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*(Original Article)*

# Nutritional Quality of Ostrich Meat, Edible Offal, and Fat Tissue

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## Abstract

Nutritional quality including gross chemical composition (moisture, protein, fat, and ash), mineral content, amino acid composition as well as fatty acid composition were investigated in ostrich meat and edible offal as well as characteristics of fat tissue. Ostrich (*Struthio Camelus*) meat and edible offal (liver, gizzard, and heart) had a considerable amount of protein (ranged from 16.54 to 20.80 % on wet wight basis), iron and zinc with low caloric value (ranged from 87.86 to 117.20 kcal/100g on wet basis) and sodium content (ranged from 57.85 to 90.01 mg/100g on wet weight basis). Methionine, lysin, and threonine were the predominant essential amino acids in ostrich meat and its giblets. The total essential amino acids were ranged from 37.15 to 47.20 g/ 100g crude protein. Moreover, alanine was the predominant non-essential amino acid followed by arginine in ostrich meat and its edible offal. On other hand, more than half of fatty acids in ostrich meat and most of its giblets are unsaturated fatty acids with discrimination of oleic and linoleic acids. Moreover, the total poly unsaturated fatty acids to saturated fatty acids ratio (P/S ratio) for ostrich meat was 0.53 and it agrees with recommendation of WHO in foods which was 0.4 to 0.5. The total lipids of ostrich meat and its edible offal fractionated to seven fractions while, its phospholipids fractionated to eight fractions. Moreover, ostrich fat tissue characteristics indicated its suitability for nutrition.

***Keywords:*** *Ostrich meat, Edible offal, Fat tissue, Nutritional quality.*

## Introduction

The Egyptians hunted ostriches since ancient times, and this was recorded through drawings Prehistoric rocks Ezz El-Din (2010). Ostrich bones were found in strata that date back to the Upper Palaeolithic Period in Egypt 13.000-10.000 B.C, Darby *et al*., (1977). When it comes to manufacturing animal protein, the poultry industry is regarded as one of the most productive. According to Al-Khalifa and Al-Naser (2014), ostrich meat is promoted as a healthy red meat due to its high polyunsaturated fatty acid content and low saturated fatty acid level when compared to other red meats like beef. Naseva *et al*. (2013) mentioned that the most common age to slaughter ostriches and obtain the best meat in terms of quality and quantity is between 12 and 14 months. Ostrich meat has a low level of

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intramuscular fat, a beneficial fatty acid composition (PUFA/SFA and n-6/n-3 ratios), high iron content and low sodium, so it has become more popular in recent years by Polawska *et al*. (2011).

Ostrich meat is a good choice for people who are concerned about their health and preferred red meat according to Akram *et al*. (2019). Slaughtering and preparing poultry produce many edible by-products, such as livers, hearts and stomachs (Murawska, 2013 and Toldrá *et al*., 2014). A lot of consumable offal from ostriches, which represents 4.2-5.8% of their live weight, is wasted due to the lack of sufficient research on their chemical composition, degradation standards and microbial quality, which are consumed immediately after cooking or processed to make meat products, by Malak (2023). According to Animal Production Research Institute (2004), oils of ratite (ostrich, emu, and rhea) represent about 15% of the whole-body weight. The lack of much information related to the quality of edible ostrich waste leads to its ineffective use in the meat processing industry. Therefore, studying the chemical composition, especially in comparison with commonly used turkey litter, may enable the use of ostrich litter on a large scale in meat and pet food production by increasing rearing and processing efficiency by Florek *et al*. (2012).

To meet the growing human population's increasing demand for meat consumption, ostrich meat can serve as a good alternative for consumers. Ostrich farming is an industry that is quickly expanding all over the world, and ostrich meat is increasingly vital for human use. The utilization of ostrich meat is hindered by the public's ignorance of its nutritional value and the paucity of scientific data regarding the nutritious makeup of ostrich meat. Information on the nutritional makeup of ostrich meat is greatly needed given the importance that people place on food's nutritive value. Therefore, the current study was aimed to determine the chemical composition, minerals content, amino acid and fatty acids composition, total lipids, and phospholipids fractions of ostrich meat, edible ostrich offal (liver, gizzard, and heart) and ostrich fat tissue.

## Materials and Methods

### Materials

Ostrich meat (*M. iliofibulars*), ostrich edible offal (liver, gizzard, and heart) and fat tissue were purchased from a local market at Cairo city, Egypt.

The samples were cut and minced using a meat mincer, packaged in bags of polyethylene, then kept in a freezer at -18±1ºC. Frozen meat was thawed overnight in a refrigerator (4±1 ºC) prior to analysis.

### Chemicals

All chemicals used in this study were obtained from EL-Gamhouria for Trading Chemicals and Drugs Co., Assiut city, Egypt.

## Methods

### Proximate chemical composition

Moisture, protein, fat, and ash contents of studied samples were determined according to AOAC (2016).

### Caloric value calculation

Caloric value was calculated as follows:

Caloric value (kcal/100 g) = (% protein × 4) + (% fat × 9) + (% carbohydrate × 4), as described by Mohamed (2005).

### Determination of minerals content

The concentration of 10 minerals (Ca, K, Mg, Na, Fe, Zn, Mn, Cd and Pb) in the samples of ostrich meat and the offal (heart, gizzard, and liver) were determined using atomic absorption spectrometry (AAS) Solar 969, while phosphors (P) was determined using UV- visible spectrophotometers " Helios Alpha", after digestion all dried samples. The determination was carried out as described by AOAC (1995).

