AVIAN KIDNEYS UNDER PRESSURE AND RENAL BIOMARKERS OF METABOLIC IMBALANCE IN BROILER CHICKEN FARMS

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Abstract

Avian renal pathophysiology reflects the homeostatic status of the organism and underlies the development of the most frequent renal disorders in birds (hyperuricaemia, visceral and articular gout, acute and chronic renal failure).These conditions may arise in association with the progressive depletion of renal functional reserve. The monitoring of certain serum indicators, such as uric acid for purine imbalance, glucose for carbohydrate imbalance, total cholesterol and triglycerides for lipid imbalance, serum sodium and potassium for fluid and electrolytic imbalance, and serum calcium together with the calcium-to-phosphorus ratio for mineral imbalance, is useful for the early detection of homeostatic disturbances in broiler chickens (Ross 308). The present review synthesises the morphofunctional particularities of the avian kidney, the pathophysiological mechanisms involved in the onset of metabolic dysfunction and their relevance to clinical diagnosis in poultry farming practice. The early identification of nephropathies enables the introduction of phytotherapeutic interventions (Silybum marianum, Aloe vera, Curcuma longa, Moringa oleifera, Rosa canina) with nephroprotective and homeostasis-regulating effects. This perspective shifts the emphasis from the treatment of established renal pathology towards its early recognition and prevention, consequently transforming routine biochemical monitoring into an effective tool for optimising health and productivity on poultry farms. As metabolic dynamics are an inherent feature of physiological adaptation, early diagnosis followed by appropriate nutritional and water-management interventions becomes essential, thereby redefining avian renal prophylaxis as an active component of veterinary sanitary management in modern poultry farming.

Key words: *renal pathologies, broiler chickens, serum indicators*

INTRODUCTION

The quantitative changes in certain blood parameters (uric acid, glucose, cholesterol, triglycerides, calcium and phosphorus) reflect the metabolic responses caused by the functional reorganization of the body according to its biological balance. The organism of meat hybrids is characterized by a high metabolic rate and substantial nutritional requirements. As birds age, changes in energy utilisation and metabolic reserves may occur, leading to the onset of pathological changes through decompensation of the renal mechanisms that regulate the detoxification function.

The adaptation of birds to intensive rearing is coordinated by the sympathetic-adrenomedullary neuroendocrine system, which releases catecholamines (adrenaline and noradrenaline). These mediators activate the hypothalamic-pituitary-adrenal (HPA) axis, which provides a slower but more sustained response through the release of glucocorticoids from the adrenal cortex [1]. Within this regulatory pathway, corticotropin-releasing hormone (CRH) and arginine vasotocin (AVT) act on the anterior pituitary gland, stimulating the secretion of adrenocorticotropic hormone (ACTH). ACTH will stimulate the adrenal

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cortex to release corticosterone, the principal glucocorticoid in birds [1]. The systemic response to stress is therefore closely associated with neuroendocrine mechanisms regulated by the circadian rhythms. Melatonin is an important endocrine mediator involved in synchronising physiological processes with the light-dark cycle. Secreted primarily by the pineal gland, it exhibits higher circulating concentrations during the night and lower concentrations during daylight [2]. In avian metabolism, melatonin influences several physiological and metabolic functions, including excretory activity [2]. External light stimuli are detected by the retina and the resulting neural signals are transmitted to the suprachiasmatic nucleus through the retino-hypothalamic pathway. Through this pathway, the synchronisation of the biological clock with the environmental light-dark cycle is maintained. The secretion of corticotropin-releasing hormone is regulated by the pineal gland and the suprachiasmatic nucleus following the stimulation of melatonin secretion in response to the absence of light stimuli [3].

Environmental stressors, such as high stocking density, together with endogenous factors, including hyperthermia associated with increased catabolism, continuously challenge the organism's regulatory mechanisms. Increased corticosterone secretion stimulates hepatic gluconeogenesis and promotes muscle proteolysis [4]. Under these conditions, alterations in serum protein concentrations may reflect enhanced catabolic activity and changes in amino acid utilisation. Increased tissue protein degradation may be associated with enhanced and energy-consuming catabolic activities and the accumulation of amino acids (hyperaminoacidemia).

