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DETECTION OF STEROIDS IN CHICKEN MEAT EMPLOYING VARIOUS ANALYTICAL METHODS

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ABSTRACT

The detection of hormone residues and steroids in food animals, particularly chicken, has grown into a global concern for food security. The current review's objective was to thoroughly examine the analytical methods that are already in use, including extraction procedures and threshold concentrations. To highlight general patterns and method variability, a description about multi-residue analytical methods is presented. Steroid hormones can be identified using these approaches, which also involve the extraction of samples with purification, chromatography separation, as well as several detection methods. In order to evaluate the existence of steroids and along with hormone residues, a plurality of monitoring and detection practices have recently been transformed, such as chromatographic techniques, PCR, ELISA, biosensors, and assays. The potential of innovative analytical techniques is also covered. This review finishes with a summary of current developments and also future directions for the advancement of steroid analysis methodologies.

Keywords: Steroid hormones, Advanced techniques, Extraction methods, Detection technologies and Multi-residue analysis

INTRODUCTION:

Chicken is widely consumed in both developed and underdeveloped countries. Global Livestock Count reports that there are approximately 19 billion chickens worldwide. It contains significant amounts of minerals, B-complex vitamins, and essential polyunsaturated fatty acids, in particular fatty acids with omega (n)-3. The chicken organisations employs drugs primarily for three purposes: growth stimulation in any way, prevention, and therapy **[1]**. In 2019, chicken meat consumed was 16,700 pounds in the US, whereas 11,672 tons in the EU, and 4355 metric in India. The poultry industry is a substantial contributor to the agricultural economy, providing animal protein to meet per capita meet demand. Steroids can greatly accelerate a chicken's growth rate, enabling it to achieve its market size faster. As a result, raising chickens might require less time and money, improving production efficiency overall. Steroids can increase the efficiency with which chickens turn grain into muscle. These lowers feeding costs since the hens can grow greater weight on the exact same amount of grain.

This sector holds great potential to provide food security and enhance the nation's economy. Between 2005 and 2050, it was projected that consumer demand for food originating from animals will rise by 70%, with chicken meat expected to have the largest growth rate at 121%. However, a variety of veterinary medications are already regularly employed in animal husbandry for the treatment of illnesses in animals. They are also capable of being fed to the animal alone or combined with food to encourage development. Cross-contamination, improper veterinary product administration, and disdain for withdrawal times can all contribute to the spread and buildup of these medications in goods derived from animals, which puts the health of the general public at considerable danger **[2]**. Epidemiologically interacting, contaminated chicken meat could be the intellect of allergies, disorders contingent on hormones, and a possible threat indicator for human cancer. Some marketing labels continue to state that their chicken is "hormone-free" in spite of the bans, which may lead consumers into believing that hormones are still utilised in other goods **[3]**. The European Union established maximum limits of residue (MRLs) as threshold levels to control animal-derived foods and safeguard consumer health. If approved by European Commission, these recommendations turn into legally enforceable food safety standards. In developing countries, antibiotics including gentamicin, ciprofloxacin, and tetracycline are regularly employed in poultry feed. Veterinary medicine uses oxytetracycline (OTC) routinely due to its broad-spectrum

bacteriostatic exertion, expenditure and a seamless experience of oral administration by feed or drinking water, often used antibiotics in veterinary medicine. The sensitivity and selectivity of these techniques are below average. It is a truth, nonetheless, that a chemical procedure is needed to measure and confirm residues. At the moment, chromatographic methods provide the most accurate assessment of residues in chickens. However, detecting these traces in biological samples is highly challenging.

SAMPLE EXTRACTION:

Sample preparation is required to detect residual levels, but it will also increase the proportion of any suspected interfering matrix contaminants. Moreover, using more aggressive extraction and cleaning techniques increases the likelihood of achieving lower recoveries. Liquid-solid partition-based organic solvents are often used for the extraction of solid materials, including muscle, fat, kidney, alongside liver. Usually, this procedure starts with grinding, freeze-drying, and homogenisation. Next comes a multi-step cleanup process. The majority often utilised extraction method for steroid hormones, according to the literature currently in publication, is liquid solid extraction (LSE), which is typically carried out as solid phase extraction.

