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Carcass Traits, Meat Quality and Nutritional Profiles of Wild Egyptian Geese (*Alopochen aegyptiaca*) and Wigeon (*Anas penelope*)

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THE gamebird species as an alternative meat are considered as one of the potential benefits for achieving sustainable food security and the nutritional benefits of high-quality protein, challenging the increasing demand for animal-based protein. Therefore, the present study aimed to evaluate the carcass traits, meat quality, mineral, protein, and lipid composition of breast and leg meat sourced from wild Egyptian geese (*Alopochen aegyptiaca*, n=8) and wigeons (*Anas penelope*, n=12) hunted in southern Egypt in 2020 and 2021. Pre-slaughter, carcass yield, and the weights of carcass parts were higher ($p < 0.05$) in male and female Egyptian geese compared to wigeons. Additionally, Egyptian geese had the highest water holding capacity (WHC), redness (a^*), and the lowest lightness (L^*) in the breast (63.34%, 12.93, and 36.43, respectively) and leg muscles (66.55%, 14.65, and 41.69, respectively). Moreover, they possessed the highest moisture, protein, and the lowest lipid content in the breast (71.64, 21.93 and 2.98%, respectively) and leg muscles (70.24, 21.43 and 3.05%, respectively) compared to wigeons. In contrast, there were no significant differences ($p > 0.05$) in dressing percentage, ultimate pH_{24}, yellowness (b^*), and ash content between the two species. However, the Egyptian geese breast and leg muscles exhibited greater amounts of sodium, potassium, calcium, and zinc, along with lower amounts of iron, and copper. The intake of 150 g of pure meat from the studied wild birds supplies a total of 28.5–34.2 g of protein, including 16.54 g of essential amino acids (EAA), which is equal to 67% of human protein demand. The absence of observed variations in fatty acid fractions and ratios as well as atherogenic (AI) and thrombogenic (TI) indicates that the lipid nutritional value is equal among species.

Keywords: Gamebird, Meat quality, Carcass yield, Amino acid, Fatty acid.

Introduction

In many countries, especially across Europe and South Africa, the gamebird market has been increasing in popularity. More than 6.4 million hunters are involved in Europe, and at least 52 million birds are caught each year. In contrast to Africa's northern nations, the gamebird market and wing-shooting sports are still far from reaching their full capacity (Hirschfeld et al., 2019). Annex II of Directive 2009/147/EC within the European Union member states outlines a list of 82 bird species that are permitted for legal hunting in multiple countries, including the Egyptian geese (*Alopochen aegyptiaca*) and Eurasian wigeon (*Anas penelope*) (EC, 2009).

The Egyptian geese (*Alopochen aegyptiaca*) and wigeon (*Anas penelope*) are members of the Anatidae family within the Anseriformes order. The wigeon inhabits almost the entire Palearctic zone and wintering areas across South Asia and North Africa, while the Egyptian geese is native to the Nile valley, southern sub-Saharan African regions and South Africa (Clements, 2007). During recent years, there has been an increase

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in demand for meat from alternative animal species due to increased consumer concerns about product safety and health (Hoek et al., 2011; Geldenhuys et al., 2013a). The rapid growth of society diseases and the increase in sudden mortality have been caused by changes in lifestyle and an unhealthy diet. This is clear to modern customers, who seek foods prepared with a focus on the natural environment, which also has distinctive flavors and health-improving benefits, including wild bird meats (Bombik et al., 2022). Hence, gamebird meat has received increasing attention as a valuable substitute for both white and red meats in several European countries due to its high protein, vitamin, and trace mineral content, along with a favorable fatty acid composition characterized by increased polyunsaturated fatty acid (PUFA) levels and decreased intramuscular fat content (Tomasevic et al., 2018). Accurate scientific data on the nutritive features of Egyptian geese and wigeon meat are vital for effective marketing. This is essential because modern consumers demand lean meat that meets the necessary dietary requirements (Hoffman and Wiklund, 2006).

Wild bird meat plays a clear role as a source of protein. Thus, all of the essential amino acids (valine, leucine, lysine, isoleucine, threonine, phenylalanine+tyrosine, and methionine+cysteine) needed for human nutrition are found in wild bird meats (Khalifa and Nassar 2001; Geldenhuys et al., 2015; Khalifa et al., 2016; Straková et al., 2016). The recommendations advise that the total daily calorie intake from fat should be in the range of less than 15–30%, comprising trans, saturated (SFA), and polyunsaturated fatty acids (PUSFA) with the aim of reducing the risk of diseases, like cardiovascular diseases as well as cancer and type 2 diabetes diseases (WHO/FAO/UNU and Expert Consultation, 2007). However, investigations have shown that the main risk factors associated with cardiovascular disease are the ratios of PUSFAto SFA and omega 6 to omega 3 (n-6/n-3). Additionally, wild bird meats are a remarkable source of essential minerals, including zinc, iron, selenium, magnesium, phosphorus, and potassium (Kokoszyński et al., 2014; Geldenhuys et al., 2015; Khalifa et al., 2016; Flis et al., 2020; Quaresma et al., 2022). Detailed nutritional data regarding the meat of gamebird species, including Egyptian geese and wigeon, are currently scarce. The investigations by Geldenhuys et al. (2013b) and Flis et al. (2020) suggest that the proximate analysis of wild bird meats is highly unique contrasted to other domesticated birds, and it is proposed that variations in dietary patterns are responsible. Therefore, this study focused on the nutritional characteristics obtained from wild birds, which may have a direct effect on the health of individuals. In addition, the influences of factors such as genotype and sex on the carcass, meat quality traits, and proximate composition were explored. Furthermore, the impact of genotype on the mineral composition, amino and fatty acid contents of meat from Egyptian geese and wigeons was investigated. These findings not only reveal the nutritional importance but also help to better understand factors that may influence the nutritional value and sensory aspects of meat in the future.

