International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

Comparison of chemical residues between broiler and layer meat in selected area

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International Journal of Science and Research Archive, 2026, 19(03), 1131-1138

Publication history: Received on 20 May 2026; revised on 27 June 2026; accepted on 29 June 2026

Article DOI: https://doi.org/10.30574/ijsra.2026.19.3.1409

Abstract

This study provides a comprehensive assessment of heavy metals, antibiotic residues, and aflatoxins in broiler and layer chicken meat and edible offal marketed in Port-Said Governorate, Egypt, and evaluates their compliance with Egyptian and international food safety standards. A total of 150 samples comprising meat, liver, and kidney tissues (25 samples each from broiler and layer chickens) were collected from local markets and analyzed for lead (Pb), cadmium (Cd), copper (Cu), arsenic (As), oxytetracycline, sulfonamides, and aflatoxins using HPLC. The obtained results revealed that lead residues were detected in 60%, 80%, and 64% of broiler meat, liver, and kidney samples, respectively, whereas all layer samples (100%) tested positive. Mean Pb concentrations in broilers were 0.013, 0.021, and 0.015 mg/kg in meat, liver, and kidney, respectively, compared with 0.137, 0.180, and 0.065 mg/kg in corresponding layer tissues. Cadmium residues demonstrated a clear bioaccumulation pattern (kidney > liver > meat), with the highest mean concentration detected in layer kidneys (0.732 ± 0.082 mg/kg), while the lowest value was observed in broiler meat (0.103 ± 0.001 mg/kg). Copper and Arsenic concentrations remained within permissible limits in all examined samples. Oxytetracycline residues were detected in all layer tissues (100%), with the highest mean concentration recorded in layer liver samples (236.3 ± 49.30 µg/kg), followed by layer kidney samples (218.3 ± 47.30 µg/kg). Based on Egyptian permissible limits, 60% and 40% of layer liver and kidney samples, respectively, were rejected for oxytetracycline residues, whereas all broiler samples complied with the standards. Sulfonamide residues represented a major concern because of their widespread detection and high rejection rates in layer tissues according to European Union limits. Aflatoxin contamination was predominantly observed in layer chickens, particularly liver tissues, while broiler samples demonstrated high compliance rates. In conclusion, layer chickens exhibited significantly higher contamination levels than broilers, particularly in liver and kidney tissues, indicating greater bioaccumulation potential associated with prolonged production lifespan. Continuous monitoring of poultry products, strict feed quality control, environmental contamination reduction, and prudent antibiotic use are essential to improve poultry food safety and protect consumer health in Egypt

Keywords: Broiler meat; Layer meat; Chemical Quality; Heavy metals and Antibiotics residues

1. Introduction

Poultry nowadays plays a vital role in worldwide food security because it is cheap, has fast and short production cycles, high conversion rate, and is widely accepted across all cultures. Consumers generally view poultry as a healthier option since it usually offers less saturated fat and a greater share of unsaturated fatty acids relative to many red meat products [1]. Chicken meat with consumable offal form key parts of global human diets, supplying a large share of protein and delivering vital micronutrients that are hard to substitute with other foods. It offers a high quality protein and contains minerals like iron and zinc, and vitamins especially vitamin B_{12} that are essential for nervous system health, immune system performance, and the formation of blood [2].

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The presence of chemical residues in chicken meat constitutes a worldwide health risk driven by industrialization, environmental contamination, and intensive farming methods. Fast paced industrial growth and the spread of contemporary farming operations are key factors leading to heavy metal contamination of food [3]. Similarly, veterinary medicines, most notably antibiotics, are extensively administered to livestock raised for food to prevent illness, treat infections, and, in certain cases, enhance growth [4]. Moreover, fungal derived natural toxins like aflatoxins can infiltrate poultry operations via tainted feed, especially during hot and moist weather or when storage in Poor conditions [5].