QuEChERS:

Ruifeng Bi *et al*. **[4]** made an extract which was prepared with a modified QuEChERS technique. As an extraction solvent, 1% formic acid (v/v) with acetonitrile was used. After passing through a nylon syringe filter, the filtrated stream is transferred to an injection vial where it is detected using UHPLC-MS/MS. Nabi Shariatifar *et al*. **[5]** progressed an approach for determination of steroids into chicken meat. Acetonitrile, sodium acetate, and magnesium sulphate solvent extraction was employed to extract the samples. C18 SPE was utilised to purify the specimens. Acetonitrile containing formic acid was used as a solvent for detection of 66 pesticides residue in livestock meat. SPE-florisil cartridge were utilised and they were activated by hexane and acetone.

Solid-Phase Extraction:

Various concentrations of steroid hormones are capable of being isolated using SPE by utilising specific solvents. Liqun Wang *et al*. **[6]** employed SPE in the Concurrent assessment of anabolic androgens into poultry and alongside livestock meat. Ten millilitres of acetonitrile mixed with one percent v/v acetic acid were used to extract the samples. In order to facilitate targeted transfer to acetonitrile and remove water, 5 g of the anhydrous sodium sulphate were administered. A QVet-NM single-step solid-phase extraction column was used to purify the supernatant. Following vortex mixing, a

hydrophilic filtering membrane was used to collect the solution for UHPLC-MS/MS analysis and place it in an injection tube. In order to identify testosterone, oxprenolol, and even methandienone in animal meat samples,

A. Temerdashev *et al*. **[7]** used solid-phase extraction. After adding 20 millilitres of a 30% methanol solution containing the internal standard, the solvent extraction process took five minutes to complete. The extract was placed in a high-density polyethylene Eppendorf tube and centrifuged. The UHPLC-Q-ToF apparatus was then used to assess the eluate. Antibiotic residues in chicken meat were detected by Choodamani Chandrakar *et al*. **[8]** where they used SPE method for pretreatment of the samples. A polypropylene centrifugal tube containing a 5 g proportion of enhanced beef was infused with 20% TCA in ACN. Citric-phosphate buffer was then used to dilute the combination. An SPE cartridge were employed to purify the recovered filtrate. SPE cartridge were utilised by Edson Ireeta Munanura *et al*. **[9]** for evaluation of the traces of Enrofloxacin and also Ciprofloxacin groups in the broiler chicken meat. A C18 SPE cartridge that was earlier activated with methanol and then deionized water. The cartridges were dried with nitrogen before being eluted with methanol comprising 2% hydrochloric acid, then rinsed with de-ionized water and transferred to autosampler vials. One gramm of meat was weighed and then three percent acetic acid was incorporated to a centrifuge tube. Four Tetracycline residues in the chicken meat was detected by applying SPE pretreatment extraction by Mohamed A. Gab-Allah *et al*. **[10]**. The samples were then extracted using oxalic acid buffer. After centrifugation, unfiltered supernatants went through filtering and put into a SPE cartridge. The specimen residues were reconfigured by vortexing with a water/acetonitrile mixture comprising oxalic and formic acids. Syringe filters were used to filter the sample solutions before being moved to automatic sample vial for LC-MS/MS analysis. Nitroimidazoles in chicken meat samples were determined by HPLC and their extraction was carried out by SPE by Mingming Xu *et al*. **[11]**. Methanol and distilled water were subsequently added progressively for column conditioning. The specimen solution (100 mL) was run via the SPE. Following loading, the column was vacuum-dried and cleaned using acetonitrile/water (5:95, v/v). Solid-phase extraction was used by Abdulrasaq O. Oyedeji *et al*. **[12]** to assessed the presence of multiclass - antibiotic traces in chicken. The homogenate was mixed with a phosphate buffer solution and centrifuged. Subsequently, the combined extracts were passed with the help of a C18 SPE columns.

Prior to being injected into the HPLC, the acquired filtrates then dried out, reconditioned in phosphate buffer, along with strained through 0.45 μm syringe filters screens.

Ultrasound-Assisted Extraction process:

A number of extraction applications have made utilization of UAE, most notably for isolation of steroids from the biological materials like chicken tissues. This method takes advantage of the mechanical impacts of ultrasonic waves, such as turbulence and microstreaming, that can disrupt cell structures and boost mass transfer rates. Shuiqiang Yu *et al*.**[13]** detected oestrogens in the meat samples using an Ultrasound Aided Extraction technique. Probes of meat samples were minced and crushed into homogeneity. After the tissue had been homogenised, it was combined with methanol, put into a centrifuge tube, and violently shaken. After 30 minutes of ultrasound, the tubes were centrifuged. Fresh containers were used to hold the supernatant. The residue has been extracted twice, both times with methanol. Using a rotary evaporator, hoover evaporated supernatants until they were dry. After being redissolved in acetonitrile, the residue was filtered using a syringe.