Materials and Methods

a. Birds and sampling

The wild Egyptian geese (*Alopochen aegyptiaca*, n=8) and wigeon (*Anas penelope*, n=12) birds utilized in the investigation were hunted in live and healthy conditions directly by hunters from the Gerf-Hussein region south of Aswan governorate, near Lake Nasser (23°20’55”N 32°51’07”E), during the hunting season (1 September to 15 November 2020 and 15 November to 31 March 2021 for the wigeon and Egyptian geese, respectively), with respect to the national laws on game and hunting according to the Environment Law (4/1994) in Egypt. The gender distribution was equal (1:1) for males to females. The birds were weighed to the nearest 0.1 g before slaughter. In accordance with Islamic tradition, they were slaughtered using a sharp instrument and left to bleed for 5 minutes. After dry plucking and dressing, the carcasses were reweighed, and the feathers and blood weight were calculated through variance. The eviscerated carcasses underwent dissection following the method outlined by Ziołecki & Doruchowski (1989). In the laboratory, carcasses were dissected into various parts. The carcass components were weighed by an electronic balance to calculate their percentage of pre-slaughter weight. Subsequently, from the deboned parts of all study groups, the breast and leg muscles were collected and then finely minced using a home blender (Moulinex, France). Meat samples were vacuum-packed and kept frozen at -18°C until examination.

b. Meat quality traits

Following dissection, color measurements on the exterior of the breast and leg muscles were conducted three times. A chroma meter (Konica Minolta, model CR 410, Japan) was utilized for color determination based on the color system of CIE *L**, *a**, and *b**. Redness (*a**) values ranged from reddish (+) to greenish (-), while lightness (*L**) was measured on a scale from dark (0) to light (100), and yellowness (*b**) values ranged from yellowish (+) to bluish (-), as calculated by the CIE (1978) standards. Afterward, a pH meter (Jenway 3510: Bench pH/mV Meter, UK) was utilized to measure and estimate the pH values of the meat samples at twenty-four hours postmortem. The filter paper press technique described by Tsai &and Ockerman (1981) was utilized to evaluate the water holding capacity (WHC %).

c. Chemical composition analysis

Standard methods were applied to determine the ash, protein, lipid, and moisture contents of the leg and breast meat (AOAC, 2000).

d. Estimation of minerals

The samples were oven-dried for 24 hours, and a sufficient quantity (at least 0.5 g) was crushed and digested in 1 mL of H_2O_2 (30%) and 9 mL of H_2NO_3 acid. A Milestone Ethos microwave digestion system (Ethos Sel/Plus, Milestone S.R.L., Sorisole, Italy) was utilized to carry out the digestion. Following the AOAC (1995) standards, the sample digestion solutions were diluted with deionized water to achieve a volume of 25 mL and evaluated using atomic absorption spectrometry.

e. Amino acid analysis

The HPLC-Pico-Tag method, which was previously reported by Heinrikson and Meredith (1984), was utilized to assess the amino acid composition of the breast and leg meat samples. In summary, 500 mg of the specimen underwent hydrolysis in a 25 × 150 mm tube with 10 mL of 6 N HCl for 24 hours at 110°C. After extraction from the oven and cooling, the hydrolyzed specimen was quantitatively added to a volumetric glass flask and adjusted to a volume of 100 mL with HPLC-grade water. Subsequently, 1 mL of this solution was diluted to 10 mL with the same water in another volumetric flask and filtered using a 0.45 µm PTFE membrane filter. The preparation of samples (precolumn derivatization) was carried out using phenylisothiocyanate (PTC). After derivatization, the solution was immediately injected into the HPLC system. The identification and quantification of amino acids were performed using a Waters HPLC system.

f. Amino acid assessment

Based on the conservation pattern of adults and the daily protein needs for conservation (0.66 g/kg/d), Fig. 1 shows the level of fulfillment of the recommended dietary intake (RDI) for amino acids that are essential, in line with the requirements determined by global organizations (WHO/FAO/UNU and Expert Consultation, 2007), taking into consideration an average body weight of 70 kg in adult humans. The recommended daily intake of leucine, isoleucine, lysine, methionine, threonine, valine, phenylalanine+ tyrosine, and histidine was 59, 30, 16, 23, 39, 38, and 15 mg/g protein, respectively.

g. Preparation and extraction oil from samples

According to Folch et al. (1957) methods, the minced samples underwent a thawing process overnight at a temperature of 4°C, followed by the extraction of lipid as follows: 2 g of samples were weighed and extracted by chloroform: methanol in a 2:1 (v/v) ratio, along with butylated hydroxytoluene (BHT)0.01% that exercised as an antioxidant.

h. Fatty acid analysis

Transmethylation of the extracted lipid: Briefly, the content of extracted lipid was heated with 2 mL of methanol:sulfuric acid (19:1; v/v), which was used as a transmethylating agent. Afterward, the mixture was permitted to cool to room temperature, and then water and hexane were added. The organic phase was removed, and the hexane phase was concentrated by drying. Fatty acid methyl esters (FAME) in a volume of 1 µL were injected into a Perkin-Elmar Gas Chromatography (model F22) device, which was equipped with a flame-ionized detector along with nitrogen as a carrier gas. Diethylene glycol succinate (DEGS) on a chromosorb W 80–100 mesh was added to the analytical glass column. As carriers, 30, 30, and 300 ml/min of nitrogen, hydrogen, and airflow, respectively, were utilized. Both the injector and detector were set to a temperature of 220°C. Peak identification was established by contrasting the duration of retention times obtained with the standard (FAME).

i. Lipid quality indices

Ulbricht and Southgate (1999) proposed the following equations for estimating the indices of Thrombogenicity (TI) and Atherogenicity (AI):

TI= (C14:0+C16:0+C18:0)/[(0.5×∑MUFA+0.5 × (∑n-6) +3×(∑n-3) + (∑n-3)/(∑n-6)]

AI= (C12:0+ 4 × C14:0 + C16:0)/[∑MUFA+ ∑(n-6) + ∑(n-3)]

According to Santos-Silva et al. (2002), the following equations are suggested for estimating the hypocholesterolemic/hypercholesterolemic ratio (h/H):
h/H=[(C18:1n-9+C18:2n-6+C18:3n-3+C20:4n-6+C20:5n-3+C22:6n-3)/(C14:0+C16:0).

