Aspects of the nutritional value of cooked Egyptian goose
\textit{(Alopochen aegyptiacus)} meat compared with other well-known fowl species

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ABSTRACT There is no scientific research regarding Egyptian goose (\textit{Alopochen aegyptiacus}) meat; therefore, a chemical analysis to establish the nutritional characteristics of the breast portion is described. Meat from guineafowl, Pekin duck, ostrich, and broiler chicken were used as a reference. The high intramuscular fat content of Egyptian goose meat (5.6 g/100 g) may be linked to the fact that this species relies on fat for heat insulation and buoyancy. Egyptian goose meat is very high in polyunsaturated fatty acids (39.7%). The polyunsaturated fatty acid/saturated fatty acid ratio is within the recommendations (>0.4), although the n-6/n-3 ratio is higher than the suggested value of 5. The high Fe content of 7.5 mg/100 g is the differentiating factor within the mineral compositions and is related to the physical activity endured by the breast muscle of Egyptian geese. This study provides new insight into the nutritional characteristics of a meat species providing crucial information that is, as of yet, not available in the literature.

Key words: gamebird, Egyptian goose, chemical composition, fatty acid, mineral

INTRODUCTION

Internationally, gamebird hunting has developed into a multimillion dollar industry that is particularly popular in places such as the United States and Europe (Viljoen, 2005). In South Africa, this is still an emerging industry, and in 2010, it was estimated that a quantity of 2 million gamebirds were shot annually (J. van Giessen, South African Wingshooting Association, Randburg, South Africa, personal communication). The gamebird hunting industry in South Africa is becoming more popular, and information on the nutritional composition of the breast portion is described. Meat from guineafowl, Pekin duck, ostrich, and broiler chicken were used as a reference. The high intramuscular fat content of Egyptian goose meat (5.6 g/100 g) may be linked to the fact that this species relies on fat for heat insulation and buoyancy. Egyptian goose meat is very high in polyunsaturated fatty acids (39.7%). The polyunsaturated fatty acid/saturated fatty acid ratio is within the recommendations (>0.4), although the n-6/n-3 ratio is higher than the suggested value of 5. The high Fe content of 7.5 mg/100 g is the differentiating factor within the mineral compositions and is related to the physical activity endured by the breast muscle of Egyptian geese. This study provides new insight into the nutritional characteristics of a meat species providing crucial information that is, as of yet, not available in the literature.

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To have a clear understanding of the benefits and shortcomings pertaining to the nutritional value of Egyptian goose meat, it is necessary to compare these characteristics with other familiar/popular fowl consumed in South Africa. Among the gamebirds hunted on a regular basis in South Africa, guineafowl (Numida meleagris) is a very popular, terrestrial gamebird species of which there is some available scientific literature regarding the meat quality (Thong, 2008; Hoffman and Thong, 2012). The meat of other domestic fowl species such as Pekin duck (Anas platyrhynchos domestica), ostrich (Struthio camelus), and broiler chicken are also consumed on a regular basis in South Africa. By means of this comparison, the positive and negative nutritional aspects of Egyptian goose meat will be evident.

Several factors determine the chemical profile of meat, and these factors are also responsible for the unique chemical characteristics that exist between meat from different species. Diet is one of the major influential factors, and variation in the dietary constituents between game and domestic species may result in a difference in the chemical composition, especially the fatty acid profile of the meat. The diet of Egyptian geese consists mainly of green plant material, small mammals, aquatic invertebrates, aquatic vegetation, and insects (Viljoen, 2005). Guineafowl forage on bulbs and stems of plants, grass seeds, harvested grains, and maize, as well as insects (Little and Crowe, 2011). Domestic species such as Pekin duck, ostrich, and broiler chicken are raised within a farming environment, and a standard commercial feed is often used for these species. Furthermore, when comparing game and domestic birds, the extent of physical exercise the different birds/species are subjected to will have a direct influence on the meat quality [i.e., the intermuscular fat (IMF) and Fe content], which is due to the difference in the constituents of muscles between active and inactive animals (Lawrie and Ledward, 2006).

Given that no scientific data are available on the meat quality of Egyptian geese, this study was conducted to quantify the nutritional value of the meat from this underutilized gamebird species. It also allows for critical evaluation of the nutritional composition because a comparison is made between Egyptian goose meat and that of other familiar game and domestic fowl. Furthermore, this research will provide valuable nutritional data for the food composition databases.