Feed is a primary pathway for chemicals to enter poultry tissue. Chicken rations commonly contain maize, wheat, soybean meals, oilseed, fats, and mineral premixes. These ingredients can become contaminated during cultivation because of polluted soil or irrigation water, or later in storage due to fungal growth. Contamination can also stem from mineral supplements that include trace minerals, as well as from accidental or fraudulent addition of polluted material [6]. The sources of heavy metal contamination in poultry systems are diverse. Soil contamination may occur due to industrial emissions, mining activities, traffic related pollution, and improper disposal of wastes. Agricultural practices can also contribute, for example using phosphate fertilizers containing cadmium impurities or through application of sewage sludge to cropland [7].

Risk assessment involves evaluating the probability and seriousness of injury caused by contact with chemical hazards, and it supplies a scientific foundation for decisions about food safety. A human health risk assessment typically comprises hazard identification, exposure assessment, hazard characterization, and risk characterization [8]. The One Health concept is being used more often for chemical threats, as contamination frequently stems from environmental pollution (heavy metals), farming methods and the use of veterinary medicines (antibiotic residues), as well as climate and storage conditions (mycotoxins). From a One Health viewpoint, measures like cutting environmental releases, securing feed quality, and bolstering antimicrobial stewardship can concurrently advance animal welfare, public health, and ecosystem health [9].

Therefore this study was conducted to assess the risk of heavy metals, antibiotic, and aflatoxin residues found in meat and offal of broilers and layers and discussing the obtained results with local and international legislations.

2. Material and methods

2.1. Study area

Chicken meat samples in this study were collected from local markets in Port-Said Governorate, Egypt. Port-Said governorate occupies a strategic location at the northern entrance of the Suez Canal on the Mediterranean Sea, at the northeastern edge of the Nile Delta, and represents a key gateway linking Egypt's internal markets with maritime trade routes.

2.2. Sample size determination

Chicken meat sample size was calculated by taking into account the prevalence of antibiotic residues reported by earlier investigations that reported the chemical residues were 30 to 40% for antibiotics [10], no available relevant studies for heavy metals and aflatoxines in meat in Port-said.

2.3. Samples Collection

A total of 150 fresh broiler and layer samples each from meat, liver and kidney were randomly collected from different shops in the Port-said governorate. Each sample was identified and kept in polyethylene bag in an ice-box then immediately transferred to Food Safety laboratory of Faculty of Veterinary Medicine, Suez Canal University for examination of heavy metals (lead, cadmium, Arsenic and Copper), Antibiotics (oxytetracyline, sulphonamides) and mycotoxins (aflatoxin) residues.

2.4. Determination of heavy metal residues

The technique of determination of heavy metal residues for lead and cadmium was applied according to [11]. Prepared samples and standard solution as well as blanks were directly aspirated into the flam for analysis of lead and cadmium. Analysis of lead and cadmium were conducted by air/ acetylene flow (5.5/1.11 /m) flame Atomic Absorption Spectrophotometer.

2.5. Determination of Oxytetracycline and sulfonamides residues

Oxytetracycline and sulfonamides residues were analyzed using high performance liquid chromatography [12] for quantification as per manufacturer protocol. Oxytetracycline and sulfonamide residues were detected using UV detector at wavelength set at 355 nm. High-performance liquid chromatography.

2.6. Determination of Aflatoxins residues

Quantitative assessment of aflatoxins residues by HPLC. Verified reference acetonitrile solutions with aflatoxins standards at a concentration of 3g/ml provided by Sigma-Aldrich Co. The Association of Official Analytical Chemists [13] technique was followed in the preparation of the stock standard solution and working standard solutions.

2.7. Statistical Analysis

The provided data includes mean concentrations, minimum and maximum values, and standard errors (S.E.) for chemical residues in each tissue type: meat, liver, and kidney. One-way analysis of variance (ANOVA), using the general linear model in SPSS version 16 [14]. P value of 0.05 was regarded as significant

3. Results and Discussion

The results in Table 1 and 2 revealed all data of heavy metal residues in broiler and chicken meat samples

3.1. Heavy metal residues in Broiler and Layers meat

3.1.1. Lead

In broiler chickens, lead was relatively low (meat: 0.013 mg/kg; liver: 0.021 mg/kg; kidney: 0.015 mg/kg). Conversely, layer chickens considerably displayed higher average concentrations (meat: 0.137 mg/kg; liver: 0.180 mg/kg; kidney: 0.065 mg/kg). For each tissue, the mean values for layers were significantly greater than those for broilers (P < 0.05). Among the tissues, the greatest mean concentration in layers was found in the liver (0.180 mg/kg), followed by meat (0.137 mg/kg) and kidney (0.065 mg/kg). In broilers, the liver also presented the highest mean level (0.021 mg/kg). The highest observed values in layers were 0.183 mg/kg (meat), 0.243 mg/kg (liver) and 0.095 mg/kg (kidney), whereas broiler peaks were 0.040 mg/kg (meat), 0.051 mg/kg (liver) and 0.048 mg/kg (kidney).

