ori (2012) stated that egg quality parameters significantly decrease in the summer due to exposure of eggs to high temperatures.

Factors such as storage and transport affect egg quality (FAO, 2003; Tan et al., 2023). In the present study, eggs from vendors were not refrigerated, whereas eggs from general dealers might have been refrigerated. Supermarket eggs were stored under refrigeration. Eggs might have been transported to supermarkets and general dealers using refrigerated trucks, whereas vendors might have been supplied by small-scale farmers who lack access to a cold chain. However, the large-scale poultry farmers might have supplied eggs to vendors.

CONCLUSION

Based on the Haugh unit values, the quality of eggs from supermarkets was higher than that from general dealers and vendors. Vendors had the lowest egg quality compared to other market segments. It is concluded that eggs from vendors had lower quality due to a lack of a cold chain. As the sample size in the present study was small, a more extensive study with a larger sample size of eggs, alongside additional factors such as specific gravity, albumen viscosity, yolk color, vitelline membrane strength, elasticity, and egg solids, is necessary to explore egg quality in these crucial market segment for furthur studies.

DECLARATIONS

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Authors' contributions

John Cassius Moreki conceived the idea and wrote the manuscript. Boineelo Katie Motiki collected and analysed data and also wrote the manuscript. Shame Bhawa and Freddy Manyeula helped with data interpretation and edited the manuscript. All authors checked and approved the last edition of the submitted article.

Competing interests

The authors declared that there are no competing interests.

Ethical considerations

All authors have examined ethical issues, including plagiarism, consent to publish, errors, data fabrication and/or deception, duplicate publication and/or submission, and redundancy.

Availability of data and materials

Data will be made available to the corresponding author upon request.

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