**MATERIALS AND METHODS**

**Sampling and Slaughtering**

The gamebirds Egyptian geese (Alopochen aegyptiacus) and guineafowl (Numida meleagris) were shot during August 2010 on Mariendahl Agricultural Experimental Farm, Western Cape, South Africa. A double-barreled shotgun was used during the wingshooting activities (ethical clearance number: 10NP_HOF01). The geese and guineafowl were collected in the field and placed in a refrigerator (4°C) overnight (±12 h), whereafter the slaughtering procedures were carried out manually. First, the head was removed at the base position, between the C1 and C2 vertebrae. Then both of the feet were removed at the ankle joint (intertarsal joint) together with the removal of the tip of each wing from the wrist region (carpal joint). Skinning involved the cutting from the neck to the tail region on the ventral side of the body, followed by the removal of the skin containing the feathers from the body. The fowl were then eviscerated by means of an incision in the abdominal muscles. The broiler chickens were slaughtered according to the commercial, standard procedures, which include immobilization by electrical stunning (50–70 V; 3–5 s), followed by exsanguination, defeathering, and evisceration (DAFF, 2006). The breasts (M. pectoralis) were removed from the respective bird carcasses, and the meat was vacuum-packed in a polystyrene bag and frozen at −18°C for approximately 6 wk. The Pekin duck breasts, ostrich fan fillets (M. iliofibularis), and moon steaks (M. femorotibialis) were derived from different birds, sourced from commercial producers, was frozen immediately after deboning at −18°C for 6 wk.

**Experimental Units**

The experimental layout is indicated in Table 1. The experimental units were the following; the breast portion of Egyptian geese, guineafowl, Pekin duck, and broiler chicken together with ostrich fan fillet (M. iliofibularis) and ostrich moon steak (M. femorotibialis). There were thus 6 meat treatments (5 species with the ostrich having 2 different muscles sampled) with 6 samples per treatment. The meat samples used were cooked in preheated (160°C) conventional ovens (model 835, Defy, Durban, South Africa) connected to a computerized monitoring system for temperature regulation (Viljoen et al., 2001). The samples were removed when a core temperature of 75°C were reached and left to acclimatize to room temperature (21°C). The chemical analyses were performed on the cooked left breasts (M. pectoralis) of the different bird carcasses. A strip was removed down the center of the cooked ostrich fan fillet (M. iliofibularis) and moon steak (M. femorotibialis) samples that were used for the chemical analyses.

**Chemical Analysis**

**Sample Preparation.** After the 6 meat treatments (6 replications/birds per treatment) were cooked, each sample was homogenized, vacuum sealed, and placed in a −18°C freezer for 4 wk until the chemical analyses were performed. The samples were thawed at 4°C for 12 h before each analysis. All of the analyses were performed in duplicate.

**Proximate Analyses.** The moisture content (%) was determined by using a 2.5-g homogenized cooked meat sample according to the AOAC standard techniques (AOAC International, 2002a) method 934.01.
The ash content (%) of the moisture-free sample was determined by the official AOAC International (2002b) method 942.05. The chloroform/methanol (1:2 vol/vol) extraction method stipulated by Lee et al. (1996) was used to determine the total lipids (%) of a 5-g homogenized cooked meat sample. To establish the total CP content (%), the Dumas combustion method 992.15 (AOAC International, 2002c) was applied. A 0.15-g defatted, dried, and finely grounded meat sample was analyzed using a Leco Nitrogen/Protein Analyzer (FP−528, Leco Corporation, St. Joseph, MI). The Leco was calibrated with EDTA samples (Leco Corporation) before each of the analysis sessions. The results were expressed in % nitrogen. The nitrogen was multiplied with a conversion factor (6.25) to determine the CP (%) present in the meat sample. All samples were analyzed in duplicate and the mean value was used for the statistical analyses. The accuracy of all the proximate analyses in the laboratory were verified by a National interlaboratory scheme (AgriLASA: Agricultural Laboratory Association of South Africa) where blind samples are analyzed once every 3 mo to control and ensure the accuracy and repeatability of the procedures used.