Ultrasonication extraction:

For confirmation of doxycycline in chicken meat by R.N. Waghamare *et al*. **[14]**. Nitric acid, methanol and citric acid monohydrate were utilised as extraction solvents. The previous suspension was ultrasonicated and for resuspension oxalic acid and acetonitrile was applied.

Dispersive solid-phase microextraction:

Tetracycline residues in chicken samples were evaluated by Ning Ma *et al*. **[15]** by applying Dispersive Solid Phase Microextraction. Chicken muscle samples were homogenized prior adding 0.4 M oxalate buffer to a centrifuge tube. After that, the tube was centrifuged and shaken. After decanting the supernatant, 5 mg of MIP-MOF was administered. After shaking the mixture, it was centrifuged. Add methanol after decanting the supernatant. After being distributed in methanol, the dried residue underwent UPLC analysis. The most extensively used technique for obtaining steroid hormones is liquids solid extraction (LSE), often known solid phase extraction, based on the literature currently in publication. New methods such as ultrasound aided extraction are being studied as an alternative.

Dispersive liquid-liquid microextraction:

An microextraction procedure were been carried out by Andrey Shishov *et al*. **[16]** to quantify the sulphonamides in chicken. For HLLME sodium carbonate and also hexanoic acid was simultaneously used with concentrated acetic acid to enhance the extraction by Xin Di *et al*. for detection of sulphonamides in chicken meat.

DETECTION:

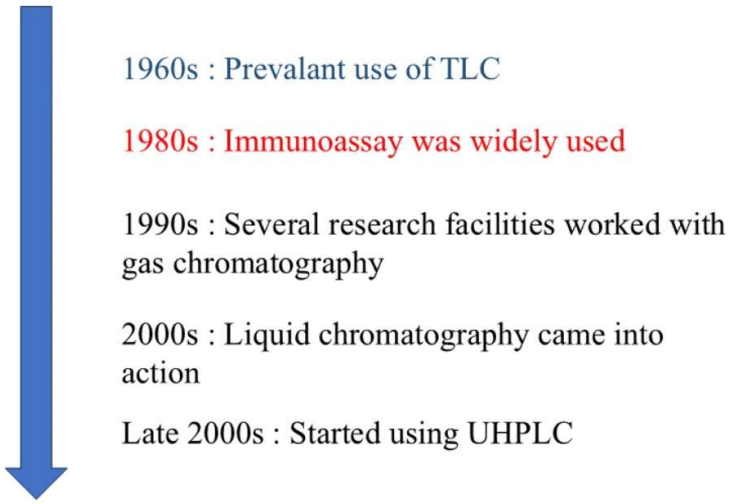

Figure 1: An overview of development of detection methods

PCR:

Another technique of detection is the polymerase chain reaction (PCR), which enables reliable replication of the target DNA segment and serves two purposes: the identification and detection for specific species. Satoshi Ito *et al*. **[17]** established a PCR technique to identify Campylobacter species in chicken samples. The detection rate of samples of chicken breast fillet by direct qPCR was 89.7%, while it was 37.5% for liver.

ELISA:

One of foremost reliable immunoassays emerging today is ELISA. The specificity, sensitivity, and precision of this method depend significantly on the antibody's purity.

Simona Hriciková *et al*. **[18]** applied ELISA technique for analysing salinomycin residue in chicken meat tissues. The kit required a comparable colorimetric ELISA test. The control group had the greatest salinomycin concentrations (4.749 $\mu g \cdot L^{-1}$), whereas the experimental group had the lowest amounts (0.310 $\mu g \cdot L^{-1}$). Akram Baghani *et al*. **[19]** also utilized indirect competitive ELISA methodology for assessment of tetracycline groups and along with ciprofloxacin traces in chicken samples. All chicken flesh samples had lower ciprofloxacin concentrations than MRL, with the exception of one (thigh segment) having 124.5 $ng*g^{-1}$ (higher than the MRL). For residual antibiotics detection in chicken tissues Yasmin El Tahir *et al*. **[20]** employed ELISA method. Where chicken liver has shown highest antibiotic residues and chicken breast were shown it have the the lowest residual antibiotic amounts.