During hyperthermia, changes in plasma sodium and chloride ions concentrations may occur alongside alterations in blood volume and acid-base balance. The increase in chloride ions concentrations favour the occurrence of respiratory alkalosis inducing tachypnea, followed by compensatory changes in electrolyte concentrations [5]. These changes should be interpreted in relation to hydration status and the environmental conditions to which the birds are exposed.

During chronic stress, the physiological response to corticosterone may diminishes with age [6]. Depending on the individual reactivity to growth conditions, alterations in serum biochemical parameters may indicate that renal functional reserve and compensatory mechanisms are being challenged. These changes are relevant in fast-growing broilers, in which high metabolic demands increase susceptibility to disturbances in homeostasis.

In birds, uric acid is eliminated predominantly through renal tubular secretion in the proximal convoluted tubules [7]. The renal portal system delivers venous blood to the peritubular capillary network and participates in uric acid secretion [8]. Arginine-vasotocin has vasoactive effects and participates in the regulation of renal function [9]. Persistent renal vasoconstriction reduces perfusion and filtration, promotes tissue hypoxia and urate retention. The subsequent accumulation and deposition of urates trigger a local, non-specific inflammatory reaction [10]. AVT also influences water reabsorption and increases the permeability of the collecting ducts, reduces diuresis and contributes to the regulation of plasma osmolarity. Changes in blood biochemical parameters reflect renal dysfunction and the progressive exhaustion of compensatory mechanisms. Conventional renal indicators (uric acid, creatinine) usually increase only after extensive tubular function impairment, whereas renal functional reserve may have been progressively depleted before these changes become apparent [8,11]. Consequently, biochemical indicators

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signal a metabolic imbalance and provides additional information for early identification of renal vulnerability and the prevention of pathological hyperuricemia.

MATERIAL AND METHOD

This study was designed as a narrative review of the scientific literature published between 2020 and 2026, with earlier publications where necessary to provide a theoretical and physiological background. The review focuses on renal biomarkers of metabolic imbalance in broiler chickens, with particular emphasis on the Ross 308 hybrid.

No experimental procedures, animal handling, surgical techniques or primary data collection were performed. The material analysed comprised published studies on commercial broiler chickens (*Gallus gallus domesticus*), namely fast-growing meat-type hybrids, from hatching to slaughter age. The literature search was conducted using *Web of Science*, *ScienceDirect*, *Google Schooler*, *ResearchGate* and other relevant scientific databases. The following keywords were included: *blood biochemical parameters*, *hyperuricaemia*, *renal failure*, *nephroprotective effect* and *poultry*. The eligibility criteria included studies reporting serum indicators of purine metabolism (uric acid), carbohydrate metabolism (glucose), lipid metabolism (total cholesterol, triglycerides), fluid-electrolyte and mineral balance (calcium, phosphorus). Studies addressing the morphofunctional and pathophysiological features of the avian kidney, as well as phytotherapeutic interventions with potential nephroprotective effects were also considered.

The selected articles were examined and their findings were synthesised qualitatively. The information was organised into four main thematic sections:

1. Morphofunctional characteristics of the avian kidney;
2. The pathophysiological mechanisms underlying metabolic dysfunction;
3. Serum biochemical indicators according to the type of metabolic imbalance (purine, carbohydrate, lipid, fluid-electrolyte and mineral metabolism);
4. Phytotherapy involves strategies with nephroprotective and homeostasis-modulating effects.