**Fatty Acid Analysis.** The fatty acid profile was determined after the homogenized cooked meat samples were defrosted. A 2-g sample was extracted by the use of a chloroform:methanol (2:1 vol/vol) solution according to the method described by Folch et al. (1957). The solvents used for extraction contained 0.01% butylated hydroxytoluene, which functioned as an antioxidant. The meat sample together with the extraction solvent was homogenized by means of a polytron mixer (WiggenHauser Homogenizer, D-500 fitted with a standard shaft 1; speed setting D). To quantify the individual fatty acids present within the meat sample, heptadecanoic acid (C17:0) was used as an internal standard (catalog number H3500, Sigma-Aldrich Inc., St. Louis, MO). A 250-μL subsample of the extracted lipids was transmethylated for 2 h at 70°C, and a methanol/sulfuric acid (19:1; vol/vol) solution (2 mL) was used as the transmethylating agent. The mixture was cooled to room temperature followed by the extraction of the fatty acid methyl esters (FAME) with water and hexane by transferal of the top hexane phase to a spotting tube and then drying it under nitrogen. Hexane (50 μL) was then added to the dried FAME sample, after which 1 μL was injected into the gas chromatograph. The FAME was determined with a Thermo Finnigan Focus gas-chromatograph (Thermo-Electron Corporation, Rodano, Milan, Italy) equipped with a flame-ionized detector and a 60-m BPX70 capillary column (internal diameter of 0.25 mm, 0.25 μm film, SGE International, Ringwood, Victoria, Australia). The gas flow rate of the carrier, hydrogen, was 30 mL/min. The following temperature settings where applied: initial temperature of 60°C, injector and detector 220°C, respectively, and a final temperature of 160°C. The GC injection volume was 1 μL with a run time of approximately 45 min. By comparing the FAME of the meat samples with a standard FAME mixture (Supelco, 37 Component FAME mix C4-C24, cat. no. 47885-U, Supelco, Bellefonte, PA), the FAME levels were identified. The results were recorded as a percentage of the total fatty acids.

**Mineral Analysis.** The minerals analyzed were Ca, K, Mg, Na, Fe, Cu, Zn, Mn, P, B, and Al. The mineral content of a 0.5 g defatted, dried, and finely ground meat sample was determined. Ashing of the sample occurred at 460 to 480°C for 6 h, followed by the cooling of the sample and addition of 5 mL of 6 M HCl. The sample was placed in an oven (50°C) for 30 min; afterward, 35 mL of distilled water was added, the solution was filtered, and distilled water was added to obtain a final volume of 50 mL (AGRILASA, 2007). An iCAP 6000 Series Inductive Coupled Plasma spectrophotometer (Thermo-Electron Corporation, Rodano, Milan, Italy) fitted with a vertical quartz torch and Cetac ASX-520 auto sampler was used to measure the elements. The concentrations of the elements were calculated by means of iTEVA Analyst software (Thermo-Electron Corporation, Rodano, Milan, Italy). The argon gas flow rate was 2 to 5 mL/min and the settings for the instrument included the following: camera temperature −27°C, generator temperature 24°C, optics temperature 38°C, radio frequency power 1,150 W, pump rate 50 rpm, auxiliary gas flow 0.5 L/min, nebulizer 0.7 L/min, coolant gas 12 L/min, and normal purge gas flow. The wavelengths for the elements were the following: Al, 167.079 nm; B, 249.773 nm; Ca, 317.933 nm; Cu, 324.754 nm; Fe, 259.940 nm; K, 766.490 nm; Mg, 285.213 nm; Mn, 257.610 nm; Na, 589.592 nm; P, 177.495 nm; and Zn, 213.856 nm. The minerals were recorded as mg/100 g of dry meat sample. After the analysis of 11 samples, standards of high, medium, and low range were analyzed for quality control.

**Statistical Analysis**

Experimentally the study consisted of a randomized block design with 6 meat treatments and 6 replications per treatment. The chemical data were subjected to an ANOVA. The Shapiro-Wilk test was performed to test for normality (Shapiro and Wilk, 1965). All of the outliers were identified and removed before final analysis of the ANOVA. The t-least significant differences were

<table>
<thead>
<tr>
<th>Table 1. Sample set and experimental units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat treatment</td>
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<tr>
<td>----------------</td>
</tr>
<tr>
<td>Egyptian goose</td>
</tr>
<tr>
<td>Guinea fowl</td>
</tr>
<tr>
<td>Pekin duck</td>
</tr>
<tr>
<td>Ostrich</td>
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<tr>
<td>Ostrich</td>
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<tr>
<td>Broiler chicken</td>
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</table>

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calculated at a 5% significance level to compare the treatment means. Results were defined as being not significant at $P > 0.05$ and significant at $P \leq 0.05$. The SAS statistical software (2006, version 9.2, SAS Institute Inc., Cary, NC) was used for the ANOVA.