Moreover, according to the Department of Health (1994), the nutritional ratio (P/S and n- 6/n-3) was calculated.

Statistical analysis

Numerical data for the characteristics were statistically analyzed and are reported as the arithmetical averages. Two-way analysis of variance (ANOVA, Duncan multiple range test) was used to determine the impact of genotype and sex on the carcass, meat quality traits, and proxi- mate composition. The linear model configura- tion is represented by:

$Y_{ij} = \mu + g_i + s_j + (gs)_{ij} + \varepsilon_{ij}$

Where: the value of the analyzed trait (Y_{ij}), the overall mean (μ), the impact of genotype (g_i), the impact of sex (s_j), the impact of the inter- action $(gs)_{ij}$ and the random error (ε_{ij}). One-way analysis of variance was used to determine the impact of genotype on the mineral, amino acid, and fatty acid profiles. The linear model configu- ration is represented by:

$Y_{ij} = \mu + g_i + \varepsilon_{ij}$

SPSS software for Windows, version 25, was utilized to statistically characterize the analyzed characteristics (IBM Corp., 2017). Statistically significant differences were defined as those for which the probability (*p-value*) was < 0.05, whereas non-significant differences were defined as those for which the *p-value* was > 0.05.

Results and Discussion

Carcass traits

Wigeon and Egyptian geese are characterized by great differences, which are demonstrated in feather and size variations between the genotypes, consisting of variations in pre-slaughter weight, carcass weight, and dressing percentage are outlined in Table 1. Male and female Egyptian geese had significantly ($p < 0.05$) heavier pre-slaughter weight, carcass yield, and the weight of carcass parts compared to wigeon. The average pre-slaughter weight of the Egyptian geese reached 1528.23 g, which was 973.34 g heavier than the pre-slaughter weight of the wigeon 554.89 g. A similar pre-slaughter weight was reported for Egyptian geese in South Africa (Geldenhuys et al., 2013c) and for 7-week-old Beyaz, Kara, and Sam geese (Isguzar & Pingel, 2003). The Egyptian geese had the highest average weight of carcass yield, the weight of breast, leg, neck, back & rib, wings, and giblets (1183.76, 352.90, 249.90, 64.45, 215.86, 219.67, and 82.11 g; $P \leq 0.05$, respectively) in comparison to the wigeon. Our findings are in compliance with those of Geldenhuys et al. (2013c) and Khalifa and Nassar (2001) for pintail and garganey ducks. Irrespective of genotype, males exhibited considerably ($p < 0.05$) higher in previous traits compared to females. Furthermore, female weights constituted 78.26 and 82.86% of male weights in Egyptian geese and wigeon, respectively. Similar observations were reported by Abd El- Rahman et al. (2022) for wild duck birds and Geldenhuys et al. (2013c) for Egyptian geese. In contrast, there were no differences in dressing percentage ($p > 0.05$) between genotype, gender, and their interaction. Although it was anticipated that genotype and sex would have an effect on the dressing proportion of birds. Comparable results have been found not only in Egyptian geese birds (Geldenhuys et al., 2013c) but also in domestic birds such as Muscovy and Sudani ducks (Makram et al., 2017). The proportions of the carcass component weights were calculated relative to the pre-slaughter weight and are presented in Figure 1a, b. Valuable carcass components (breast, legs, back&rib, wings, and giblets) and carcass remainders accounted 77.42 and 22.14% of the total pre-slaughter weight of Egyptian geese (Figure 1a) 75.93 and 24.45% of wigeon (Figure 1b) of wild birds, respectively. Comparable findings were documented for pintail and garganey (Khalifa & Nassar, 2001), but the studied birds were distinguished by higher percentages of valuable components compared to wild mallards (Janiszewski et al., 2018).

Meat quality

Data of physical properties of the meat specimens are summarized in Table 2. There was no statistically significant difference ($p >$

0.05) in pH_{24} from breast and leg samples found between wigeon and Egyptian geese birds. Regardless of genotype, significant differences ($p < 0.05$) in pH_{24} of breast and leg samples were found between males and females, where females exhibited higher pH_{24} than males. Compared with leg samples, breast samples were distinguished by greater acidity. Our findings are in line with the results reported by Kokoszyński et al. (2014) in Poland (*Phasianus colchicus*) game pheasants. Furthermore, Kirmizibayrak et al. (2011) discovered an elevated pH_{24} value of the sample muscles in females versus males in Turkish native geese. In general, changes in the pH value may be caused by variations in the storage of glycogen at slaughter, as well as reactions to pre-slaughter stress or slaughter weight. The term of the WHC% ($p < 0.05$) was significantly influenced by genotype and sex, with elevated values observed in the Egyptian geese muscles (63.34% in breast and 66.55% in leg), whereas females exhibited higher WHC% compared to males (62.26% vs. 60.68% and 66.05% vs. 64.39% for breast and leg muscles, respectively). In turn, low meat pH levels are related to decrease WHC%, tenderness (pale, soft, and exudative) as well as increased cooking loss% of meat. The detected findings are approximately comparable to that of Muhlisin et al. (2013) and Kowalska et al. (2020) (58.01– 60.94% and 62.93–64.78% for breast and leg muscles, respectively). The color of meat is an essential indicator reflecting the quality of the meat that customers use to evaluate the meat's freshness and quality and is strongly correlated with the final pH. The breast muscles of Egyptian geese exhibited significantly higher redness (a^*) and lower lightness (L^*), while the leg muscles exhibited significantly higher redness (a^*) compared to wigeon. Regardless of genotype, females displayed significantly higher yellowness (b^*) compared to males. In both wigeon and Egyptian geese birds, the breast and leg meat had a darker color than the meat of domestic Korean native ducks (Muhlisin et al., 2013) and 12- 17-week-old game pheasants (Kokoszyński et al., 2014). A lower L* value was reported in the meat specimens of the studied birds, which explains that these variations are linked to a decrease in the ultimate pH of the meat specimens, as observed by Abdullah et al. (2010) in 42-day-old chickens.