RESULTS AND DISCUSSIONS

Morphological Characteristics of the Avian Kidney

The avian kidney contains two functionally distinct nephron populations: loopless reptilian-type nephrons and looped mammalian-type nephrons, the latter contributing to urinary concentration. Its dual arterial and renal portal circulation supports glomerular filtration and tubular uric acid excretion [12]. Nephrogenesis continues during post-hatch development in domestic chickens, with renal growth involving both the formation of new nephrons and subsequent nephron hypertrophy [13]. These developmental and functional characteristics provide a physiological basis for investigating renal vulnerability in fast-growing broilers, particularly when increasing metabolic demands coincide with nutritional, hydration-related or environmental stressors.

Uric acid is the primary nitrogenous metabolite in birds. Its production involves enzymatic pathways that include adenosine deaminase and xanthine oxidoreductase (XOD), which catalyses the oxidation of hypoxanthine and xanthine to uric acid. At 42 days of age, serum uric acid concentrations of approximately 7-12 mg/dL have been reported as physiological values.

Visceral gout develops when increased protein catabolism coincides with impaired renal tubular function, resulting in urate accumulation and the deposition of monosodium urate crystals. These deposits will damage the renal parenchyma and contribute to inflammatory and fibrotic

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changes (glomerular fibrosis). The inflammatory vicious cycle is formed by the accumulation of uric acid which activates the nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB) inflammatory signaling pathway in tubular epithelial cells and triggering severe interstitial inflammation and the attraction of lymphocytes and macrophages.

Visceral gout is a multifactiorial disorder secondary to renal injury of various origins. Impaired tubular excretion leads to hyperuricaemia and the precipitation of urate crystals on serosal surfaces and tissues [14]. Predisposing nutritional factors include dietary calcium, high crude-protein levels, hypovitaminosis A, hypervitaminosis D_3, dehydration and exposure to mycotoxin-contaminated feed. The main infectious agents are nephropathogenic infectious bronchitis virus, avian nephritis virus and chicken astrovirus [14]. Experimental evidence indicates that diets containing up to 3.78% calcium can induce renal damage and a marked increase in serum uric acid concentrations by day 17 [10]. Owing to the considerable functional reserve of the avian kidney, the remaining nephrons may compensate for early nephron loss. Consequently, plasma uric acid concentrations and clinical signs may become evident only after substantial renal tissue damage has occurred [14]. Therefore, renal disorders often remain undetected until renal functional reserve has been considerably depleted.

In the liver, adenosine deaminase catalyses the deamination of adenosine to inosine, while xanthine oxidoreductase is involved in the conversion of hypoxanthine and xanthine into uric acid. These enzymatic reactions are essential to purine degradation and the regulation of uric acid production [15]. Enzymatic deficiencies, alterations in XOD activity influence circulating uric acid concentrations by modifying the rate of purine oxidation. Increased XOD activity contributes to enhanced uric acid production and oxidative stress [16].

Phytotherapeutic intervention aims that XOD enzymatic activity may be inhibited, thereby helping to control hyperuricemia, through the administration of natural antioxidants, such as phenolic compounds derived from *Rosa canina* and eupatilin.

Acute-Phase Proteins and Serum Total Protein Dynamics

Hypoproteinemia and hypoalbuminemia may indicate malabsorption, inadequate amino acid intake or chronic inflammation. During an inflammatory response, interleukin-6 (IL-6) can influence hepatic protein synthesis, promoting the production of acute-phase proteins, including C-reactive protein and fibrinogen, at the expense of albumin synthesis. During acute stress or dehydration, serum albumin concentrations may also appear elevated because of haemoconcentration or changes in fluid distribution (apparent hyperalbuminemia). Such increases do not necessarily reflect enhanced albumin synthesis.

In broiler chickens, total serum protein concentrations generally increase with age, with the highest value reported at approximately 32 days of age, according to the exacerbation of metabolic processes [17].

Inadequate protein intake is associated with nitrogen metabolism disorders and with the impairment of hepatic activity, which depresses the capacity for protein synthesis [18]. In renal disorders accompanied by proteinuria, urinary protein losses may further contribute to hypoproteinaemia.