### Amino acids composition analysis

Amino acids composition using HPLC-Pico-Tag: The amino acids composition of experimental samples was determined using HPLC-Pico-Tag method according to Millipore Cooperative (1987). The Pico-Tag method was described by Heinrikson and Meredith (1984), White *et al*. (1986) and Cohen *et al*. (1987).

### Fatty acid composition analysis

Fatty acid composition was determined according to Rossell *et al*. (1983) and Kates (1972).

### Physicochemical properties of ostrich fat tissue

The refractive index was calculated using abbe refractometer and total acidity according to ISO (2009). Density and specific weight according to the methods mentioned by Pearson (1970). Iodine number of ostrich fat was estimated by the method reported by AOAC (1984). Saponification number according to the methods mentioned in AOAC (2005). The pH value determined according to the method described by Fernandez-Lopez *et al*. (2006).

### Lipids analysis

The lipids were extracted from tissue samples by chloroform: methanol mixture (2:1, v/v) according to the method described by Folch *et al*. (1957).

### Fractionation of total lipids by thin layer chromatographic technique (TLC)

The total lipids of ostrich meat, offal (liver, gizzard, and heart) and fat tissue were fractionated on silica gel G-coated thin layer plates using a solvent system of petroleum ether: diethyl ether: glacial acetic acid (80: 20: 1, v/v/v) as described by Mangold (1969). The lipid fractions were visualized by exposure to iodine vapor.

**Thin layer chromatographic fractionation of phospholipids**

The phospholipids were separated on silica gel G-coated thin layer plates using a solvent system of chloroform: methanol: water mixture (65: 25: 4, v/v/v) mentioned by Kates (1972), with some modification. The separated fractions of phospholipids were visualized by exposure to iodine vapor. For quantitative analysis, the TLC chromatograms were scanned using Mobil program (Cam Scanner Version 6.50.0.2309210000) and the data were analyzed by QS computer program analysis (TL see V2.0 version Demo) according to the method described by Molander (1960).

**Statistical analysis**

The obtained data from three replicates were analyzed by ANOVA using. The SPSS statistical package program, and differences among the means were compared using the Duncan's Multiple Range test (SPSS, 2011).

**Results and Discussion**

**Proximate chemical composition and caloric value of ostrich meat, edible offal, and fat tissue**

The proximate chemical composition and caloric value (wet weight basis) of ostrich meat (*M. iliofibulars*), edible offal (liver, gizzard, and heart) and fat tissue are presented in Table (1). There were significant differences at ($p<0.05$) between the studied ostrich parts expect moisture content between ostrich meat and heart.

The obtained results for moisture of ostrich meat were in the same line with the results of Horbanczuk *et al*. (2019) and Akram *et al*. (2019) they determined the chemical composition of raw ostrich meat as moisture 75.40±0.26%, 76.51±0.05% respectively. Regarding the moisture content of ostrich heart, gizzard, and liver the obtained data in Table (1) was in agreement with the results of Adamczak *et al*. (2017).

Regarding protein content, the highest value (20.80%) was recorded for ostrich meat while, the lowest value (4.24%) was found in fat tissue.

Besides, liver, gizzard, and heart recorded intermediate values of protein contents. Moreover, there were significant differences at ($p<0.05$) between the studied ostrich parts for its content of protein. Moreover, the obtained protein value in fan muscle (20.80 ± 0.21%) was lower than that reported by Zarasvand *et al*. (2012) they found that the crude protein was 22.40±0.55%, it was slightly less than of that given by Akram *et al*. (2019) and Horbanczuk *et al*. (2019) which were 21.18±0.06 and 21.50±0.11%, respectively and that might be due the differences of strains, sex, feeding and ages.

Besides, the protein content of ostrich liver, gizzard, and heart was in the same line with the results of Adamczak *et al*. (2017) they stated, that fresh ostrich heart, liver and stomach muscle contained 17.10 to 19.30, 13.00 to 19.50 and 18.20

to 20.50% protein, respectively. Regarding to the fat content, there was a significant difference at ($p<0.05$) between the studied ostrich parts, except between ostrich meat and gizzard. However, ostrich meat considers low fat (1.28%) compared with other meat types according to USDA (1979&1986). Moreover, fat tissue recorded the highest fat content (86.41± 0.35%).

Besides, the fat content of ostrich heart, gizzard and liver recorded (2.84±0.17, 1.42±0.05 and 5.67±0.13% respectively) was in the same line with the results of Adamczak *et al*. (2017) they stated, that fresh ostrich heart, stomach muscle and liver contained 1.6 to 2.80, 0.6 to 1.30 and 4.40 to 28.40% fat, respectively.

The obtained results of fat tissue were in the same line with the results of Al-Baidhani and Al-Mossawi (2019) they indicated that the ostrich fat tissue percentages of moisture, protein, fat, and ash were 5.56%, 5.16%, 87.88% and 1.03%, respectively.

The ash content of ostrich meat, edible offal and fat tissue ranged from 0.97 to 1.17% as indicated in Table (1). However, Akram *et al*. (2019) and Horbanczuk *et al*. (2019) mentioned higher content of ash (1.14±0.03 and 1.15±0.01% ash, respectively) for ostrich meat. Besides, the ash content of ostrich liver, gizzard and heart agreed with the results of Adamczak *et al*. (2017). Data in Table (1) indicated that ostrich meat and its edible offal were low in its caloric value which ranged from 87.86 to 117.20 kcal/100g and that may be due to low fat content. As expected, fat tissue recorded high caloric value (794.66 kcal/100g).