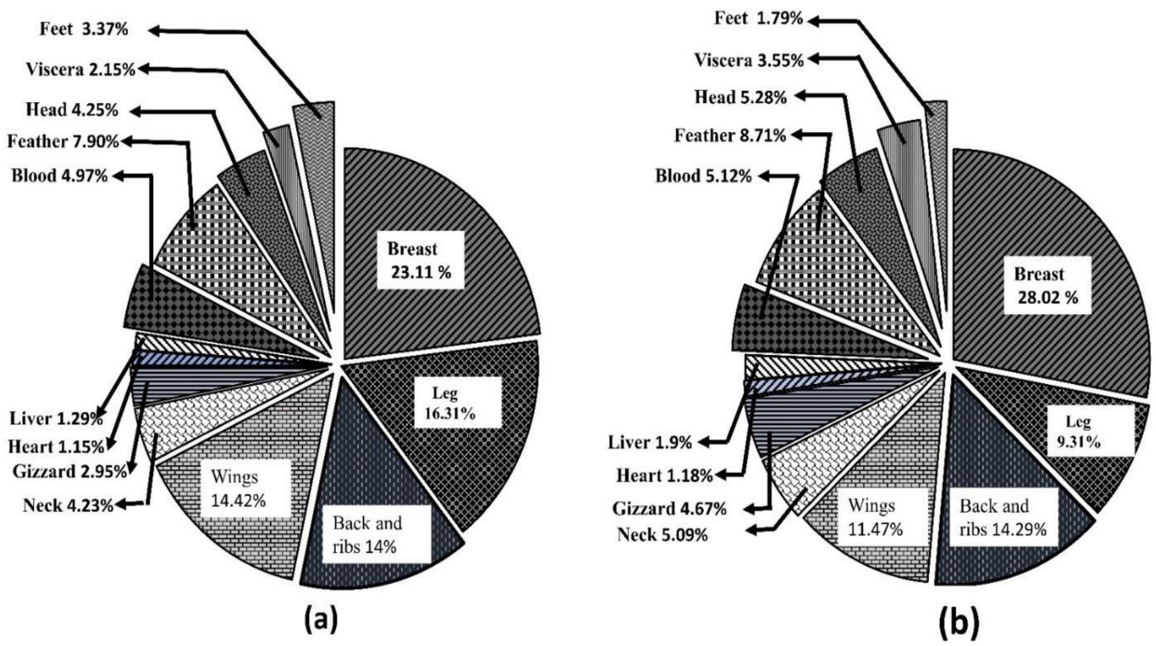


Fig. 1. Distribution of carcass components as a percentage share in the total live body weight of (a) Egyptian geese and (b) Eurasian wigeon.

TABLE 1. Pre-slaughter weight and carcass traits of wild Eurasian wigeon and Egyptian geese birds.

Item	Eurasian wigeon			Egyptian geese			p-Value		
	Male (n=6)	Fe-male (n=6)	Total (n=12)	Male (n=4)	Fe-male (n=4)	Total (n=8)	Geno-type	Sex	G×S
(Pre-slaughter weight (g	595.96	493.83	544.89	1714.66	1341.80	1528.23	< 0.001	<0.001	0.004
Carcass yield (g)	452.69	374.73	413.71	1334.8	1032.71	1183.76	<0.001	<0.001	0.006
Dressing percentage (%)	75.94	75.86	75.91	77.78	76.97	77.37	0.057	0.543	0.529
Carcass parts (g)									
Breast	171.51	134.81	153.16	394.32	311.48	352.90	<0.001	<0.001	0.067
Legs	55.84	45.85	50.85	280.1	219.72	249.90	<0.001	0.004	0.032
Neck	29.54	25.83	27.68	70.81	58.10	64.45	<0.001	0.002	0.059
Back and ribs	85.79	69.99	77.89	251.45	180.27	215.86	<0.001	<0.001	0.011
Wings	67.77	56.83	62.30	246.01	193.32	219.67	<0.001	<0.001	0.002
Giblets	43.35	40.67	42.01	92.13	72.10	82.11	<0.001	<0.001	0.003

TABLE 2. Selected meat quality traits of breast and leg muscles in wild Eurasian wigeon and Egyptian geese birds.

	Item	Genotype		Sex			p-Value		
		Eurasian wigeon (n=12)	Egyptian geese (n=8)	Male (n=10)	Female (n=10)	Total (n=20)	Geno-type	Sex	G×S
Breast muscles	pH_{24}*	5.83	5.82	5.73	5.92	5.83	0.386	<0.001	0.225
	WHC (%)	59.61	63.34	60.68	62.26	61.47	<0.001	0.014	0.065
	Lightness (L*)	37.51	36.43	37.26	36.68	36.97	0.020	0.158	0.057
	Redness (a*)	10.95	12.93	11.31	12.57	11.94	0.040	0.064	0.164
	Yellowness (b*)	1.78	1.99	1.28	2.49	1.88	0.425	0.001	0.133
Leg muscles	pH_{24}	6.67	6.62	6.45	6.64	6.54	0.071	<0.001	0.061
	WHC (%)	63.89	66.55	64.39	66.05	65.22	0.027	0.031	0.444
	Lightness (L*)	41.94	41.69	41.92	41.70	41.81	0.768	0.793	0.756
	Redness (a*)	11.92	14.65	11.07	11.49	12.28	0.001	0.061	0.860
	Yellowness (b*)	4.51	4.05	2.37	6.19	4.28	0.303	<0.001	0.854

pH_{24}*: pH value after 24 h postmortem

Proximate chemical composition

The compared species of wild birds exhibited significant differences ($P < 0.05$) in moisture and lipid content in the breast and leg samples and protein content in the leg samples. The breast and leg meats of the Egyptian geese showed noticeably higher moisture content and lower lipid content in comparison to the breast and leg meats of the wigeon; in contrast, the leg meats of the Egyptian geese had a markedly greater protein amount compared with the leg meats of the wigeon. Regardless of genotype, female specimens showed significantly lower ($P < 0.05$) moisture content and higher levels of lipid and ash in both breast and leg meat than their male counterparts (Table 3). Data revealed that, the breast and leg meat of the examined Egyptian geese birds exhibited similar moisture and protein amounts but lower fat amounts, as assessed by Geldenhuys et al. (2013c). The detected findings of the analyzed wigeon birds are in compliance with those of Khalifa & Nassar (2001). Moreover, Kokoszyński et al. (2020) reported notable differences in the moisture, fat, and protein composition of breast and leg muscles among domestic Pekin ducks from the P33, P8, and LsA strains, which are compatible with our study. Abd El-Rahman et al. (2022) reported increased protein and reduced fat content in the breast meat of males compared with females, which corresponds with our results. The moisture content was lesser while the lipids content was higher than that in the previous studies by Muhlisin et al. (2013) for domestic Korean native ducks and by Kokoszyński et al. (2020) for Pekin ducks, possibly because of the inclusion of the skin with meat in the current study.