During chronic systemic inflammation, IL-6 influences the hepatic synthesis of albumin and transport proteins, favouring the production of acute-phase proteins. The increased capillary permeability facilitates the extravasation of albumin into the

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interstitial space and altering its distribution within the body [19]. Although this mechanism has been extensively described in mammals, changes in acute-phase responses have also been investigated in broiler chickens [20]. The inflammatory response contributes to reduced circulating albumin concentrations through changes in hepatic synthesis and distribution. Furthermore, sustained catabolic activity may aggravate this condition by increasing amino acid utilisation and limiting the availability of substrates required for plasma protein synthesis [21]. Serum total protein and albumin concentrations should consequently be interpreted in conjunction with hydration status, nutritional consumption and other indicators of systemic inflammation.

Secondary Markers of Renal Function

In birds, creatinine has limited sensitivity as a renal biomarker. Reported physiological concentrations are approximately 0.1–0.5 mg/dL, while concentrations exceeding 1 mg/dL may indicate advanced stages of acute tubular necrosis.

The interpretation of creatinine and urea concentrations in birds requires particular caution because their metabolism and renal processing differ from those observed in mammals. Serum urea concentrations, reported at approximately 1–5 mg/dL provides additional information about hydration status. When renal tubules are altered but glomerular filtration remains intact, the mechanism of tubular reabsorption of creatinine may remain efficient and it might lead to a paradoxical decrease in its blood concentration.

During dehydration, reduced renal perfusion and changes in neurohormonal regulation, the activity of arginine vasotocin can influence water reabsorption and increase tubular urea reabsorption relative to creatinine.

The diagnostic value of renal biomarkers depends on the severity and nature of the underlying lesions. At slaughter age, serum uric acid concentrations may be higher in birds with moderate or severe acute tubular necrosis than in those with no or mild lesions, whereas blood urea nitrogen and creatinine increased only in severe acidosis complications [22]. This pattern is consistent with avian renal physiology. Uric acid is actively secreted by the proximal renal tubules, so even moderate tubular damage impairs its excretion, whereas urea and creatinine concentrations are modulated mainly by glomerular filtration and increase only once the damage tissue is extensive [10]. Uric acid is the most sensitive biomarker to the assessment of altered renal excretion, whereas urea may also provide useful information about hydration status and with elevated creatinine levels indicate advanced renal injury.

The Metabolic Implications of Glucose

Birds have naturally high blood glucose concentrations and a pattern of carbohydrate metabolism that differs from that of mammals. These characteristics are associated with relatively low insulin sensitivity and distinct mechanisms of glucose regulation. Hepatic glycogenolysis is dominated by glucagon secretion. Glucose is particularly important as an energy source for the central nervous system (CNS), while muscle glycogen supports muscular activity during both short-term and prolonged exercise [23]. The availability of glucose is essential for meeting the high energy requirements associated with fast generation of cellular ATP and metabolic adaptation in broiler chickens [24].

Chronic hyperglycaemia represents either a physiological adaptation of broiler chickens or a consequence of excessive dietary carbohydrates intake. During

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prolonged stress, glucocorticoids (cortisol in mammals, corticosterone in birds) stimulate hepatic gluconeogenesis and reduce tissue sensitivity to insulin, which perpetuates hyperglycaemia. [25].

Hepatic lipid metabolic disorders in poultry are associated with an imbalance between lipid synthesis, fatty acid oxidation and triglyceride export, which may result in excessive accumulation of triglycerides and other lipids in hepatocytes. In broiler chickens, hepatic *de novo* lipogenesis represents a major pathway of fatty acid synthesis, and its dysregulation contributes to altered hepatic lipid homeostasis [26,27]. Excessive lipid accumulation in hepatocytes contributes to the development of hepatic insulin resistance, while disturbances in lipid and glucose metabolism interact and have synergistic effects, further aggravating metabolic dysfunction, with the liver serving as a central site of their interaction [28].

Serum biochemical parameters in broiler chickens, including cholesterol concentration, are influenced by genetic characteristics, sex and age. Sex-related differences have been reported in serum concentrations of uric acid, total proteins and glucose, while genetic strain also affects uric acid and total protein concentrations [29].