## RESULTS

### Proximate Composition

The results of the proximate analysis (Table 2) on the cooked meat samples indicate that broiler chicken and guineafowl were the species with the highest moisture content (65.7 and 64.5 g/100 g, respectively). The moisture content of ostrich fan fillet and moon steak did not differ ($P > 0.05$) from guineafowl or Egyptian goose. The treatments with the lowest moisture contents were Pekin duck and Egyptian goose with mean values of 61.8 and 62.2 g/100 g for moisture, respectively.

In terms of protein content, ostrich fan fillet had the highest value (32.7 g/100 g). It was higher ($P \leq 0.05$) than that of Egyptian goose and broiler chicken with the latter having the lowest protein content. Guineafowl, ostrich moon steak, and Pekin duck both had average protein contents that did not differ ($P > 0.05$) from ostrich fan fillet or Egyptian goose.

Egyptian goose (5.9 g/100 g) and Pekin duck (5.8 g/100 g) were higher ($P \leq 0.05$) in intramuscular fat content compared with the other treatments. Ostrich fan fillet and moon steak, broiler chicken, and guineafowl had IMF contents that were more than 2 g/100 g lower ($P \leq 0.05$) than that of Egyptian goose and Pekin duck. These 4 treatments did not differ ($P > 0.05$) from each other.

The different species did not differ ($P > 0.05$) in the amount of ash (g/100 g) present in their cooked muscle.

### Fatty Acid Composition

The fatty acid composition of different species differs. The mean scores $\pm$ SD for the fatty acid composition of the 6 cooked meat treatments are presented in Table 3. The fatty acid composition is expressed as a percentage of the total identified fatty acids present. Although all of the fatty acids are presented in the table, only specific fatty acids will be discussed.

Considering the overall saturated fatty acid (SFA) content of the species; ostrich moon steak (45.9%), ostrich fan fillet (43.9%) and guineafowl (43.6%) were significantly higher ($P \leq 0.05$) in SFA compared with the other species except for Pekin duck. Egyptian goose and broiler chicken differed ($P \leq 0.05$) from each other in terms of SFA with broiler chicken having the lowest content (33.3%). It is noticeable that individual SFA differed between the species (Table 3). Palmitic acid (C16:0) was the major SFA in all the species with the Pekin duck, ostrich fan fillet, ostrich moon steak, and guineafowl having the highest concentration, although they did not differ ($P > 0.05$) from each other. This fatty acid was the lowest ($P \leq 0.05$) in Egyptian goose and broiler chicken. There were no differences ($P > 0.05$) between ostrich moon steak, ostrich fan fillet, guineafowl, and Egyptian goose in terms of the concentration of stearic acid (C18:0). Pekin duck and broiler chicken did not differ ($P > 0.05$) from each other, but the latter had a lower ($P \leq 0.05$) percentage compared with the other 4 treatments.

Regarding the total monounsaturated fatty acids (MUFA), Pekin duck (34.0%) has the highest ($P \leq 0.05$) concentration. Broiler chicken (22.7%) and Egyptian goose (22.2%) had the lowest concentrations of MUFA and did not differ ($P \leq 0.05$) from each other. Pekin duck dominated with regard to the content of oleic acid (C18:1cis-9), having a higher ($P \leq 0.05$) concentration (30.8%) of this fatty acid compared with the other treatments.