Mineral profile

Essential inorganic minerals, comprising trace elements, are inorganic components considered nutritionally necessary for maintaining normal physiological activities. It is categorized as macrominerals and microminerals (those necessary in quantities more than 100 and less than 100 milligrams per day, respectively) (Quaresma et al., 2022). The results of the essential mineral contents of the meat specimens are outlined in Table 4. The comparison among wild bird species revealed notable variations ($P < 0.05$) in 4 macrominerals, including potassium, magnesium, sodium, and calcium, and significant variations ($P < 0.05$) in 3 microminerals, including zinc, manganese, and copper. In this regard, the breast meat of Egyptian geese exhibited higher contents of potassium, sodium, calcium, and zinc (more 24.41, 39.82, 21.23, and 35.83%, respectively), but lower of magnesium, iron, manganese, and copper content (less 14.55, 6.80, 57.89, and 23.76%, respectively) compared to the breast meat of Wigeon. While the leg meat of Egyptian geese exhibited higher content of potassium (more 13.65%), magnesium (more 26.19%), sodium (more 22.77%), zinc (more 23.04%), and calcium (more 12.87%), but a lower content of iron (less 36.98%) compared to leg meat of wigeon. The comparison of the mineral contents of the meat from the studied wild birds with those of the meats of other wild bird species revealed that the breast and leg specimens of the current study exhibited the highest iron and zinc contents compared to game pheasants (25.2 − 36.5 and 7.1 −15.7 g/kg dry matter, respectively) (Kokoszyński et al., 2014), Egyptian geese (5.3−5.4 and 1.5−1.6 g/100 g dry matter, respectively) (Geldenhuys et al., 2015) and wild pheasants (95.1−68.1 and 21.9−15.7 g/kg dry matter, respectively) (Flis et al., 2020). The higher iron content of the breast and leg specimens is also clear. The metabolic rate and fiber type of muscle are linked to this high concentration of iron. The fiber type of muscles is largely composed of red type IIa, with a small percentage of type IIb. Therefore, type IIa fibers are aerobic and have elevated myoglobin amount for a supply of oxygen (Geldenhuys et al., 2015). Consistent with the findings reported by Geldenhuys et al. (2013c), phosphorus was identified as the most abundant mineral in the meat of Egyptian geese, followed by potassium and magnesium.

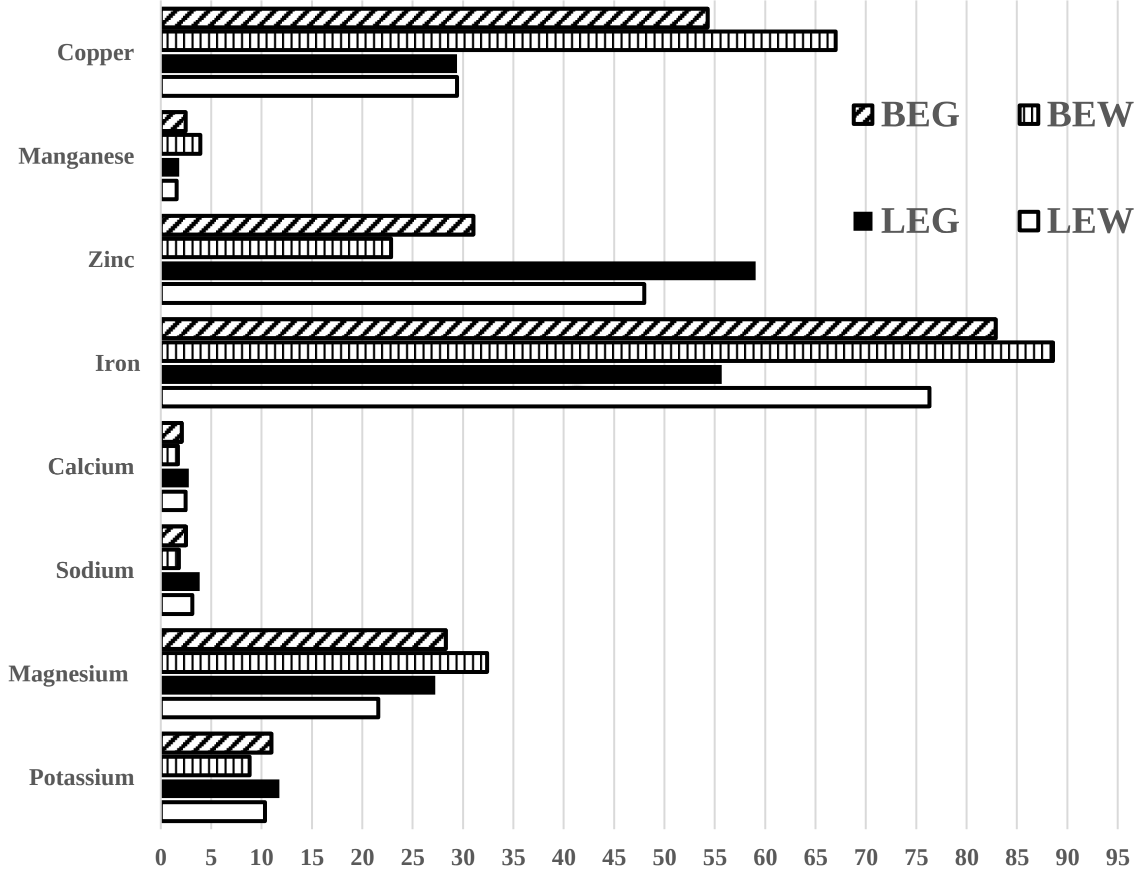
According to the European Food Safety Authority (EFSA, 2017), the dietary reference values (DRVs) (Fig. 2) were used to evaluate the meat of wild birds as a crucial supplier of essential minerals for human dietary needs. The data revealed that 100 g of wild bird meat supplies almost more half of dietary needs of iron (55.70−88.56% of the DRVs) and supplies an essential amount of zinc (22.86−59.06% of the DRVs), copper (29.40−67 % of the DRVs), magnesium (21.60−32.40% of the DRVs) and supplies little amount of potassium, sodium and manganese.