Environmental stressors also modify the lipid and protein profile. Thermal stress has been associated with increased plasma cholesterol concentrations, reduce serum proteins, enhanced lipid peroxidation and disturbances in electrolyte balance [30]. Saturated fatty acids are the ones synthesized directly from glucose. Short-chain fatty acids (SCFAs) play a role in glucose regulation [31]. The short-chain fatty acids or acetate can be utilised as an energy substrate by peripheral tissues, butyric acid represent the primary energy source for colonocytes, while propionic acid can serve as a substrate for hepatic gluconeogenesis [32].

Mineral Homeostasis and Its Impact on Renal Function

Excess calcium is a recognised nutritional risk factor for renal dysfunction and visceral gout associated with disturbances in mineral metabolism and urate excretion.

Magnesium is a marker of vulnerability, as a physiological antagonist of calcium that inhibits calcium salt crystallization. Variations in serum magnesium may indicate an inflammatory response and progressive pathological changes.

Phosphorus deficiency can lead to osteoporosis and neuromuscular disorders. Dietary supplementation with exogenous phytases is crucial for maintaining an optimal calcium-to-phosphorus ratio (Ca/P) and support mineral homeostasis.

Nutritional and management factors, including an imbalanced Ca/P ratio (often formulated at approximately 2:1), low dietary phosphorus, excessive sodium intake, inappropriate bicarbonate supplementation during heat stress and dehydration promote urate crystal deposition and urolith formation, thereby aggravating renal dysfunction [14]. For this reason, serum sodium and potassium should be interpreted together with hydration status, dietary composition and thermal conditions.

Phytotherapeutic Strategies with Nephroprotective Potential

Several studies have investigated the beneficial effects of phytogenic feed additives and plant-derived products: *Silybum marianum*, silymarin seed extract, *Aloe vera*, *Curcuma longa*, fermented shrimp extract, *Urtica dioica* extract, bee pollen [33–39]. In broilers, *Curcuma longa* demonstrated antioxidant and hepatoprotective properties. Reductions in serum cholesterol, triglycerides and glucose concentrations have also been reported, although results might vary according to

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supplementation dose, duration and environmental conditions [40].

Avian phytotherapy relies on bioactive compounds with antioxidant, anti-inflammatory and immunomodulatory properties: silymarin from *Silybum marianum*, curcuminoids from *Curcuma longa*, thymol and carvacrol from *Thymus vulgaris*, flavonoids and phenolic acids from *Moringa oleifera*, phenolic compounds from *Aloe vera*, vitamin C, flavonoids, tannins and phenolic acids from *Rosa canina* [41].

Herbal formulations, plant extracts and other bioactive substances have been proposed as alternatives to antibiotic growth promoters, with reported benefits for growth performance, animal health and product quality [42]. In addition to their direct biological effects, these natural additives may also improve nutrient digestibility and help maintain a favourable intestinal microbiota. This is particularly relevant to renal health because gut dysbiosis and altered protein and carbohydrates metabolism may elevate serum uric acid concentrations reflecting impaired nitrogen utilization and renal workload [43].

The nephroprotective potential of *Silybum marianum* in poultry is supported by experimental evidence showing that dietary milk-thistle supplementation can mitigate renal impairment in broiler chickens. In Ross 308 broilers, the inclusion of *Silybum marianum* in the diet has been associated with reduced serum uric acid and creatinine concentrations, together with a lower severity of histopathological lesions in renal tissue, indicating a protective effect against kidney damage [44]. These effects have been attributed to reduced lipid peroxidation and enhanced endogenous antioxidant activity, mechanisms consistent with the proposed membrane-stabilising and cytoprotective properties of silymarin [45].