The obtained results for caloric value of ostrich meat were agreed with the results of Abd El Kareem (2021) who found that the mean caloric value of thigh, back, and leg ostrich meat was 101.3 ± 0.73, 97.03 ± 0.93 and 96.25 ± 0.67 Kcal/100gm, respectively.

**Table 1. Proximate chemical composition (%) and caloric value of ostrich meat, edible offal, and fat tissue (Wet weight basis)**

| Constituents | The Studied parts | | | | |
|---|---|---|---|---|---|
| | Ostrich Meat | Liver | Gizzard | Heart | Fat tissue |
| **Moisture** | $77.75^{b} \pm 0.31$ | $69.30^{c} \pm 0.11$ | $79.84^{a} \pm 0.23$ | $77.62^{b} \pm 0.21$ | $6.28^{d} \pm 0.15$ |
| **Dry matter** | $22.25^{c} \pm 0.31$ | $30.70^{b} \pm 0.11$ | $20.16^{d} \pm 0.23$ | $22.38^{c} \pm 0.21$ | $93.72^{a} \pm 0.15$ |
| **Protein** | $20.80^{a} \pm 0.21$ | $16.54^{d} \pm 0.14$ | $18.77^{b} \pm 0.19$ | $17.91^{c} \pm 0.31$ | $4.24^{e} \pm 0.01$ |
| **Fat** | $1.28^{d} \pm 0.05$ | $5.67^{b} \pm 0.13$ | $1.42^{d} \pm 0.05$ | $2.84^{c} \pm 0.17$ | $86.41^{a} \pm 0.35$ |
| **Ash** | $0.97^{c} \pm 0.00$ | $1.14^{a} \pm 0.02$ | $1.10^{b} \pm 0.03$ | $1.17^{a} \pm 0.02$ | $1.06^{b} \pm 0.02$ |
| **Caloric value (Kcal/100g)** | $94.70^{c} \pm 0.62$ | $117.20^{b} \pm 0.92$ | $87.86^{d} \pm 0.40$ | $97.18^{c} \pm 1.82$ | $794.66^{a} \pm 3.21$ |

Different superscript letters indicate significance within the same row ($p<0.05$).

## Minerals content of ostrich meat and edible offal

The concentrations of ten minerals in the studied ostrich parts are revealed in Table (2). Ostrich meat and its edible offal seem to be low in calcium content which recorded 5.20, 9.96, 4.97, and 4.17 mg/100g in ostrich meat, liver, gizzard, and heart respectively. The obtained results were in same line with results of

USDA (2016); Shameeva *et al*. (2018) and Akram *et al*. (2019). The obtained results of phosphorous indicated that ostrich meat (185.33 mg/100g) had more phosphorous than the studied edible offal where its content ranged from 54.76 to 107.38 mg/100g. However, more values for phosphorous (193.9 – 329.8 mg/100g) were reported by Poławska *et al*. (2016) and Abd El Kareem (2021).

Liver and heart contained lower potassium compared with ostrich meat and gizzard. Moreover, potassium content was 308.34, 85.24, 297.18, and 94.95 mg/100g in ostrich meat, liver, gizzard, and heart respectively. On other hand, Abd El Kareem (2021) found that potassium content of ostrich meat ranged from 210.5 to 375.7 mg/100g.

Regarding sodium, ostrich meat was of low sodium content (57.85 mg/100g) It can be recommended for high blood pressure patients. Generally, the sodium levels in ostrich meat are far lower than in meats such as beef (63 mg/100g) and chicken (77 mg/100g) as also indicated by Sales and Oliver-lyons (1996) and Polawska *et al*. (2011).

As indicated to Table (2) magnesium recorded 17.20 mg /100 g ostrich meat Majewska *et al*. (2009) found that ostrich meat contained 23.8 to 25.3 mg/100g of magnesium. Beside the studied ostrich edible offal contained 8.12 to 11.54 mg/100g of magnesium. However, magnesium plays an important role in the metabolism of potassium and calcium and is an important part of the formation of bones and teeth. As the bone contains about half of the magnesium in the body while the blood contains little yang *et al*. (2020).

Moreover, the micro element, iron (Fe) content was 8.43, 16.98, 5.75, and 6.16 mg/100g in ostrich meat, liver, gizzard, and heart respectively. However, the obtained result for iron was higher than previous studies by Lombardi-Boccia *et al*. (2005), Karklina and Kivite (2007), Majewska *et al*. (2009), Abd El Kareem (2021), and that may be due to the differences of strains, sex, feeding and ages. Furthermore, is one of the vital minerals needed for the optimum function of blood where iron deficiency causes anemia, especially in pregnant women and children Benoist (2001).

On other hand, the contents of zinc (Zn) were 2.02, 2.79, 3.17 and 1.42 mg/100g in ostrich meat, liver, gizzard, and heart respectively as shown in Table (2). Levels of zinc in ostrich meat evaluated by Majewska *et al*. (2009) varied between 2.02 and 4.30 mg/100 g in different muscles. Zinc is an important mineral needed for good health to keep our immune systems healthy.

Furthermore, manganese content was 0.30, 0.38, 0.20, and 0.16 mg/100g in ostrich meat, liver, gizzard, and heart respectively. However, manganese content of ostrich meat was raged form 0.012 – 0.017 mg/100g as found by Majewska *et al*. (2009). Manganese helps with blood sugar regulation, bone formation, reproduction, immune health and reduces oxidative stress National institute of health, (2021).