TABLE 3. Proximate chemical composition of breast and leg meats in wild Eurasian wigeon and Egyptian geese birds.

Item	%	Genotype: Eurasian wigeon (n=12)	Genotype: Egyptian geese (n=8)	Sex: Male (n=10)	Sex: Female (n=10)	Total (n=20)	p-Value: Genotype	p-Value: Sex	p-Value: G×S
Breast muscles	Moisture	63.25	71.64	68.03	66.87	67.45	<0.001	0.05	0.052
	Protein	22.80	21.93	22.83	21.90	22.37	0.244	0.210	0.302
	Lipids	12.37	2.98	7.72	8.63	8.18	<0.001	0.127	0.062
	Ash	1.39	1.28	1.21	1.46	1.34	0.268	0.032	0.106
Leg muscles	Moisture	65.63	70.24	66.52	69.35	67.93	<0.001	<0.001	0.077
	Protein	18.79	21.43	19.47	20.76	20.11	0.005	0.099	0.064
	Lipids	12.13	3.05	6.85	8.33	7.59	<0.001	0.032	0.106
	Ash	1.96	1.64	1.60	2	1.80	0.099	0.05	0.059

TABLE 4. Mineral's content of breast and leg meats (mg/100g on a dry basis) in wild Eurasian wigeon and Egyptian geese birds.

Item	Breast muscles		p-Value	Leg muscles		p-Value
	Wild birds with different genotypes			Wild birds with different genotypes		
	Eurasian wigeon	Egyptian geese		Eurasian wigeon	Egyptian geese	
Potassium (K)	1030.50	1282	0.016	1207.25	1372	0.003
Magnesium (Mg)	378	330	0.010	252	318	0.001
Sodium (Na)	89.40	125	0.002	156.78	192.48	<0.001
Calcium (Ca)	48.95	59.34	0.013	70.50	79..57	0.035
Iron (Fe)	26.56	24.87	0.240	22.89	16.71	0.007
Zinc (Zn)	5.33	7.24	0.008	11.20	13.78	<0.001
Manganese (Mn)	0.30	0.19	0.023	0.13	0.14	0.087
Copper (Cu)	2.24	1.81	0.051	0.98	0.98	1.000
Cobalt (Co)	0.50	0.48	0.669	0.51	0.48	0.214



	Potassium	Magnesium	Sodium	Calcium	Iron	Zinc	Manganese	Copper
BEG	10.99	28.29	2.50	2.07	82.90	31.03	2.48	54.30
BEW	8.83	32.40	1.79	1.71	88.56	22.86	3.91	67.00
LEG	11.76	27.26	3.85	2.78	55.70	59.06	1.83	29.40
LEW	10.35	21.60	3.14	2.46	76.30	48.00	1.57	29.40

% of the Dietary Reference values (DRVs) for humans ≥ 18 years old

Fig. 2. The role of 100 grams of wild meat sourced from breast muscles of Egyptian geese (BEG) and Eurasian wigeon (BEW), as well as leg muscles of Egyptian geese (LEG) and Eurasian wigeon (LEW) in fulfilling the DRVs for substantia

Amino acid profile

The wild bird breast and leg meat detailed amino acid profile is shown in Table 5. Wild bird species displayed significant variations ($P < 0.05$) in their sum of total amino acids (∑TAA) content. The breast meat of wigeon exhibited a greater amount of ∑TAA compared to the breast meat of Egyptian geese (94.85 and 93.92 g/100 g protein, respectively) and a similar trend in leg meat (98.62 and 93.80 g/100g protein, respectively). The genotype effect ($P < 0.05$) was demonstrated for the contents of 14 amino acids of breast meat, except for leucine, aspartic, and glutamic, and 12 amino acids in leg meat, except phenylalanine, glycine, tyrosine, aspartic, and serine. Glutamic acid, lysine, alanine, and aspartic acid were predominant in wigeon meat. In contrast to Egyptian geese meat, the predominant amino acids were glutamic acid, glycine, threonine, and aspartic acid. The EAA/N-EAA ratio averaged from 0.79 to 0.94, which means that the amino acid profile of wild bird breast and leg meat was dominated by non-essential amino acids (N-EAA) (54.55−51.63% of total AA), followed by essential amino acids (EAA) (48.37−45.45% of total AA). In accordance with previous research on the amino acid profiles of wild bird meat, the dominance of glutamic acid compared to other amino acids and the superiority of (N-EAA) over (EAA) align with our findings (Khalifa and Nassar, 2001; Geldenhuys et al., 2015; Khalifa et al., 2016; Straková et al., 2016). The intake of 150 g of pure meat of studied wild birds supplies a total of 28.5–34.2 g of protein, comprising 16.54 g of EAA, which is equal to 67% of human protein demand. The daily protein intake (0.66 g of protein/per kg/day) was determined by international organizations (WHO/FAO/UNU and Expert Consultation, 2007). This evaluation is still unfinished, and it is crucial to ascertain whether the overall quantity of provided protein is adequate to achieve the dietary requirements for distinct essential amino acids. However, such assessment was carried out using the data offered herein on wild birds' meat amino acid profile and real data on the essential amino acid requirements for adults (WHO/FAO/UNU and Expert Consultation, 2007), and the findings are visually represented in Fig. 3. Thus, the breast and leg meat of wild birds provides an adequate supply to meet the daily needs for individual essential amino acids.