Several other phytogenic compounds have demonstrated promising protective effects in broiler chickens subjected to different metabolic and toxic challenges. Curcumin, the principal bioactive constituent of *Curcuma longa*, attenuated aflatoxin B1-induced renal oxidative stress by modulating antioxidant enzyme activities, including superoxide dismutase, catalase and glutathione peroxidase activities, as well as malondialdehyde levels and NADPH oxidase expression [46]. Similarly, nanocurcumin reduced the incidence and severity of renal histopathological lesions and inflammatory-cell infiltration in the renal cortex and medulla of broilers exposed to salinomycin toxicity [47]. Beyond direct renal protection, dietary *Moringa oleifera* leaf supplementation improved blood metabolites, haematological parameters and antioxidant status in heat-stressed broilers [48].

Rosa canina deserves particular attention because rose hips are a rich natural source of L-ascorbic acid and contain substantial amounts of polyphenols and flavonoid with antioxidant properties. In *vitro* studies have demonstrated antimicrobial activity against bacterial species such as *Staphylococcus aureus*, *Enterococcus faecalis* and *Escherichia coli* [49,50]. These properties are relevant to the pathophysiology of renal injury in poultry, where oxidative stress and intestinal dysbiosis interact, impair nitrogen utilization and increase the renal load of uric acid. Rosehip has been proposed as a supplement for administration through drinking water, to help to reduce oxidative stress, modulate the intestinal microbiota and support renal function and nitrogen excretion. Nevertheless, the optimal dose and method of administration required further investigation [43,51].

Overall, the available evidence concerning the nephroprotective effects of phytogenic additives in broilers derives

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mainly from experimental challenge models involving mycotoxins or ionophores and from studies assessing oxidative-stress parameters. Within the literature considered in this review, no controlled trial specifically evaluating the effects of *Rosa canina* on renal biomarkers in Ross 308 broilers was identified. This gap supports the preventive, biomarker-guided approach proposed here, whereby routine biochemical monitoring identifies the birds and flocks most likely to benefit from phytotherapeutic interventions aimed at preserving renal functional reserve.

By limiting oxidative stress and supporting hepatic function, gastrointestinal tract and protein metabolism, selected plant-derived compounds may contribute to systemic homeostasis and indirectly help preserve renal functional reserves (Fig. 1). Such interventions targets purine, lipid, electrolyte and mineral imbalances before they progress to clinically apparent nephropathy. Herbal medicine should be considered a potential preventive or complementary strategy rather than a substitute for the management of established renal lesions (Fig. 2).

Water Availability and Phytogenic Supplementation

Water availability is an essential component of renal homeostasis in broiler chickens, as inadequate water intake affects hydration status, renal perfusion and the elimination of nitrogenous metabolites. The physiological response to water deprivation also differ according to the birds' genetic background and water-use efficiency [52].

In addition to hydration management, the combined use of plant-derived bioactive compounds represents a modern strategy. For example, combining *Moringa oleifera* and *Thymus vulgaris* extracts might have beneficial effects on growth performance, intestinal acid-base balance, humoral immunity and nutrient digestibility in broiler chickens, suggesting their potential as phytogenic supplements to support metabolic balance [53].