Broiler chicken (43.9%) and Egyptian goose (39.7%) had a higher ($P \leq 0.05$) total polyunsaturated fatty acid (PUFA) content than the other species. Pekin duck had the lowest percentage of PUFA. Although broiler chicken had the highest total PUFA content, this was only due to the very high concentrations of 3 of the individual fatty acids: linoleic acid (C18:2cis-6), eicosadienoic acid (C20:2), and eicosapentaenoic acid (C20:5n-3). The amount of these 3 fatty acids within broiler chicken was much higher and thus increased the total PUFA content. Egyptian goose, guineafowl, ostrich moon steak, and ostrich fan fillet had higher con-
<table>
<thead>
<tr>
<th>Species</th>
<th>Egyptian goose, ( n = 6 )</th>
<th>Guineafowl, ( n = 6 )</th>
<th>Ostrich fan fillet, ( n = 6 )</th>
<th>Ostrich moon steak, ( n = 6 )</th>
<th>Pekin duck, ( n = 6 )</th>
<th>Broiler chicken, ( n = 6 )</th>
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<tr>
<td>C14:0</td>
<td>0.26c ± 0.08</td>
<td>0.43b ± 0.08</td>
<td>0.35ab ± 0.12</td>
<td>0.37abc ± 0.08</td>
<td>0.39ab ± 0.12</td>
<td>0.31bc ± 0.10</td>
<td>0.11</td>
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<td>C15:0</td>
<td>0.16b ± 0.01</td>
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<td>0.15b ± 0.02</td>
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<td>0.08b ± 0.03</td>
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<tr>
<td>C16:0</td>
<td>20.03b ± 1.57</td>
<td>25.98a ± 1.61</td>
<td>25.24b ± 1.69</td>
<td>25.87b ± 3.11</td>
<td>26.56b ± 1.80</td>
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<td>C18:0</td>
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<td>16.30b ± 2.69</td>
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<td>17.56b ± 1.91</td>
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<td>11.06b ± 1.09</td>
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<td>0.14b ± 0.09</td>
<td>0.12b ± 0.08</td>
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<td>0.05c ± 0.003</td>
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<td>0.06b ± 0.03</td>
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<td>0.09b ± 0.30</td>
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<td>0.45b ± 0.21</td>
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<td>0.17b ± 0.28</td>
<td>1.93b ± 0.66</td>
<td>0.58b ± 0.36</td>
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<td>0.43</td>
</tr>
<tr>
<td>SFA</td>
<td>37.91c ± 2.22</td>
<td>43.63ab ± 2.80</td>
<td>43.85ab ± 1.40</td>
<td>45.90a ± 3.92</td>
<td>40.87bc ± 1.63</td>
<td>33.27c ± 4.36</td>
<td>3.60</td>
</tr>
<tr>
<td>MUFA</td>
<td>22.24b ± 5.93</td>
<td>26.70b ± 3.58</td>
<td>27.54b ± 2.39</td>
<td>25.71bc ± 2.19</td>
<td>34.00b ± 2.31</td>
<td>22.71cd ± 3.06</td>
<td>4.17</td>
</tr>
<tr>
<td>PUFA</td>
<td>39.70b ± 3.93</td>
<td>29.47b ± 2.99</td>
<td>28.33b ± 2.59</td>
<td>27.70b ± 3.91</td>
<td>24.89b ± 2.40</td>
<td>43.86b ± 7.06</td>
<td>4.74</td>
</tr>
<tr>
<td>PUFA/SFA</td>
<td>1.05b ± 0.06</td>
<td>0.68b ± 0.09</td>
<td>0.65b ± 0.07</td>
<td>0.61b ± 0.12</td>
<td>0.61b ± 0.07</td>
<td>1.36b ± 0.33</td>
<td>0.18</td>
</tr>
<tr>
<td>n-6/n-3</td>
<td>9.94b ± 1.79</td>
<td>8.56b ± 2.37</td>
<td>9.60b ± 2.60</td>
<td>7.06b ± 1.03</td>
<td>17.78b ± 8.09</td>
<td>21.83b ± 10.17</td>
<td>6.29</td>
</tr>
</tbody>
</table>

\(^a\)Means in rows with different superscripts differ significantly at \( P \leq 0.05 \).

\(^b\)SFA (saturated fatty acids); MUFA (monounsaturated fatty acids); PUFA (polyunsaturated fatty acids); PUFA/SFA (polyunsaturated fatty acid/saturated fatty acid ratio).

LSD (least significant difference). \( P = 0.05 \).
centrations in more of the individual PUFA than the broiler chicken. Guineafowl and ostrich moon steak had the highest ω-linolenic acid (C18:3n-3) content. With regard to γ-linolenic acid (C18:3n-6), Egyptian goose meat had the highest \( P \leq 0.05 \) concentration. The eicosapentaenoic acid (C20:5n-3) was found to be higher in broiler chicken and Egyptian goose meat, whereas the docosadienoic acid (C22:2) content was higher in the latter species. Homo-γ-linolenic acid (C20:3n-6) content was equally high \( P \leq 0.05 \) in Egyptian goose meat. The percentages of docosapentaenoic acid (C22:5n-3) were significantly higher \( P \leq 0.05 \) in ostrich moon steak, Egyptian goose, and ostrich fan fillet.

The PUFA to SFA ratio \( \frac{P}{S} \) was higher \( P \leq 0.05 \) in broiler chicken (1.2%) and Egyptian goose (1.1%); these species’ ratio also differed significantly from each other. However, this ratio did not differ \( P > 0.05 \) between the other species.

Considering the n-6/n-3 ratio, broiler chicken and Pekin duck had a higher \( P \leq 0.05 \) ratio of 21.8 and 17.8% respectively, compared with the other species. These species’ ratio also differed significantly from each other. However, these species’ ratio also differed significantly from each other.