Toxic heavy metal concentrations were also investigated in the present study as Cd and Pb in ostrich meat, liver, gizzard, and heart. Cadmium was found to be

0.09, 0.01 and 0.06 mg/100g of ostrich meat, liver, and gizzard respectively, while it was absent in ostrich heat. On other hand, lead was found only as 0.44 mg/100g in ostrich liver. Moreover, lead content was lower than in other wild birds such as the Woodcock bird (0.59-0.89 mg /100gww), Turtledove bird (3.34 mg /100gww) and quail bird (9.85 mg /100gww) that investigated by Roselli *et al*. (2016). The lead content of Northern Pintail meat ranged from 1.08 to 1.43 mg/100g dry wight while, cadmium ranged from 0.05 to 0.11 mg/100g dry wight as reported by Abd El-Rahman *et al*. (2022).

The permissible limits of lead were 0.10 mg/kg ww and Cadmium 0.05 mg/kg ww established by EC, (2006) and thus, Pb and Cd exceeded maximum admissible levels. And thus, may be due to the high contamination of water and feed as well as environmental conditions.

**Table 2. Minerals content of ostrich meat and edible offal (mg/100g wet weight basis)**

| Minerals | The studied parts | | | |
|---|---|---|---|---|
| | Ostrich meat | Liver | Gizzard | Heart |
| **Ca** | 5.20 | 9.69 | 4.97 | 4.17 |
| **P** | 185.33 | 93.35 | 107.38 | 54.76 |
| **K** | 308.34 | 85.24 | 297.18 | 94.95 |
| **Na** | 57.85 | 90.01 | 85.32 | 59.18 |
| **Mg** | 17.20 | 11.05 | 11.54 | 8.12 |
| **Fe** | 8.43 | 16.98 | 5.75 | 6.16 |
| **Zn** | 2.02 | 2.79 | 3.17 | 1.42 |
| **Mn** | 0.30 | 0.38 | 0.20 | 0.16 |
| **Cd** | 0.09 | 0.01 | 0.06 | ND |
| **Pb** | ND | 0.44 | ND | ND |

ND- No detected.

## Amino acids composition of ostrich meat and edible offal

Amino acids composition of ostrich meat and its edible offal are presented in Table (3). The total essential amino acids ranged from 37.15 to 47.20 g/ 100g crude protein. However, predominant amino acids were methionine, lysine, and threonine.

According to, National Center for Biotechnology Information CID 6137 (2024) methionine necessary for tissue growth and absorption of zinc and selenium, minerals that are vital to our health.

Lysine plays major roles in protein synthesis, calcium absorption, and the production of hormones and enzymes. It’s also important for energy production, immune function, and collagen and elastin production, reported by National Center for Biotechnology Information CID 5962 (2024).

Threonine is a principal part of structural proteins such as collagen and elastin, which are important components of our skin and connective tissue. It also plays a role in fat metabolism and immune function, National Center for Biotechnology Information CID 6288 (2024). Moreover, the daily required intakes for these essential amino acids were 10.40, 30, and 15 mg/kg of body weight for adults of methionine, lysin, and threonine, respectively according to the World Health Organization. WHO, (2002 technical report series; no. 935).

On other hand, the non-essential amino acids constituted from 46.64 to 56.81 g/100g crude protein of ostrich meat and its edible offal as revealed in Table (3). Furthermore, predominant non-essential amino acids were alanine, arginine, and tyrosine. Moreover, Sales and Hayes (1996) reported that lysin was predominant essential while glutamic acid was the major of non-essential amino acids.

**Table 3. Amino acids composition of ostrich meat and edible offal (g/ 100g crude protein)**

| Amino acid | The studied parts | | | |
|---|---|---|---|---|
| | Ostrich Meat | Liver | Gizzard | Heart |
| Threonine | 6.24 | 6.27 | 5.71 | 8.98 |
| Valine | 3.83 | 3.80 | 4.95 | 5.91 |
| Methionine | 14.03 | 11.83 | 14.35 | 15.72 |
| Isoleucine | 0.74 | 0.70 | 0.90 | 0.94 |
| Leucine | 4.13 | 3.18 | 3.88 | 4.74 |
| Phenylalanine | 5.15 | 4.56 | 2.57 | 4.14 |
| Lysine | 7.15 | 6.81 | 6.36 | 6.78 |
| **Total essential amino acids (E)** | 41.26 | 37.15 | 38.72 | 47.20 |
| Histidine | 3.51 | 3.72 | 3.81 | 2.38 |
| Arginine | 7.38 | 7.39 | 7.91 | 6.43 |
| Aspartic acid | 2.39 | 3.25 | 2.80 | 3.13 |
| Serine | 5.71 | 6.01 | 5.31 | 4.38 |
| Glutamic acid | 6.94 | 5.26 | 4.49 | 5.53 |
| Proline | 5.21 | 5.84 | 6.01 | 6.66 |
| Alanine | 11.74 | 14.36 | 13.76 | 8.40 |
| Cysteine | 2.53 | 3.29 | 3.33 | 1.81 |
| Tyrosine | 6.49 | 7.33 | 7.21 | 6.82 |
| Glycine | 0.74 | 0.35 | 0.75 | 1.11 |
| **Total non-essential amino acids (NE)** | 52.64 | 56.81 | 55.39 | 46.64 |
| **Total amino acid** | 93.90 | 93.96 | 94.11 | 93.84 |
| **E/NE ratio** | 0.78 | 0.65 | 0.70 | 1.01 |

## Fatty acids composition of ostrich meat, edible offal, and fat tissue

Fatty acid composition of ostrich meat, edible offal (liver, gizzard, and heart) and fat tissue are presented in Table (4). Total saturated fatty acids ranged from 36.11 to 56.88 % of total fatty acids. Among the studied parts, ostrich meat recorded the lowest saturated fatty acids (36.11), while liver recorded the highest. However, palmitic, and stearic acids were the most predominant saturated fatty acids in ostrich meat and the offal (liver, gizzard, and heart) and fat tissue.