Table 1 Concentration of Heavy Metals (mg/kg) in meat, liver and kidney of Broiler and Layer Chickens

Chickens	Samples	Lead		Cadmium		Copper		Arsenic	
		Mean	± S.E.	Mean	± S.E.	Mean	± S.E.	Mean	± S.E.
Broiler Layer	Meat	0.013^{a} 0.137^{b}	0.002 0.015	0.103^{a} 0.215^{b}	0.001 0.021	12.41^{a} 9.72^{b}	2.20 2.12	0.012^{a} 0.024^{b}	0.001 0.002
Broiler Layer	Liver	0.021^{a} 0.180^{b}	0.003 0.030	0.179^{a} 0.542^{b}	0.002 0.028	13.48^{a} 11.73^{b}	2.02 2.24	0.010^{a} 0.030^{b}	0.002 0.020
Broiler Layer	Kidney	0.015^{a} 0.065^{b}	0.002 0.011	0.324^{a} 0.732^{b}	0.032 0.082	8.52^{a} 10.36^{b}	1.83 1.29	0.012^{a} 0.022^{b}	0.001 0.010

*S.E. means Standard Error of mean. Row in the same level with the different letter were significantly differ (P<0.05)

Using the EOS's highest allowed concentration of lead in chicken (0.10 mg/kg), Results sorts the samples into accepted and rejected categories. In broilers, every meat sample passed (100 %), whereas 4 % of liver samples (1 of 25) and 8 % of kidney samples (2 of 25) were deemed unacceptable. For layers, 40 % of the meat samples (10 of 25) and 68 % of the liver samples (17 of 25) were rejected. The rejection proportion for layer kidney specimens; nonetheless, the reported highest kidney concentration in layers (0.095 mg/kg) falls under the cited limit (0.10 mg/kg).

Lead is a persistent environmental toxin that may infiltrate the food chain through polluted water, feed components, soil, dust, and industrial releases. Because lead provides no physiological advantage and can be toxic even at minimal exposure, finding lead in poultry tissues poses a significant public health issue [15]. The European Food Safety Authority notes that exposure to lead is linked to developmental neurotoxicity, cardiovascular problems, and renal injury, and that certain harmful effects lack a defined safe limit [16].

Table 2 Results (%) of rejected meat, liver and kidney of Broiler and Layer Chickens samples (N0. = 25) based on Egyptian legislations for heavy metal residues

Chickens	Samples	Lead		Cadmium		Copper		Arsenic	
		Number	%	Number	%	Number	%	Number	%
Broiler Layer	Meat	0 10	0 40	0 0	0 0	0 0	0 0	0 0	0 0
Broiler Layer	Liver	1 17	4 68	0 20	0 80	0 0	0 0	0 0	0 0
Broiler Layer	Kidney	2 23	8 92	2 25	8 100	0 0	0 0	0 0	0 0

3.1.2. Cadmium

Cadmium was detected in broiler meat with concentrations between 0.072 and 0.201 mg/kg (average 0.103 ± 0.001). In layer meat, cadmium was ranging from 0.140 to 0.428 mg/kg (average 0.215 ± 0.021). Regarding liver, cadmium was found in concentrations between 0.126 and 0.296 mg/kg (average 0.179 ± 0.002). In layer chickens, cadmium showing levels from 0.232 to 0.789 mg/kg (average 0.542 ± 0.028). For kidney samples, cadmium was found in concentrations between 0.239 and 0.431 mg/kg (average 0.324 ± 0.032). Cadmium residue levels were distributed as kidney > liver > meat for both broilers and layers, with the greatest average concentration found in the kidneys of layers (0.732 mg/kg) and the smallest average in broiler meat (0.103 mg/kg).