Mineral Composition

The mean concentrations ± SD for the mineral composition of the 6 meat treatments are presented in Table 4. The most significant result in terms of the mineral composition is the Fe content. It is evident that Egyptian goose meat had an elevated Fe content, higher \( P \leq 0.05 \) than the other species. The Fe content is approximately 3.3, 3.9, and 2.9 mg/100 g higher than that of ostrich fan fillet, ostrich moon steak, and Pekin duck, respectively, and more than 5 mg/100 g higher than what was found in guineafoal and broiler chicken. Broiler chicken and guineafoal had the lowest Fe content, with the former being lower \( P \leq 0.05 \) than the latter. Regarding the P and K content of the meat, the highest contents were found in broiler chicken and the lowest in ostrich fan fillet and guineafoal. The Na content of Pekin duck was higher \( P \leq 0.05 \) than the rest with guineafoal having the lowest content. The Mn content of Egyptian goose meat was higher \( P \leq 0.05 \) compared with the other treatments and the Cu content of Egyptian goose and Pekin duck did not differ \( P > 0.05 \) from each other but was also higher than the other treatments. The lowest Mn content was found in the ostrich moon steak. Broiler chicken and guineafoal had the lowest Cu contents, with broiler chicken being slightly lower, although there was no difference \( P > 0.05 \). The Zn and B contents were the highest in the ostrich treatments. Guineafoal and broiler chicken had the lowest Zn content \( P \leq 0.05 \), whereas Egyptian goose, guineafoal, and Pekin duck had the lowest B content. The effect of species was not significant \( P > 0.05 \) in relation to the Al content. The results for Mg and Ca are similar to that of Al except for broiler chicken and Pekin duck, which was higher \( P \leq 0.05 \) in Mg and Ca, respectively, compared with the other species.

DISCUSSION

The results of the various chemical analyses that were performed in this study indicate that the meat from Egyptian geese is somewhat unique compared with the other more well-known fowl. This is due to the major difference in some of the key chemical factors such as the IMF content, fatty acid profile, and Fe content of Egyptian goose meat.

Fat and Moisture—Why Is the Waterfowl Species So Different?

The average fat content of Egyptian goose meat of 5.9 g/100 g (Table 2) was not only higher than the other bird species in this study, but is also high when compared with that of ungulate game species, which generally have an IMF of less than 3% as indicated by Von la Chevallerie (1972) and Hoffman and Wiklund (2006). This significantly higher IMF content of the meat from Egyptian geese, as well as Pekin duck, could be associated with the fact that both are aquatic birds. The increased fat deposition on an intramuscular level may be involved in body insulation for these waterfowl species of which water forms an essential part of their being. According to De Vries and Van Heerden (1995), water has 25 times greater heat capacity than air. Therefore, when animals are in contact with water (waterfowl), the thermal conductivity between the animal and the water is increased (De Vries and Van Heerden, 1995). For this reason, aquatic birds generally have a thick subcutaneous fat layer for heat insulation because the ability of fat to conduct heat is poor (Evans, 1972; O’Malley, 2005). Smith (1962) states that fat is essential in insulation because its heat insulation ability is 3 times that of water. However, no research specifically indicating that the IMF content of waterfowl species is related to or involved in heat insulation could be found. In a study investigating the effect of wind protection and the patterns of airflow on cattle in an outside feedlot, Mader et al. (1997) found that the carcasses of cattle raised in an area exposed to these environmental conditions not only had a larger \( P \leq 0.05 \) fat thickness but also had increased \( P \leq 0.05 \) IMF (marbling fat) values. It is therefore suggested that the increased IMF content of Egyptian goose meat may be related to heat insulation. Another contributing factor to the higher fat content of these species could be the matter of buoyancy because this mechanism is an additional advantage of fat deposition (Pond, 1978). Waterfowl species such as Egyptian geese spend a lot of time floating on the water, and therefore buoyancy is required. Buoyancy is the propensity of a fluid (water)
to lift a body, which is submerged in this fluid upward (Cullerne, 2009) and is related to the density characteristics where the body floats in the fluid when the density of the body is less than that of the fluid (Giancoli, 1998). For this reason, certain constituents of the body with a lower density than water, such as fat, will have a positive effect on the floating ability of the waterfowl. This theory proposes that the higher IMF of the waterfowl species may be linked to the involvement of fat in the heat insulation and buoyancy mechanisms of the animal. It is based on the fact that, although fat deposition initially occurs subcutaneously, the body will not resort to using these reserves until it is necessary. This means that when the animal is in a cold environment (water), other lipid sources will be used for energy metabolism instead (Evans, 1972; i.e., IMF). It is therefore hypothesized that fat depots, such as IMF, may have a possible higher content to ensure availability of reserves for energy metabolism.