On other hand, the total unsaturated fatty acids were 54.01, 39.06, 59.40, 58.33, and 50.53 % of total fatty acids for ostrich meat, liver, gizzard, heart, and fat tissue, respectively. Generally, oleic acid was the major unsaturated fatty acids in the studied parts. Also, as in this study, oleic acid (C18:1) is the most abundant fatty acid in ostrich meat, followed by palmitic acid (C16:0) and linoleic acid (C18:2n-6) Sales (1994); Horbanczuk *et al*. (1998); Paleari *et al*. (1998); Sales (1998); Hoffman and Fisher (2001) and Antunes *et al*. (2018).

Besides, the poly unsaturated fatty acids constituted 19.27 % of total fatty acids in ostrich meat while it was 8.29 % in liver, 19.23 % in gizzard and 17.31 % in heart but fat tissue contained lowest value (3.24% of total fatty acids) and that because fat tissue contained high level of oleic acid (42.04% of total fatty acids) as indicated in Table (4).

**Table 4. Fatty acids content of ostrich meat, edible offal, and fat tissue (% of total fatty acids)**

| Carbon chain | Fatty acid (name) | The studied parts | | | | |
|---|---|---|---|---|---|---|
| | | Ostrich meat | Liver | Gizzard | Heart | Fat tissue |
| **C14:0** | Myristic acid | 0.59 | 0.43 | 0.64 | 0.69 | 0.90 |
| **C15:0** | Pentadecanoic acid | 0.28 | 0.00 | 0.00 | 0.34 | 0.34 |
| **C16:0** | Palmitic acid | 20.96 | 28.14 | 25.96 | 26.23 | 33.95 |
| **C16:1 ω7** | Palmitolic acid 9 Hexadecenoic acid | 4.19 | 2.42 | 3.60 | 4.76 | 4.64 |
| **C17:0** | Margarinic acid | 0.44 | 0.43 | 0.40 | 0.53 | 0.53 |
| **C17:1 ω7** | Heptadeconoic acid | 0.20 | 0.31 | 0.09 | 0.19 | 0.14 |
| **C18:0** | Stearic acid | 13.50 | 27.70 | 11.34 | 10.35 | 12.36 |
| **C18:1 ω9** | Oleic acid | 26.48 | 25.44 | 33.37 | 35.76 | 42.04 |
| **C18:1 T ω9** | Oleic acid trans | 3.69 | 2.60 | 3.10 | 0.00 | 0.00 |
| **C18:2 ω6** | Linoleic acid | 17.13 | 7.62 | 12.68 | 14.79 | 2.95 |
| **C18:3 ω3** | Linolenic acid | 1.63 | 0.56 | 2.13 | 2.24 | 0.10 |
| **C18:3 ω6** | α Linolenic acid | 0.16 | 0.11 | 0.00 | 0.00 | 0.19 |
| **C20:0** | Arachidic acid | 0.09 | 0.18 | 0.18 | 0.14 | 0.16 |
| **C20:1 ω9** | Gondoic acid 5-Ecosenic acid (Trans) | 0.18 | 0.00 | 0.00 | 0.31 | 0.47 |
| **C20:2 ω6** | Ecosadienoic acid | 0.34 | 0.00 | 4.42 | 0.28 | 0.00 |
| **C22:0** | Behenic acid | 0.25 | 0.00 | 0.00 | 0.07 | 0.02 |
| **Total Fatty acids %** | | 90.12 | 95.94 | 97.92 | 96.67 | 98.78 |
| **Non identified fatty acid** | | 9.88 | 4.06 | 2.08 | 3.33 | 1.22 |
| **Essential fatty acid** | | 18.85 | 8.36 | 14.98 | 17.16 | 3.20 |
| **Total saturated fatty acid (SFA)** | | 36.11 | 56.88 | 38.52 | 38.34 | 48.25 |
| **Total unsaturated fatty acid (UFA)** | | 54.01 | 39.06 | 59.40 | 58.33 | 50.53 |
| **Total monounsaturated fatty acid (MUFA)** | | 34.74 | 30.77 | 40.17 | 41.02 | 47.29 |
| **Total polyunsaturated fatty acid (PUFA)** | | 19.27 | 8.29 | 19.23 | 17.31 | 3.24 |
| **ω6/ ω3** | | 10.79 | 13.74 | 8.04 | 6.73 | 32.12 |
| **PUFA/SFA ratio** | | 0.53 | 0.15 | 0.50 | 0.45 | 0.07 |

Oleic acid might improve heart conditions by lowering cholesterol and reducing inflammation, Sales-Campos (2013).

The high content of oleic acid in ostrich fat tissue indicates the importance of using ostrich fat tissue in this concern. On other hand, similar results for fatty acids composition in ostrich fat tissue were found by Al-Baidhani and Al-Mossawi (2019).