Based on the Egyptian Organization for Standardization's cadmium limit in chicken tissues (MRL = 0.50 mg/kg) [17]. All meat from both broilers and layers met the requirement (100%). For broiler livers, every sample was compliant (100%), while layer livers displayed a high rejection rate of 80% (20/25). Regarding kidneys, broiler samples were largely accepted (92%) with an 8% rejection, whereas all layer kidney samples failed (100%).

The pattern of tissue distribution reported here (kidney > liver > meat) aligns with biological expectations. Cadmium generally builds up in the liver and kidneys, as these organs play key roles in detoxifying and eliminating the metal. After being absorbed, cadmium may attach to proteins like metallothionein and can stay for extended times, particularly within renal tissue, accounting for the significantly higher kidney levels observed in layers.

Regarding food safety, cadmium raises major concerns because of its long term toxicity. The World Health Organization notes that cadmium primarily harms the kidneys and can also impact the skeletal and respiratory systems; it is listed as a human carcinogen [18]. In line with this, the European Food Safety Authority (EFSA) set a tolerable weekly intake (TWI) of 2.5 µg per kilogram of body weight for cadmium, derived from kidney related biomarkers [19].

3.1.3. Copper

For meat samples, broiler chickens exhibited copper levels ranging from 10.41 to 14.29 mg/kg with an average of 12.41 mg/kg (± S.E. 2.20). In contrast, layer chickens displayed a lower range of 7.32 to 12.28 mg/kg with a mean of 9.72 mg/kg (± S.E. 2.12). The broiler meat average was significantly higher than that of layers ($P < 0.05$). In liver specimens, copper levels in broilers varied between 11.92 and 14.051 mg/kg, averaging 13.48 mg/kg (± S.E. 2.02). Layer liver samples ranged from 9.42 to 13.31 mg/kg, with a mean of 11.73 mg/kg (± S.E. 2.24). Similar to meat, broiler livers displayed significantly higher mean copper concentrations than layer livers ($P < 0.05$). Kidney specimens exhibited the lowest average copper level in broilers (6.53 to 10.28 mg/kg; average 8.52 mg/kg ± S.E. 1.83). In contrast, layer kidneys presented a broader span of 7.52 to 12.74 mg/kg with an average of 10.36 mg/kg (± S.E. 1.29). For this organ, the layer average was markedly greater than the broiler average ($P < 0.05$).

In poultry, copper is routinely incorporated into feed formulas to support growth, immunity and metabolism, and it may also be applied at higher levels as a growth promoter in certain production systems [20]. Consequently, measurable residues in edible tissues and organs are expected, particularly in metabolically active organs that participate in copper storage and regulation.

In the current findings, copper was found in every sample (100% detection), indicating uniform dietary exposure among broiler and layer flocks. The greatest average levels were recorded in the liver for both groups (13.48 mg/kg in broilers and 11.73 mg/kg in layers), which is biologically reasonable since the liver is central to copper regulation, storage, and biliary excretion. Comparable results have been documented in Egyptian research examining metals in poultry tissues, where liver concentrations generally exceed those of muscle due to accumulation mechanisms [21].

From a food safety standpoint, every copper measurement fell beneath the EOS maximum allowable limit of 15 mg/kg, so all samples complied with Egyptian regulations [22]. This result is consistent with recent Egyptian risk assessment studies showing that copper concentrations in chicken meat and liver generally stayed within the national permissible range [23]. Notably, the observed levels are far lower than copper amounts reported in certain animal livers under specific conditions, where extremely high values have been recorded [24].

3.1.4. Copper

For meat samples, broiler chickens exhibited arsenic levels ranging from 0.001 to 0.030 mg/kg with an average of 0.012 mg/kg (± S.E. 0.001). In contrast, layer chickens displayed a lower range of 0.003 to 0.042 mg/kg with a mean of 0.024 mg/kg (± S.E. 0.002). The broiler meat average was significantly higher than that of layers ($P < 0.05$). In liver, arsenic levels in broilers varied between 0.002 and 0.040 mg/kg, averaging 0.010 mg/kg (± S.E. 0.002). Layer liver samples ranged from 0.004 to 0.041 mg/kg, with a mean of 0.030 mg/kg (± S.E. 0.020). Similar to meat, broiler livers displayed significantly higher mean arsenic concentrations than layer livers ($P < 0.05$). Kidney exhibited the lowest average arsenic level in broilers (0.002 to 0.023 mg/kg; average 0.012 mg/kg ± S.E. 0.001). In contrast, layer kidneys presented a broader span of 0.014 to 0.022 mg/kg with an average of 0.022 mg/kg (± S.E. 0.010). For this organ, the layer average was markedly greater than the broiler average ($P < 0.05$).