Thin-Layer Chromatography (TLC):

TLC is the most prevalent analytical method for both quality control analysis and food inspection. Food items are examined by combining different partition layers, ion-exchange, and absorption strategies. On the other hand, most separations take place over a stationary phase that has silica gel that has already been coated. In certain food samples, cellulose and alumina are used as stationary phases. Employing a mobile phase within a glass chamber, samples climb from gravity flow in this one-dimensional approach. Antibiotic residues in chicken were detected by Aminatu Abubakar San *et al*. **[21]** by using TLC method. In 23.5% of the analysed samples, their examination found traces of six different antibiotic classes. MRL for antibiotic residues was exceeded in 3.3% of egg samples and 2.5% of meat tests.

High-Performance Liquid Chromatography (HPLC):

Since HPLC operates automatically, it gained popularity as a screening technique in the 1990 Choodamani Chandrakar *et al*. **[22]** employed HPLC-PDA for determination of antibiotic in chicken meat. A ZORBAX-XDB, column with C18 was used to separate residues under isocratic conditions at 30 ◦C. Aqueous oxalic acids, ACN, with MeOH in ratio (60:10:20, v/v) made up the respective mobile phase. Out of the 336 specimens of chicken meat that were examined, 150 (45.7%) had shown positive results for antibiotic traces, including SMZ, CIP, ENR, TC, OTC, and CTC.

In Another study, Edson Ireeta Munanura *et al*. **[9]** found fluoroquinolone antibiotics such as Ciprofloxacin and Enrofloxacin in liver tissues and chicken breasts using HPLC-UV method.

Abdulrasaq O. Oyedeji *et al*.**[12]** utilized this technique to determine multiclass antibiotic traces in frozen poultry specimens from both imported and local sources, comprising turkey gizzard and tissue from the muscle and chicken muscle tissues. C18 SPE-column were utilised for analysis along with Solid-phase extraction was employed, and extracts were analyzed using HPLC-DAD(LOQ) and (LOD) ranged from 17.9 to 185 µg/kg and 5.37 to 55.4 µg/kg, respectively. One millilitre of formic acid solution was added to one litre of each of the two components, acetonitrile (B) and clean water (A) to generate the mobile phase.

Mingming Xu *et al*. **[11]** employed HPLC to identify nitroimidazoles in chicken samples. Water in addition acetonitrile (30:80 v/v) were blended to formulate the mobile phase, which had an average flow rate of 1.0 mL min^{-1}. For the NDZs with the optimised settings, significant recovery (84.0-114.5%), significant limits of detection (0.7-1.2 ng g^{-1}), and extremely linear ranges (2.5-100.0 ng g^{-1}) were exceeded. Next doxycycline residues were also confirmed in chicken meat by R.N.

Waghamare *et al*. **[14]**. In all, 275 specimens of feed, water, meat, and serum were acquired; these came from 180 chicken farms, 81 chicken processing facilities, and 10 facilities that processed poultry products. The mobile phase were made up of acetonitrile in ratio (85:15 v/v), 0.01M oxalic acid, and distilled water. Qualitative antimicrobial screening was performed using the Microbial Inhibition Assay Test Kit, followed by confirmation using HPLC/LCMS. HPLC examination detected doxycycline residual in 9.5% of muscle and 5.26% of liver samples.

UHPLC-MS:

Antibiotic like hainanmycin compounds in chicken samples were detected by Ruifeng Bi *et al*. **[4]** by employing UHPLC technique. A triple quadrupole mass spectrometer and a 1290B Infnity UHPLC system were used to analyse the samples, corresponding. 5 mmol/L NH4Ac in addition to 0.1% of the overall formic acid (v/v) in a blend comprising acetonitrile (solvent B) along with water (solvent A) made up the mobile phase. The average recoveries ranged from 80.9 to 85.5%, while the CCα values ranged from 0.23 to 0.25 µg/kg.