Regarding ω6/ ω3 fatty acids ratio, it is clear that ostrich meat and its edible offal as well as fat tissue had higher content of ω6 than ω3 fatty acid. According to Lunn and Theobald (2006) both (ω-3) and (ω-6) fatty acids are important components of cell membranes and are precursors to many other substances in the body such as those involved in regulating blood pressure and inflammatory responses. In addition, the polyunsaturated to saturated fatty acids ratio were 0.53, 0.15, 0.50, 0.45, and 0.07 for ostrich meat, liver, gizzard, heart, and fat tissue.

The polyunsaturated to saturated fatty acid value recommended by WHO (2003) and FAO (1985) is 0.4 to 0.5 in foods, which means that ostrich meat, ostrich gizzard as well as ostrich heart can be consumed as a healthy product for people seeking healthy lifestyle.

**Physicochemical properties of ostrich fat tissue**

The results in Table (5) showed the physicochemical properties of ostrich fat tissue, total acidity recorded 0.66 % as oleic acid, while saponification value was 200 mg/ KOH equivalent /g fat. pH value was 7.23, on other hand Iodine number recorded 78.65 (I/100 g fat). Regarding refractive index was 1.46, density was 0.9194, specific weight 0.8891. The obtained results were in the same line as the results of Al-Baidhani and Al-Mossawi (2019).

Generally, the relative density and melting point are the basic qualities of fat, which reflects the degree of purity and the high iodine number which was 78.65 ($gI_2$/100g fat) reflects a high proportion of fatty acids unsaturated (50.53 % of total fatty acid) as well as its the fatty acid composition. So, according to the characteristics of the ostrich fat it is considered suitable and appropriate for use it in food industry, and in manufacture of drugs and cosmetics as previously reported by Al-Baidhani and Al-Mossawi (2019).

**Table 5. physicochemical properties of ostrich fat tissue**

| | |
|---|---|
| Total acidity (as oleic acid) | 0.66 |
| Saponification (equivalent/g fat) | 200.00 mg KOH |
| pH | 7.23 |
| Iodine number ($gI_2$/100g fat) | 78.65 |
| Refractive index | 1.46 |
| Density | 0.9194 |
| Specific weight | 0.8891 |

**Total lipids composition of ostrich meat, edible offal, and fat tissue**

The data presented in Table (6) revealed the total lipid fractions of lipids extracted from ostrich meat, edible offal, and fat tissue. The total was fractionated to seven fractions namely: phospholipids, monoglycerides, cholesterol, diglycerides, free fatty acids, triglycerides, and hydrocarbons using thin layer chromatographic technique (TLC) as shown in Figure (1).

**Table 6. Total lipid composition of ostrich meat, edible offal, and fat tissue (as% of total lipids)**

| Fractions | The Studied parts | | | | |
|---|---|---|---|---|---|
| | Ostrich meat | Liver | Gizzard | Heart | Fat tissue |
| **Hydrocarbons** | 1.06 | 4.09 | 3.60 | 10.69 | 4.67 |
| **Triglycerides** | 22.18 | 47.20 | 53.99 | 26.80 | 48.11 |
| **Free fatty acids** | 0.55 | 5.44 | 2.54 | 3.40 | 7.20 |
| **Diglycerides** | 6.25 | 12.81 | 8.30 | 19.10 | 8.92 |
| **Cholesterol** | 1.08 | 3 | ND | 3.34 | 7.59 |
| **Monoglycerides** | 1.11 | 3.97 | 4.79 | 11.83 | 18.92 |
| **Phospholipids** | 67.78 | 20.34 | 23.23 | 24.82 | 4.58 |

ND- No detected.

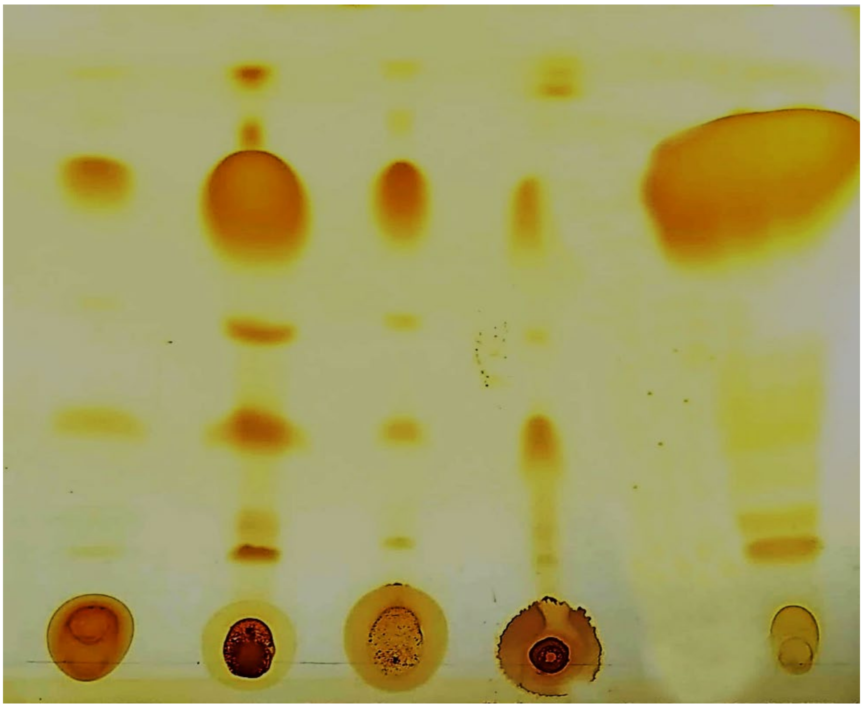


**Figure 1. Total lipid composition of ostrich meat, edible offal, and fat tissue**

The total lipids of ostrich meat contained 67.78, 1.11, 1.08, 6.25, 0.55, 22.18 and 1.06 phospholipids, monoglycerides, cholesterol, diglycerides, free fatty acids, triglycerides, and hydrocarbons (as % of total lipids) respectively.