Fatty acid profile

The fatty acids profile of breast and leg meat, accompanied by their ratios and nutritional quality indices for wild bird meat, are provided in Table 6. The findings indicated that wild bird species showed no significant ($P > 0.05$) variations in their saturated fatty acids (SFA) content, nor mono- and polyunsaturated fatty acids (MUSFA and PUSFA) partial sums, and their concentrations were consistent with those presented in the literature on gamebirds (Khalifa and Nassar 2001; Bombik et al., 2022). Among the individual fatty acids shows that the Egyptian geese breast exhibited markedly higher contents of palmitoleic (C16:1 cis-9, more 28.17%), but lower content of oleic acid (C18:1 cis-9, less 6.18%) compared to the breast meat of wigeon. Similar to the results reported by Khalifa and Nassar (2001). The ratio of n-6:n-3 content in the breast did not vary ($p > 0.05$) among the wild bird strains. These findings could be explained by the similarity in the concentrations of n-3 PUFAs and n-6 PUFAs. Similar results were discovered in meat mallard ducks (*Anas platyrhynchos L.*) (Bombik et al., 2022). The percentage of omega-6 to omega-3 fatty acids in meat represents one of the important criteria for evaluating the dietetic characteristics of food. Regardless of genotype, analysis of the fatty acid composition indicated that the major fatty acids in both the breast and leg muscles were C18:1 cis-9 (oleic acid), C16:0 (palmitic acid), C18:2n-6 (linoleic acid), and C18:0 (stearic acid). Similar findings were reported for shovelers and pintail meats (Abd El-Rahman et al., 2022). There was no significant difference ($P > 0.05$) in the h/H ratio and the AI, TI indices by the genotype. Therefore, the meat from wild bird examination was described by a small AI value, which was linked to a lower SFA/MUFA ratio. This has been suggested for a healthy diet (Laudadio et al., 2015).

Conclusion

In conclusion, wild Egyptian geese (*Alopochen aegyptiaca*) and wigeon (*Anas penelope*) are distinguished by acceptable carcass quality traits such as the distribution of carcass components. Valuable carcass components accounted for 77.42% in geese to 75.93% in wigeon of the total body weight. The normal acidity, increased water holding capacity, and dark color of the studied wild bird meats suggest elevated suitability for technology and has enhanced sensory characteristics. On the other hand, Egyptian geese breast and leg meat were demonstrated to be superior sources of protein, potassium, calcium, and zinc and lower sources of fat than wigeon meat. The studied wild bird meat is sufficient to supply the daily demands of all individual essential amino acids. However, the primary fatty acid identified was oleic acid (C18:1 cis-9) around 46 to 49%. The findings from this research suggest that wild bird meat can be appealing to contemporary consumers.

TABLE 5. Amino acid profile of breast and leg meats (mg/100 g protein) in wild Eurasian wigeon and Egyptian geese birds.

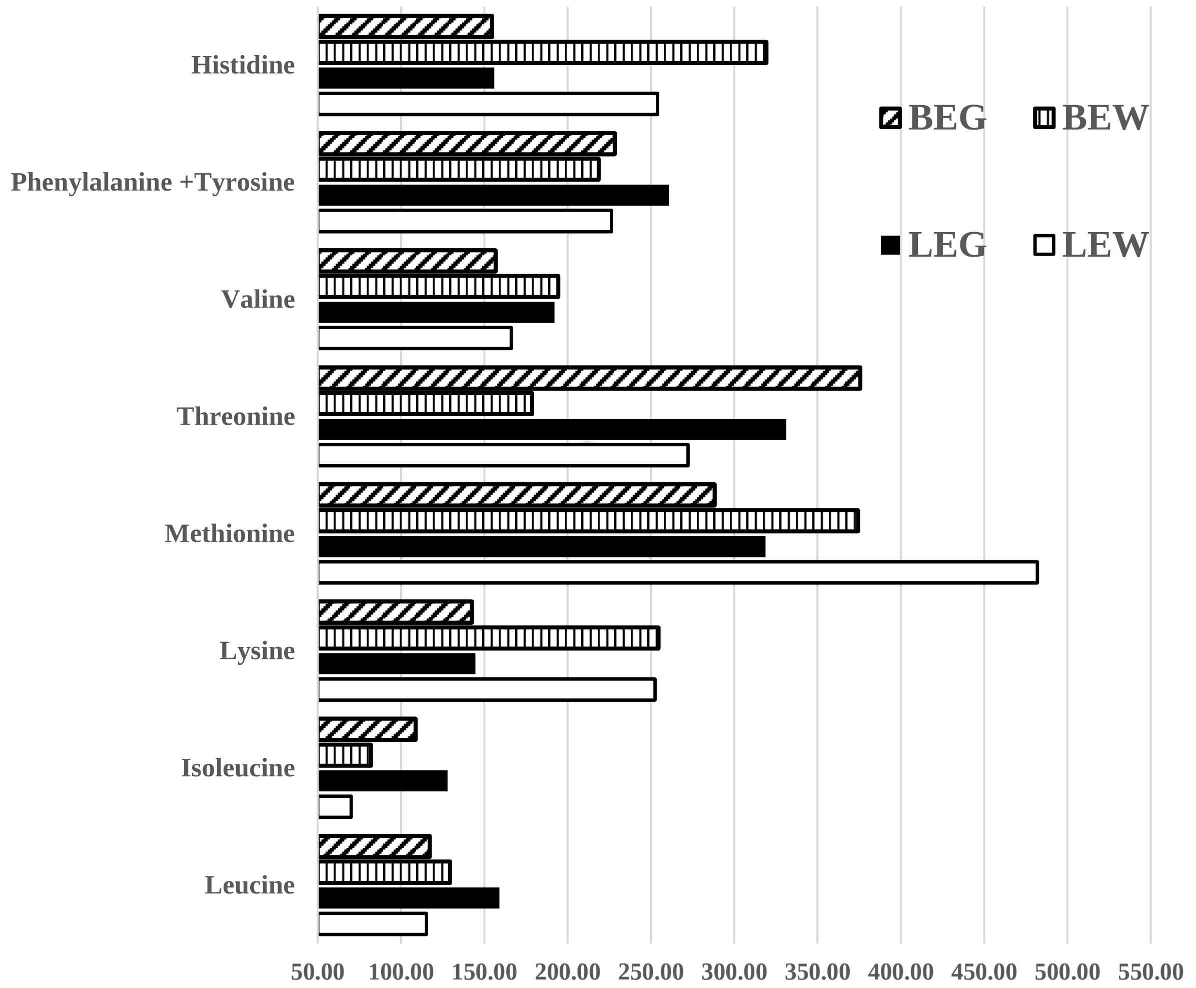
Item	Breast muscles		*p*-Value	Leg muscles		*p*-Value
	Wild birds with different genotypes			Wild birds with different genotypes		
	Eurasian wigeon	Egyptian geese		Eurasian wigeon	Egyptian geese	
Essential amino acids						
Leucine	7.64	6.91	0.558	6.80	9.39	0.003
Isoleucine	2.46	3.26	0.013	2.10	3.84	0.001
Lysine	11.46	6.41	<0.001	11.36	6.51	<0.001
Methionine	5.99	4.61	0.001	7.71	5.10	0.006
Threonine	4.11	8.64	0.001	6.26	7.62	0.003
Valine	7.58	6.11	0.004	6.48	7.49	0.004
Phenylalanine	4.47	5.42	0.043	4.12	5.44	0.048
Non-Essential amino acids						
Histidine	4.79	2.32	0.001	3.81	2.34	0.016
Arginine	2.50	3.34	<0.001	3.82	2.74	0.003
Glycine	5.45	9.55	<0.001	6.34	6.52	0.544
Cysteine	0.05	0.13	<0.001	0.04	0.07	0.016
Proline	2.41	5.44	<0.001	3.19	2.54	0.001
Tyrosine	3.84	3.25	0.005	4.48	4.47	0.966
Alanine	8.84	3.37	0.000	6.48	5.04	0.009
Aspartic	7.13	7.82	0.078	8.33	7.60	0.061
Glutamic	12.59	11.08	0.090	11.90	10.79	0.015
Serine	3.74	6.28	<0.001	5.42	6.34	0.098
∑TAA	95.05	93.92	0.045	98.62	93.80	0.002
∑EAA	43.71	41.35	0.007	44.82	45.37	0.442
∑N-EAA	51.34	52.57	0.474	53.80	48.43	<0.001
EAA /N-EAA ratio	0.85	0.79	0.105	0.83	0.94	0.003