Regarding how residues are distributed among tissues, the liver and kidney are anticipated to hold greater concentrations than muscle since they are key organs for detoxifying and eliminating substances. The present data corroborate this biological reasoning, showing that arsenic was detected more often in the liver and kidney than in meat, particularly in layer chickens. Comparable organ specific buildup has been noted in recent evaluations of possibly toxic elements in poultry tissues, highlighting the importance of ongoing surveillance of feed quality to lower consumer exposure [25].

Viewed through a public health lens, the total arsenic levels detected in this research were low and stayed below the [26]. allowable threshold of 0.10 mg/kg for chicken. Nevertheless, arsenic occurs in several chemical species, and the inorganic variant is especially worrisome from a toxicological standpoint because of its genotoxic and carcinogenic properties. EFSA has verified that long term dietary intake of inorganic arsenic links to harmful health effects, notably higher chances of cancers like skin, bladder, and lung cancer [27]. Moreover, the Joint FAO/WHO Expert Committee on Food Additives keeps assessing inorganic and organoarsenic compounds as important food contaminants and acknowledges growing proof of cancer links to inorganic arsenic [28].

3.2. Antibiotics and aflatoxin Residues in Broilers and Layers Meat

The results in Table 3 and 4 revealed all data of Antibiotics and aflatoxin Residues in broiler and chicken meat samples.

3.2.1. Oxytetracycline

The average residue concentrations in layers were significantly higher than those in broilers across all examined tissues ($P < 0.05$). The highest mean concentration was recorded in layer livers (236.3 µg/kg), followed by layer kidneys (218.3 µg/kg), while broiler meat had the lowest mean concentration (70.2 µg/kg).

The maximum permissible limit for oxytetracycline in chicken is 200 µg/kg. Based on this limit, all broiler samples were within the acceptable range. However, a substantial proportion of layer liver (60%) and kidney (40%) samples exceeded 200 µg/kg, suggesting potential non-compliance in layer offal if this criterion is applied uniformly to all tissues.

3.2.2. Sulfonamide

Mean concentrations were 39.34 ± 3.87 µg/kg in meat, 61.48 ± 5.44 µg/kg in liver, and 52.38 ± 7.31 µg/kg in kidney. Importantly, all mean values in broilers remained below the EU MRL (100 µg/kg) across the examined tissues. In contrast, layer chickens showed a much higher frequency of detection, where sulfonamides were present in 100% of samples for meat, liver, and kidney (25/25). The mean concentrations were 90.81 ± 3.87 µg/kg in meat, 130.42 ± 5.44 µg/kg in liver, and 138.62 ± 7.31 µg/kg in kidney. The maximum recorded values reached 130.22 µg/kg (meat), 182.95 µg/kg (liver), and 170.52 µg/kg (kidney). A statistically significant difference between broilers and layers was noted in meat tissue ($P < 0.05$).

Table 3 Concentration of Oxytetracycline, Sulfonamides and Aflatoxins (µg/kg) in meat, liver and kidney of Broiler and Layer Chickens (No. = 25)

Chickens	Samples	Oxytetracycline		Sulfonamides		Aflatoxins	
		Mean	± S.E.	Mean	± S.E.	Mean	± S.E.
Broiler Layer	Meat	70.2[a] 118.6[b]	23.62 38.90	39.34[a] 90.81[b]	3.87 10.23	0 16.92	0 2.47
Broiler Layer	Liver	97.4[a] 236.3[b]	17.42 49.30	61.48[b] 130.42[b]	5.44 13.6	12.73[a] 28.40[b]	2.41 5.39
Broiler Layer	Kidney	82.2[a] 218.3[b]	24.62 47.30	52.38[b] 138.62[b]	7.31 155.73	0 17.82	0 3.67

*S.E. means Standard Error of mean. Row in the same level with the different letter were significantly differ ($P<0.05$)

All broiler samples were compliant with the MRL, resulting in 100% acceptance for meat, liver, and kidney. However, layer chickens showed substantial non-compliance: 72% of meat samples were accepted while 28% were rejected. Even more critically, all layer liver and kidney samples (100%) exceeded the limit and were rejected, indicating that edible organs from layers carried the highest risk of non-compliance.