Egyptian goose meat also had a higher IMF content compared with the 3.39 g/100 g present in the breast muscle of wild mallard ducks (Anas platyrhynchos; Cobos et al., 2000). The proximate results indicated that there was a negative relationship between the moisture content and IMF (g/100 g) which is in agreement with the findings of Alfaia et al. (2010). The cooking process causes moisture loss, which results in a significant increase in the IMF content of the cooked compared with the raw meat. As the proximate analysis was performed after completion of the cooking process, meat with a higher cooking loss will have a higher intramuscular fat content (Alfaia et al., 2010). This is another possible explanation for the high fat (g/100 g) of Egyptian goose meat, and this theory could also be similar with regard to the Pekin duck and both of the ostrich treatments. Muscle that mainly consists of red fibers, such as the breast muscle of Egyptian geese, is generally higher in total lipid content and, more specifically, PUFA content (Lawrie and Ledward, 2006), a phenomenon that may also contribute to the higher IMF values.

The important question, however, is the impact of the high fat content. The IMF content of Egyptian goose meat may have an influence on the sensory properties. Fat is involved in the secretion of saliva in the mouth during mastication (Lawrie and Ledward, 2006); therefore, it is possible that a correlation may exist between high IMF and sustained juiciness of the meat. Even though the IMF content of Egyptian goose meat is fairly high, MacRae et al. (2005) and McAfee et al. (2010) emphasize that, in terms of human health, the fatty acid profile of the meat is more important, especially the P/S.

**Fatty Acid Profile—Game (Egyptian Goose) vs. Domestic**

It is evident that all of the muscles/species had a significantly different fatty acid profile (Table 3). The
main factors influencing the fatty acid composition of meat are species differences and the variation in their diets (Wood and Enser, 1997). In monogastric animals, such as gamebirds and poultry, diet is a key factor because the fatty acid profile of the intramuscular lipids is a reflection of the dietary constituents (Wood and Enser, 1997; Coetzee and Hoffman, 2002; MacRae et al., 2005). The mean fatty acid percentages (Table 3) indicate that the profile of Egyptian goose meat was dominated by the presence of PUFA contributing 39.7% to the total fatty acids. The diet of Egyptian geese is mainly composed of green plant material, growing crops, aquatic vegetation, and aquatic invertebrates (Viljoen, 2005). This forage-based diet is of a more unsaturated nature, due to the higher linolenic acid content (Marner et al., 1984; Enser et al., 1998; Ward et al., 2003) compared with that of the other domestic species that received a standardized commercial feed. The major individual PUFA within the profile seems to be γ-linolenic acid (C18:3n-6) and homo-γ-linolenic acid (C20:3n-6), with significantly higher values than the other species.

The high PUFA and lower SFA content results in Egyptian goose meat having a high P/S (1.05) compared with the other species. This value is in agreement with the findings of Cobos et al. (2000) in a study on the breast muscle of wild ducks indicating a P/S of 1.17. The only other species with a higher P/S than Egyptian goose meat is broiler chicken (1.36); however, the range of PUFA within broiler chickens differs according to the diet fed to these birds. Linoleic acid (C18:2n-6) constituted 33% of the total PUFA (43%) present in broiler chicken, and the percentage values for some of the other PUFA were smaller when compared with that of Egyptian goose meat. The P/S is considered to be important in terms of human health because SFA are the fats generally associated with having negative effects on human health, whereas MUFA and PUFA are more favorable (Luciano, 2009). It is thus believed that a reduction in the intake of SFA together with an increase in the P/S may decrease the occurrence of cardiovascular disease in humans (Gidding et al., 2006). According to Raes et al. (2004) the P/S should not be below 0.7, but Scollan et al. (2006), Durand et al. (2005), and Wood et al. (2008) indicate that the recommended dietary intake of P/S must be >0.4. Considering these recommendations, it is evident that Egyptian goose meat has an acceptable P/S ratio of 1.05. The n-6/n-3 fatty acid ratio is another vital aspect with regards to human health. Smolin et al. (2003) explains that the n-6 and n-3 fatty acids linoleic and α-linolenic acid are essential because they cannot be synthesized by the human body and are used for the production of other important omega fatty acids. Therefore, both n-6 and n-3 fatty acids are beneficial; however, the ratio in which these fatty acids are consumed must be considered because an increased intake of n-6 may decrease the levels of HDL cholesterol, leading to health risks (Smolin et al., 2003). It is suggested that the n-6/n-3 ratio of meat should be below 5 (Raes et al., 2004; Durand et al., 2005; Scollan et al., 2006). This value for Egyptian goose meat, however, is above the recommendation, which can be ascribed to a very high content of C18:3n-6.