Abbreviations: ∑TAA-sums of total amino acids; ∑EAA -sums of essential amino acids; ∑N-EAA-sums of non-essential amino acids.

TABLE 6. Fatty acid profile of breast and leg meats (% of total fatty acids) in wild Eurasian wigeon and Egyptian geese birds.

Item	Breast muscles		*p*-Value	Leg muscles		*p*-Value
	Wild birds with different genotypes			Wild birds with different genotypes		
	Eurasian wigeon	Egyptian geese		Eurasian wigeon	Egyptian geese	
Fatty acids						
C12:0	0.057	0.040	0.132	0.047	0.030	0.122
C14:0	0.970	0.623	0.012	0.890	0.573	0.003
C15:0	0.060	0.100	<0.001	0.077	0.097	0.013
C16:0	26.946	27.020	0.899	25.560	24.710	0.353
C17:0	0.117	0.147	0.033	0.160	0.147	0.016
C18:0	6.960	6.596	0.059	7.577	7.543	0.941
C20:0	0.286	1.346	0.000	0.220	1.507	0.003
C22:0	0.067	0.100	0.392	0.087	0.157	0.002
C14.1 *cis*-9	0.137	0.067	0.002	0.100	0.057	<0.001
C16:1 cis-9	5.573	7.143	0.001	5.509	7.721	0.060
C17:1 cis-9	0.087	0.077	0.349	0.107	0.087	0.251
C18:1 cis-9	49.206	46.340	0.001	48.800	46.687	0.027
C20:1 cis-9	0.286	0.170	0.155	0.450	0.360	<0.001
C18:2n-6	7.950	7.360	0.127	9.267	7.830	<0.001
C18:3n-3	0.746	0.730	0.815	0.540	1.170	0.002
Sums						
∑ SFA	35.463	35.973	0.347	34.617	34.763	0.875
∑ MUFA	55.290	53.797	0.062	54.307	53.167	0.203
∑ PUFA	8.696	8.090	0.074	9.807	9.000	0.068
Ratios						
P/S	0.245	0.224	0.011	0.283	0.259	0.017
n-6/n-3	10.680	10.287	0.783	17.171	6.743	<0.001
h/H	2.074	1.969	0.057	2.102	2.018	0.204
Indices						
Atherogenic Index	0.483	0.477	0.451	0.455	0.434	0.248
Thrombogenic Index	1.027	1.042	0.464	1.017	0.961	0.146

Abbreviations: ∑ SFA-sums of Saturated fatty acids; ∑ MUFA- sums of monounsaturated fatty acids; ∑ PUFA- sums of Polyunsaturated fatty acids; n-6/n-3- PUFA n-6/ n-3; h/H- hypocholesterolemic/hypercholesterolemic.



	Leucine	Isoleucine	Lysine	Methionine	Threonine	Valine	Phenylalanine +Tyrosine	Histidine
BEG	117.12	108.67	142.44	288.13	375.65	156.67	228.16	154.67
BEW	129.49	82.00	254.67	374.38	178.70	194.36	218.68	319.33
LEG	159.15	128.00	144.67	318.75	331.30	192.05	260.79	156.00
LEW	115.25	70.00	252.44	481.88	272.17	166.15	226.32	254.00

% of the Recommended Daily Intake (RDI) for humans ≥ 18 years old

Fig. 3. The recommendations of the amount of wild meat protein from breast muscles of Egyptian geese (BEG) and Eurasian wigeon (BEW), as well as leg muscles of Egyptian geese (LEG) and Eurasian wigeon (LEW) required to fulfill the RDI on essential amino acids, calculated for a normal adult person weighing 70 kg.

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Data availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Conflict of interest: The authors have no conflicts of interest to declare for this article.

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