Anabolic Andro-Genic Steroids were also evaluated in chicken meat specimens by Liqun Wang *et al*. **[6]**. The LOQs and detection LODs were ranged between 0.10–0.95 µg/kg and alongside 0.04-0.33 µg/kg, accordingly. Androgen with anabolic steroids (AAS) like methandienone along with oxprenolol and testosterone are analysed in chicken by A. Temerdashev *et al*. **[7]**. In this investigation, a quadruple time-of-flight mass spectroscopy (MS) fitted with an UHPLC and with electrospray ionisation (ESI) source was put to work. The samples were eluted employing gradient elution, with a 0.1 percent of the formic acid solutions in methanol (solvent A) as well as 0.1 percent formic acids mixture within water (solvent B) serving as the mobile phases. Sample contained 7 ng/g oxprenolol, 30 ng/g methandienone, and 4 ng/g testosterone. Ning Ma *et al*. **[15]** evaluated tetracycline residues in chicken meat by using uplc. Acetonitrile and oxalic acid were used as solvents. The detection limits was found to be 0.3-0.8 ng/g, whereas the quantification limit was 0.5-2.0 ng/g.

LC–MS/MS:

Using ID-LC-MS/MS, Mohamed A. Gab-Allah *et al*. **[10]** found four tetracycline components in chicken flesh. The UPLC system was linked to a tri quadrupole mass spectrometer via an electrospray ionisation interface. In both of the portable phases (mobile phase A, and mobile phase B), 0.2 mM oxalic acid and 0.2% formic acid have been present. The pair of mobile phases had a 95/5, v/v ratio of water to acetonitrile.

The approach was highly sensitive, with quantification limits of less than 0.2 µg kg-

1. Steroid concentration in chicken meat were evaluated by Nabi Shariatifar *et al*. **[5]**. The solvents A (deionised water in addition acid formic 0.1%) and B (acetonitrile in conjunction acid formic 0.1%) constituents of the mobile phase. The analyses were conducted using a reversed-phase C18 column. Recovery rates varied between 77.4% to 118.6%. The LOD for two substances were found to be 0.16μg/kg, with a quantification limit (LOQ) of 0.5. ranged from 73.67% to 117.6% for all the sulfonamides.

GC–MS/MS:

Hye Soon Kang *et al*. **[23]** detected 66 pesticide reminants meat samples by utilizing GC MS/MS. A capillary column was adopted for chromatographic separation process. Multi-class pesticides had LOQs ranging 0.75 to 22.3 lg/kg and recovery rates ranged from 75 to 110%.

CONCLUSION:

This paper provides data from 2019 to 2024, which includes a overall description of sample pretreatment(extraction) along with detection methods of steroids and hormones in chicken meat. The pre-processing and detection methods currently implemented on chicken meat have become expensive or challenging to use. Presently, PCR is a useful non-culturable approach for identifying the steroids; yet, MS methods have become an efficient way to identify them and find their residues. Moreover, on-site testing is not possible with HPLC and GC, which require skilled operators. SPE in extraction techniques, along with GC-MS, HPLC, and LC-MS/MS when coupled with different detectors, are often used detection techniques. In light of the aforementioned issues, future efforts should focus on the steady advancement of portable, automated, low-cost pretreatment methods as well as the integration of such instruments with detecting technologies.

S. No.	Sample No.	Meat type	Site of sample isolation	Residue type	Methodology	Mobile phase	LOD	LOQ	Extraction type	Reference
1	5.00-g-sample homogenate	Chicken	Meat and whole egg	Hainanmycin	UHPLC-MS/ MS	0.1% formic acid (v/v) + 5 mmol/L NH4Ac in water (eluent A) and acetonitrile (eluent B)		0.2 µg/kg	centrifuge tube and SPE cartridges	[4]
2	32 samples	Chicken, beef, lamb, and pork	Muscle	Anabolic Andro-Genic Steroids	UHPLC–MS/MS	0.1% aqueous formic acid (v/v) containing 2 mM ammonium acetate; mobile phase B was acetonitrile	0.03–0.33 µg/kg	0.09–0.9 µg/kg	One-Step Solid-Phase Extraction	[6]
3	10.0 g homogenized sample	Chicken	Muscle	nitroimidazoles	HPLC	acetonitrile–water (20:80 v/v)	1.0–1.2 ng g− 1	3.5–4.0 ng g− 1	solid phase extraction	[11]
4	2 g sample of homogenized meat	Chicken and turkey	muscle and gizzard tissues of chicken and turkey, and table-size live chickens (broilers and cockerels)	multiclass antibiotic	HPLC with diode array detection	ultrapure water (A) and acetonitrile (B) prepared by adding 1 mL of formic acid solution into 1 L of A and B	5.37 – 55.4 µg/kg	17.9–185 µg/kg	solid-phase extraction	[12]
5	Homogenized tissue (5.0 g)	Chicken, pork, fish.	Muscles	Estrogen	HPLC with Fluorescence detection	Solvent A- 30% acetonitrile in water B - acetonitrile	0.95 to 3.3 µg· kg−1.		Centrifuge tube	[13]
6	271 samples	chicken	muscle, liver and kidney	Doxycycline	HPLC	Distilled water (0.01M oxalic acid) / acetonitrile (85:15 v/v)			centrifuge tube	[14]
7	1 g sample	Chicken	muscle	Tetracyclines	UPLC	(A) acetonitrile/methanol (3:2, v/v) and (B) 0.01% oxalic acid	0.2–0.6 ng/mL	0.5–2.0 ng/mL	Dispersive Solid Phase Microextraction	[15]
8	Four different chicken meat samples	Chicken	Muscle	sulfonamide	HPLC-UV	methanol and phosphate 144 buffer solution 60:40 (v/v)	3 µg kg-1 and 7 µg kg-1	9 µg kg-1 and 21 µg kg-1	Microextraction	[16]
9	6 batches of liver(340-390g) and 12 batches of breast fillet(330-380g)	Chicken	liver and breast fillet	Campylobacter spp	PCR				Wrap procedure	[17]
10	41 beef and 41 chicken	Chicken	Muscle	Tetracycline and ciprofloxacin	ELISA				centrifuge tube	[19]
11	200 samples	Chicken	breast muscle and liver tissue	Antibiotics	ELISA				centrifuge tube	[20]