The question also arises of why there is such variation in the fatty acid profiles of the 2 gamebird species: Egyptian goose and guineafowl. This can be ascribed to the fact that these 2 types of gamebirds have different diets. The diet of guineafowl is much more domestic, in a sense, with seeds and grains as the main food source (Little and Crowe, 2011). It can be assumed that the main dietary PUFA, in this case, is linoleic acid (C18:2); this assumption is supported by the higher content of this fatty acid (Table 3) in the guineafowl meat compared with that of Egyptian geese. Likewise, this also applies to the difference in the profile of Egyptian goose meat, compared with the other domestic (farmed) birds used in this study that receive a standardized commercial feed primarily composed of grains and seeds.

It can be postulated that the overall fatty acid composition will be an influential factor with regard to the flavor characteristics of Egyptian goose meat (Hornstein and Crowe, 1960; 1963), particularly because PUFA is associated with the game attributes found in meat. These aspects warrant further research.

**Fe Is the Differentiating Factor Within the Mineral Profile**

Several factors could be responsible for the variation within the overall mineral content of the species. In this case, the main influence is the fact that this study consisted of different species. Considering the mineral contents of the 6 different meat treatments (Table 4), it is clear that the Fe content was significantly higher in the red meat types compared with guineafowl and broiler chicken known for having a whiter colored meat. The most apparent result, however, was the elevated Fe level (7.46 mg/100 g) of Egyptian goose meat (Table 4). This result is consistent with the study by Khalifa and Nassar (2001) where higher levels of Fe were present in game duck species than domestic ducks. The Fe values of the game ducks ranged between 4.22 and 6.19 mg/100 g of meat and are more or less twice the amount present in domestic ducks. The high Fe levels of Egyptian goose meat is attributed to an elevated myoglobin content because the breast muscle of this gamebird endures a high level of physical activity on a regular basis. The pectoralis muscle in volant birds mainly consists of red type IIa, fast oxidative glycolytic fibers together with a small percentage of type IIb, fast glycolytic fibers (Butler, 1991; Baeza et al., 2000). Type IIa fibers are aerobic, thus having a high myoglobin content for oxygen supply. This also explains the elevated Fe contents of the meat with an overall higher concentration of red fibers. Meat is considered to be a
very good source of Fe because 50 to 60% is in the heme form and is therefore more readily absorbed (Luciano, 2009). It is also speculated that the high Fe levels of the meat from this species may have an effect on the palatability as studies regarding the sensory properties of meat have found correlations between Fe content and metallic/liver flavor (Yancey et al., 2006). The Fe content could also have a detrimental effect on the flavor of the meat as it is considered to be a prooxidant in the flavor formation process. Excluding the results pertaining to Fe, the overall mineral compositions of the meat from the different species did not vary considerably. The data, however, did reveal that, besides the high Fe content, Egyptian goose meat also contains high levels of Zn and Cu (Table 4). The concentrations of both Fe and Cu is higher than what was found in beef, lamb, ostrich, pork, chicken, and turkey meat in the study by Lombardi-Boccia et al. (2005). Phosphorus was found to be the most abundant mineral present in Egyptian goose meat, followed by K and Mg.

Conclusions

This study quantified the chemical profile of Egyptian goose meat in relation to that of other well-known species. A high IMF content may be linked to the fact that this species is a waterfowl. However, the fatty acid profile rather than the total fat content should be considered in terms of human health. In general, Egyptian goose meat is very high in PUFA. The P/S ratio of Egyptian goose meat is within the recommendations, although the n-6/n-3 ratio is somewhat higher than the suggested value. With regard to the mineral composition of Egyptian goose meat, the high Fe content is the major differentiating factor and is mainly related to a higher level of physical activity. This research provides new insight into the nutritional characteristics of Egyptian goose meat, which is, to date, not available in the literature. It is suggested that further research evaluates the effects of diet, sex, and age on the chemical composition of this gamebird species. However, it would be very difficult to quantify these effects, especially pertaining to age and sex, because it is extremely challenging to classify wild birds according to the categories while they are in flight.

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REFERENCES


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