Moreover, ostrich liver, gizzard, and heart contained 20.34, 23.23 and 24.82% phospholipids, 3.97, 4.79 and 11.83% monoglycerides, 3.00, 0.00 and 3.34% cholesterol, 12.81, 8.30 and 19.11% diglycerides, 5.44, 2.54 and 3.40% free fatty acids, 47.20, 53.99 and 26.80% triglycerides, 4.09, 3.60 and 10.69% hydrocarbons: respectively. Regarding to, ostrich fat tissue, triglyceride constituted 48.11% of total lipids while, it recorded the lowest phospholipids content (4.76% of total lipids).

Furthermore, cholesterol fraction was low in ostrich meat (1.08 %of total lipids) and an opposite trend was observed in ostrich fat tissue recording (7.59 % of total lipids) while, liver and heart recorded intermediate levels (3.00 and 3.34 % of total lipids respectively) of cholesterol. Such data are in agreement with the results reported by Khalifa (1995) for chicken meat and Henry (2020) for chicken edible by-products.

**Phospholipid fractions of ostrich meat, edible offal, and fat tissue**

According to Ali *et al*. (2019), there is ample evidence that phospholipids (PLs) provide specific nutritional advantages for human health, including lowering the risk of cardiovascular diseases, enhancing liver functions, and lowering the absorption of cholesterol. The data given in Table (7) and Figure (2) revealed the phospholipids fractionation of ostrich meat, edible offal, and fat tissue. Phospholipids of ostrich meat, edible offal, and fat tissue were fractionated to eight different fractions of phospholipids namely: phosphatidyl serine (PS), lysophosphatidyl choline (LPC), phosphatidyl inositol (PI), sphingomyelin (SL), phosphatidyl choline (PC), phosphatidyl ethanol amine (PE), phosphatidic acid (PA) and phosphatidyl glycerol (PG). Such data agree with the results reported by Khalifa (1995), who indicated that phospholipids of chicken and of quail meats contained the same fractions. The highest value of phosphatidyl serine was found in ostrich meat and ostrich heart (42.30 and 51.14 % of total phospholipids, respectively).

**Table 7. Phospholipid fractions of ostrich meat, edible offal, and fat tissue (as% of total phospholipids) Conclusion**

| Fraction | The Studied parts | | | | |
|---|---|---|---|---|---|
| | Ostrich meat | Liver | Gizzard | Heart | Fat tissue |
| **Phosphatidyl glycerol (PG)** | 18.26 | 12.21 | 52.44 | 6.12 | 97.29 |
| **Phosphatidic acid (PA)** | 4.25 | 10.17 | 0.85 | ND | ND |
| **Phosphatidyl ethanolamine (PE)** | 10.95 | 23.91 | 17.49 | 1.47 | 0.74 |
| **Phosphatidyl choline (PC)** | 13.96 | 27.85 | 23.64 | 16.92 | ND |
| **Sphingomyelin (SL)** | 1.57 | 1.65 | 1.28 | 1.20 | 0.55 |
| **Phosphatidyl inositol (PI)** | 3.70 | 2.39 | 1.28 | 17.51 | 0.20 |
| **Lysophosphatidyl choline (LPC)** | 5.01 | 12.25 | 0.72 | 5.14 | 0.17 |
| **Phosphatidyl serine (PS)** | 42.30 | 9.04 | 2 | 51.14 | 1.04 |

ND- No detected.

According to Cleveland Clinic medical (2023) phosphatidyl serin enhances glucose metabolism as well as protects nerve cells in brain and enables them to communicate with each other. Less amounts of phosphatidyl serine were found in ostrich liver, gizzard, and fat tissue as 9.04, 2.00, and 1.04 % of total phospholipids respectively. Lysophosphatidyl choline was found as 12.25, 5.14, and 5.01 % of total phospholipids in ostrich liver, heart, and meat respectively while small amounts (0.72 and 0.17 % of total phospholipids) in ostrich gizzard and fat tissue respectively. Moreover, phosphatidyl choline recorded 13.96, 27.85, 23.64, and 16.92 %of total phospholipids) in ostrich meat, liver, gizzard, and heart respectively but it was absent in ostrich fat tissue. Parian *et al* (2018), reported that phosphatidylcholine acts as a surfactant within the mucus to create a hydrophobic surface to prevent bacterial penetration as it is an important component of the colon mucosal layer.