REFERENCES

[1] Kamouh HM, Abdallah R, Kirrella GA, Mostafa NY, Shafik S. Assessment of antibiotic residues in chicken meat. Open Vet J 2024;14:438–48. https://doi.org/10.5455/OVJ.2024.v14.i1.40.

[2] Noppe H, Le Bizec B, Verheyden K, De Brabander HF. Novel analytical methods for the determination of steroid hormones in edible matrices. Anal Chim Acta 2008;611:1–16. https://doi.org/10.1016/j.aca.2008.01.066.

[3] Scarth JP, Kay J, Teale P, Akre C, Le Bizec B, De Brabander HF, *et al*. A review of analytical strategies for the detection of "endogenous" steroid abuse in food production. Drug Test Anal 2012;4:40–9. https://doi.org/10.1002/dta.1354.

[4] Bi R, Zhang W, Fu S, Li H, Sun Y, Deng S. Development, Optimization, and Validation of a Sensitive UHPLC-MS/MS Method for the Determination of Hainanmycin in Chicken Meat and Eggs. Food Anal Methods 2024;17:373–81. https://doi.org/10.1007/s12161-024-02580-2.

[5] Shariatifar N, Nabizadeh S, Amirahmadi M. Concentration of Steroid Hormones in Chicken Meat Samples from Iranian Markets Using Liquid Chromatography-Tandem Mass Spectrometry n.d. https://doi.org/10.21203/rs.3.rs-115833/v1.

[6] Wang L, Yan Y, Wang Y, Lv Q, Teng S, Wang W. Rapid and Simultaneous Determination of Anabolic Andro-Genic Steroids in Livestock and Poultry Meat Using One-Step Solid-Phase Extraction Coupled with UHPLC–MS/MS. Molecules 2024;29. https://doi.org/10.3390/molecules29010084.

[7] Temerdashev A, Dmitrieva E, Azaryan A, Gashimova E. Determination of oxprenolol, methandienone and testosterone in meat samples by UHPLC-Q-ToF. Heliyon 2023;9. https://doi.org/10.1016/j.heliyon.2023.e13260.

[8] Chandrakar C, Shakya S, Patyal A, Bhonsle D, Pandey AK. Detection of antibiotic residues in chicken meat from different agro-climatic zones of Chhattisgarh, India by HPLC-PDA and human exposure assessment and risk characterization. Food Control 2023;148. https://doi.org/10.1016/j.foodcont.2023.109667.

[9] Munanura EI, Ntale M, Wasswa J, Kaggwa B. Assessment of Enrofloxacin Usage and Residue Levels of Enrofloxacin-Ciprofloxacin in Breast and Liver Tissues of Commercial Broilers Sold in Kampala-Uganda. Infect Drug Resist 2023;16:7629–39. https://doi.org/10.2147/IDR.S419793.