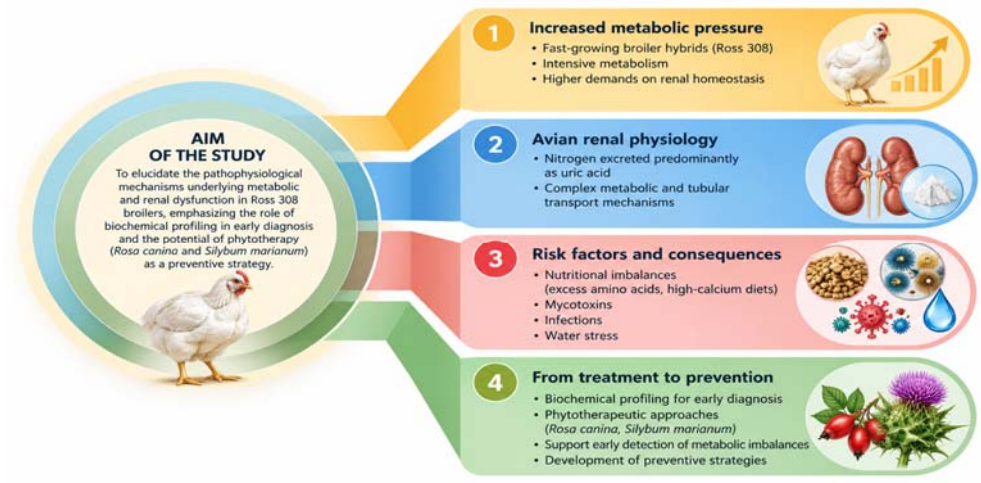


Fig. 1 Metabolic stress, renal physiology, risk factors and preventive strategies in fast-growing Ross 308 broilers

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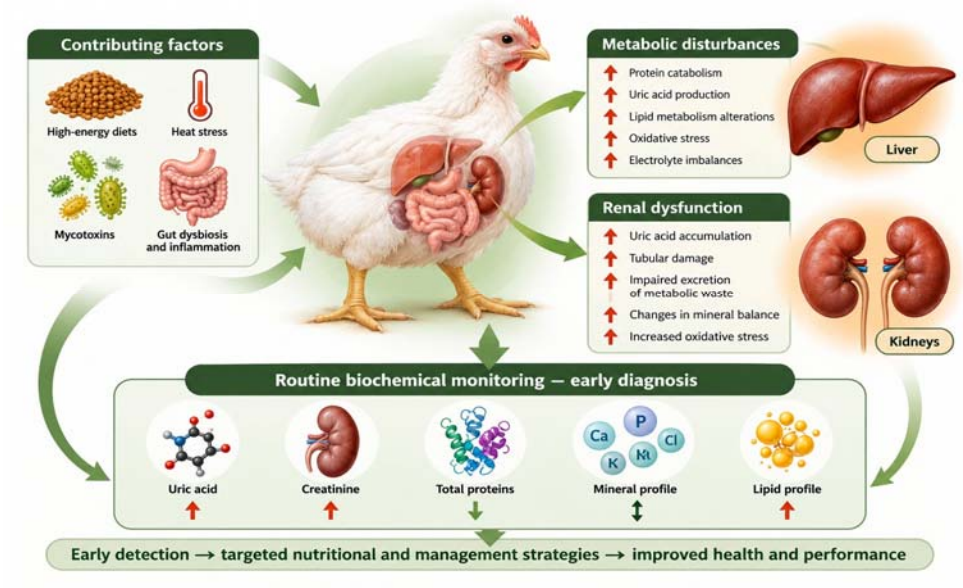


Fig. 2 Importance of contributing factors and serum biomarkers in the early diagnosis of renal disorders in broiler chickens

CONCLUSIONS

Practical application involves routine biochemical monitoring and early nutritional or fluid correction.

Routine monitoring of serum uric acid, glucose, lipids, electrolytes and the Ca/P ratio, interpreted in relation to age, hydration status and environmental stressors, enables the early detection of metabolic imbalances before the onset of clinical nephropathy. Phytotherapy based on additives with antioxidant and hepatoprotective properties, such as *Silybum marianum*, *Curcuma longa*, *Moringa oleifera* and *Rosa canina*, represent promising complementary approaches to nutritional and hydration management. However, their nephroprotective effects in Ross 308 require further confirmation through controlled trials that combining renal biomarker assessment with histopathological examination.

The economic benefits of phytotherapy are associated with a potential reduction in the need for veterinary interventions, particularly through internal parasite control and vaccination programmes, as well as with its potential impact on quality of animal-derived products intended for human consumption.

An aqueous infusion of *Rosa canina* may represent a natural strategy for modulating metabolic and catabolic processes in meat-type hybrids. Rosehips are also widely recognized in Romania for their antioxidant properties and may offer opportunities for the development of cultivation and processing businesses. Such initiatives could combine modern technologies with practical solutions designed to improve water accessibility on broiler farms, thereby supporting production efficiency and performance.

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