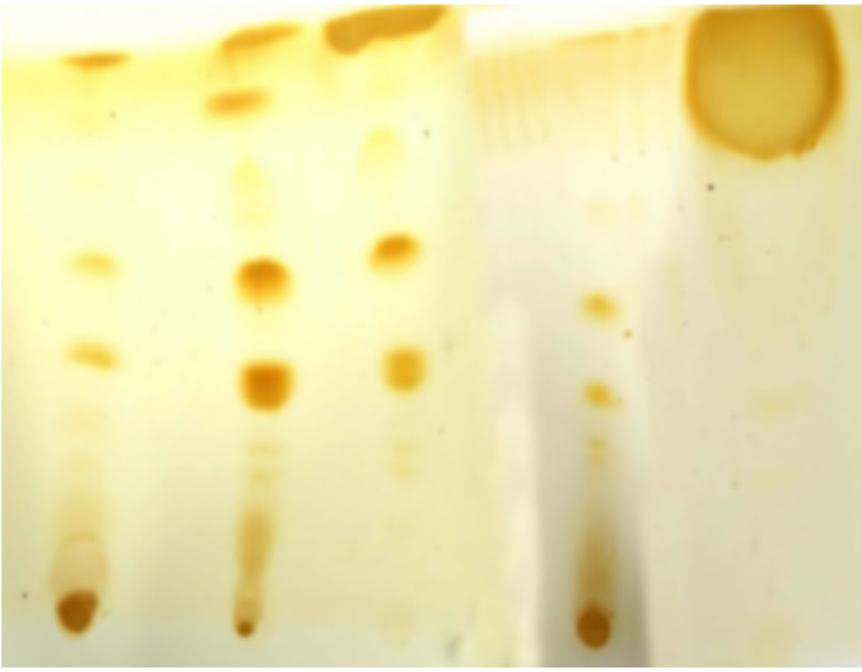


**Figure (2) Phospholipids fractions of ostrich meat, edible offal, and fat tissue.**

Regarding phosphatidyl inositol, the high amount was found in ostrich heart 17.51 % of total phospholipids while, the small amounts were found in ostrich meat (3.70 %), liver (2.39%), gizzard (1.28%) and fat tissue (0.20%). Furthermore, Sphingomyelin was found by nearly similar amounts in the studied parts which ranged from 0.55 to 1.65 % of total phospholipids as indicated in Table (7). Phosphatidyl ethanolamine recorded 10.95, 23.91, 17.49, 1.47, and 0.74 % of total phospholipids in ostrich meat, liver, gizzard, heart, and fat tissue respectively.

Phosphatidic acid was 4.25 and 10.17 % of total phospholipids in ostrich meat and liver respectively, while found with small amount in gizzard (0.85%), but it was absent in ostrich heart and fat tissue. Ridgway (2021) mentioned that phosphatidyl glycerol stabilizes alveolar structure and contributes to the innate immune response, PG is present at high concentrations in lung surfactant (5–17% of lipid mass), PG comprises only approximately 1% of mammalian membrane phospholipid mass. However, among those studies parts, ostrich fat tissue contained the highest value of phosphatidyl glycerol (97.29 %) followed by gizzard (52.44 % of total phospholipids). Besides, phosphatidyl glycerol was found to be 18.26, 12.21, and 6.12 % of total phospholipids in ostrich meat, liver, and heart, respectively.

## Conclusion

Ostrich meat and edible offal (liver, gizzard, and heart) had a considerable amount of protein, iron and zinc with low caloric value and sodium. Methionine, lysin, and threonine were the predominant essential amino acids in ostrich meat and its giblets. More than half of fatty acids in ostrich meat and most of its giblets are unsaturated fatty acids with discrimination of oleic and linoleic acids. The P/S ratio agree with recommendation of WHO in foods. The total lipids of ostrich meat and its edible offal fractionated to seven fractions while, its phospholipids fractionated to eight fractions. Moreover, ostrich fat tissue characteristics indicated its suitability for nutrition.

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# الجودة الغذائية لحم النعام ومنتجاته الثانوية الصالحة للأكل والأنسجة الدهنية

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## الملخص

تم فحص الجودة الغذائية بما في ذلك التركيب الكيميائي الإجمالي (الرطوبة والبروتين والدهون والرماد)، والمحتوى المعدني، وتكوين الأحماض الأمينية وكذلك تكوين الأحماض الدهنية في لحم النعام ومنتجاتها الثانوية الصالحة للأكل (الكبد والقوانص والقلب) وكذلك خصائص النسيج الدهني. يحتوي لحم النعام (*Struthio Camelus*) ومنتجاته الثانوية الصالحة للأكل على كمية معتبرة من البروتين (تراوحت بين 16.54 إلى 20.80% على أساس الوزن الرطب)، والحديد والزنك مع قيمة منخفضة من السعرات الحرارية (تراوحت من 87.86 إلى 117.20 كيلو كالوري/ 100 جرام على أساس الوزن الرطب) والصوديوم (الذي تراوح من 57.85 إلى 90.01 ملجم/100 جم). كانت الميثيونين والليسين والثريونين هي الأحماض الأمينية الأساسية السائدة في لحم النعام ومنتجاته الثانوية الصالحة للأكل. تراوح إجمالي الأحماض الأمينية الأساسية من 37.15 إلى 47.20 جم / 100 جم بروتين. علاوة على ذلك، كان الألانين هو الحمض الأميني غير الأساسي السائد، يليه الأرجينين في لحم النعام ومنتجاته الثانوية الصالحة للأكل. ومن ناحية أخرى فإن أكثر من نصف الأحماض الدهنية الموجودة في لحم النعام ومعظم الثانوية الصالحة للأكل هي أحماض دهنية غير مشبعة مع سيادة أحماض الأوليك واللينوليك. علاوة على ذلك، بلغت نسبة الأحماض الدهنية عديدة عدم التشبع إلى الأحماض الدهنية المشبعة (نسبة P/S) في لحم النعام 0.53 وهي تتفق مع توصية منظمة الصحة العالمية في الأطعمة (0.4 إلى 0.5). تم تجزئة الدهون الكلية في لحم النعام ومنتجاته الثانوية الصالحة للأكل إلى سبعة تجزؤات بينما تجزأ الفوسفوليبيدات الكلية إلى ثمانية تجزؤات. علاوة على ذلك، أشارت خصائص النسيج الدهني للنعام إلى صلاحيتها للتغذية.