[10] Gab-Allah MA, Lijalem YG, Yu H, Lim DK, Ahn S, Choi K, *et al*. Accurate determination of four tetracycline residues in chicken meat by isotope dilution-liquid chromatography/tandem mass spectrometry. J Chromatogr A

2023;1691. https://doi.org/10.1016/j.chroma.2023.463818.

[11] Xu M, Guo L, Wang Y, Wang Q, Hao L, Wang C, *et al*. Heterocyclic frameworks as efficient sorbents for solid phase extraction-high performance liquid chromatography analysis of nitroimidazoles in chicken meat. Microchemical Journal 2021;165. https://doi.org/10.1016/j.microc.2021.106096.

[12] Oyedeji AO, Msagati TAM, Williams AB, Benson NU. Detection and quantification of multiclass antibiotic residues in poultry products using solid-phase extraction and high-performance liquid chromatography with diode array detection. Heliyon 2021;7. https://doi.org/10.1016/j.heliyon.2021.e08469.

[13] Yu S, You J, Shi X, Zou X, Lu Z, Wang Y, *et al*. Rapid Analysis of Estrogens in Meat Samples by High Performance Liquid Chromatography with Fluorescence Detection. J Fluoresc 2024;34:425–36. https://doi.org/10.1007/s10895-023-03248-6.

[14] Waghamare RN, Paturkar AM, Vaidya VM, Zende RJ, Kumar A, Bedi JS. Screening of antimicrobial residues and confirmation of doxycycline in samples collected from chicken farms and processing units located around Mumbai, India. Indian J Anim Res 2020;54:1415–21. https://doi.org/10.18805/ijar.B-3899.

[15] Ma N, Feng C, Qu P, Wang G, Liu J, Liu JX, *et al*. Determination of Tetracyclines in Chicken by Dispersive Solid Phase Microextraction Based on Metal-Organic Frameworks/Molecularly Imprinted Nano-polymer and Ultra Performance Liquid Chromatography. Food Anal Methods 2020;13:1211–9. https://doi.org/10.1007/s12161-020-01744-0.

[16] Shishov A, Gorbunov A, Baranovskii E, Bulatov A. Microextraction of sulfonamides from chicken meat samples in three-component deep eutectic solvent. Microchemical Journal 2020;158. https://doi.org/10.1016/j.microc.2020.105274.

[17] Ito S, Kishimoto M. Development of a Sampling and Real-time PCR Method for the Quantitative Detection of Campylobacter spp. in Retail Chicken Meat Without DNA Extraction. J Food Prot 2023;26. https://doi.org/10.1016/j.jfp.2022.100028.

[18] Hriciková S, Kožárová I, Koréneková B, Marcinčák S. The Effect of the Supplementation of Humic Substances and Fermented Products in the Feed on the Content of Salinomycin Residues in Poultry Tissues. Foods 2024;13. https://doi.org/10.3390/foods13010068.

[19] Baghani A, Mesdaghinia A, Rafieiyan M, Soltan Dallal MM, Douraghi M. Tetracycline and ciprofloxacin multiresidues in beef and chicken meat

samples using indirect competitive ELISA. J Immunoassay Immunochem 2019;40:328–42. https://doi.org/10.1080/15321819.2019.1597735.

[20] El Tahir Y, Elshafie EI, Asi MN, Al-Kharousi K, Al Toobi AG, Al-Wahaibi Y, *et al*. Detection of residual antibiotics and their differential distribution in broiler chicken tissues using enzyme-linked immunosorbent assay. Antibiotics 2021;10. https://doi.org/10.3390/antibiotics10111305.

[21] Sani AA, Rafiq K, Hossain T, Akter F, Haque A, Hasan MI, *et al*. Screening and quantification of antibiotic residues in poultry products and feed in selected areas of Bangladesh. Vet World 2023;16:1747–54. https://doi.org/10.14202/vetworld.2023.1747-1754.

[22] Chandrakar C, Shakya S, Patyal A, Bhonsle D, Pandey AK. Detection of antibiotic residues in chicken meat from different agro-climatic zones of Chhattisgarh, India by HPLC-PDA and human exposure assessment and risk characterization. Food Control 2023;148. https://doi.org/10.1016/j.foodcont.2023.109667.

[23] Kang HS, Kim MK, Kim EJ, Choe WJ. Determination of 66 pesticide residues in livestock products using QuEChERS and GC–MS/MS. Food Sci Biotechnol 2020;29:1573–86. https://doi.org/10.1007/s10068-020-00798-4.