The findings clearly demonstrate that layer chickens contained higher sulfonamide residues and a higher rate of positive samples compared with broilers across all tissues examined. This difference may be explained by the distinct production and management systems of both categories. Layers generally have a longer lifespan, making them more likely to receive repeated therapeutic treatments during their production cycle, which increases the probability of residue persistence if withdrawal times are not strictly followed [29 and 30].

Table 4 Concentration of Oxytetracycline, Sulfonamides and Aflatoxins (µg/kg) in meat, liver and kidney of Broiler and Layer Chickens (No. = 25)

Chickens	Samples	Oxytetracycline		Sulfonamides		Aflatoxins	
		Mean	± S.E.	Mean	± S.E.	Mean	± S.E.
Broiler Layer	Meat	0 0	0 0	0 7	0 28	0 7	0 28
Broiler Layer	Liver	0 15	0 60	0 25	0 100	0 25	0 100
Broiler Layer	Kidney	0 10	0 40	0 25	0 100	0 9	0 36

From a biological standpoint, residue distribution among tissues followed an expected pattern. In layer chickens, the highest mean concentrations were reported in kidney and liver, which is consistent with the pharmacokinetic behavior of sulfonamides. These drugs undergo metabolism in the liver and are primarily eliminated through renal excretion; therefore, residues tend to accumulate more in metabolically active and excretory organs than in muscle tissues [31]. This provides a logical explanation for the severe rejection rates observed in layer liver and kidney samples.

3.2.3. Aflatoxins

Mean concentrations of Aflatoxins in broiler meat were 0 ± 0 µg/kg in meat, 12.73 ± 2.41 µg/kg in liver, and 0 ± 0 µg/kg in kidney. Importantly, all mean values in broilers remained below the EU MRL (100 µg/kg) across the examined tissues. In contrast, layer chickens showed a much higher frequency of detection, where Aflatoxins, the mean concentrations were 16.92 ± 2.47 µg/kg in meat, 28.40 ± 5.39µg/kg in liver, and 17.82 ± 3.67µg/kg in kidney. A statistically significant difference between broilers and layers was noted in meat tissue ($P < 0.05$).

When the results were evaluated using the maximum limit of 20 µg/kg, [32] all broiler tissues were accepted, indicating that broiler chicken tissues posed a comparatively lower aflatoxin risk in the sampled population. However, the situation for layers was markedly different. All layer liver samples were rejected, and substantial proportions of layer meat (28%) and kidneys (36%) exceeded the same limit. This indicates a potentially significant consumer exposure risk if such tissues enter the food chain without adequate official control.

Aflatoxins are among the most significant naturally occurring mycotoxins contaminating feed ingredients used in poultry production. They are primarily produced by toxigenic strains of Aspergillus flavus and Aspergillus parasiticus, which commonly proliferate under conditions of high temperature and humidity, particularly in improperly stored grains and feedstuffs [33]. Due to the reliance of poultry production systems on cereal-based diets, the risk of aflatoxin contamination is a persistent concern in both developing and developed countries

4. Conclusion

This study comprehensively evaluated the occurrence and distribution of selected chemical contaminants, including heavy metals (lead, cadmium, copper, and arsenic), veterinary drug residues (oxytetracycline and sulfonamides), and aflatoxins in edible tissues (muscle, liver, and kidney) of broiler and layer chickens collected from Port-Said Governorate Local Markets. These findings highlight the importance of implementing an integrated farm to fork approach to control chemical hazards in poultry production. This includes strict monitoring of feed quality, controlling environmental contamination, and ensuring responsible veterinary drug use with proper adherence to withdrawal periods

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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