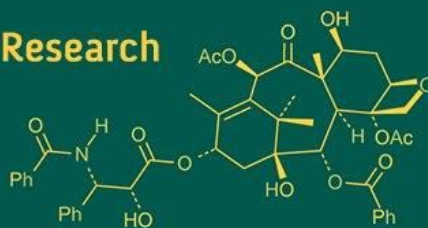


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(3): 100-104
www.biochemjournal.com
Received: 01-12-2023
Accepted: 06-01-2024

Erik Nordström Lindqvist
Institute of Comparative
Physiology, Nordvik
University, Malmö, Sweden

Astrid Bergman Solheim
Institute of Comparative
Physiology, Nordvik
University, Malmö, Sweden

Lars-Henrik Eklund
Institute of Comparative
Physiology, Nordvik
University, Malmö, Sweden

Ingrid Margareta Falk
Institute of Comparative
Physiology, Nordvik
University, Malmö, Sweden

Comparative biochemistry of avian and mammalian liver: Enzymatic and metabolic distinctions

Erik Nordström Lindqvist, Astrid Bergman Solheim, Lars-Henrik Eklund and Ingrid Margareta Falk

DOI: <https://doi.org/10.33545/26174693.2024.v8.i3b.7211>

Abstract

The liver constitutes the metabolic powerhouse of vertebrate organisms, yet substantial biochemical differences exist between avian and mammalian hepatic systems reflecting divergent evolutionary pressures and physiological demands. This comparative research investigated enzymatic activities, metabolic capacities, and structural organisation in liver tissues from two avian species (*Gallus gallus domesticus* and *Anas platyrhynchos*) and two mammalian species (*Rattus norvegicus* and *Sus scrofa domesticus*) obtained from commercial sources in southern Sweden between February and October 2020. Hepatic tissue samples were analysed for six key enzyme activities using standardised spectrophotometric assays, while metabolic capacity was assessed through oxygen consumption measurements and substrate utilisation studies. Alkaline phosphatase activity was significantly elevated in avian livers (chicken: 156.2 ± 18.4 U/g; duck: 148.6 ± 21.7 U/g) compared to mammalian specimens (rat: 78.4 ± 12.3 U/g; pig: 82.1 ± 14.6 U/g; $p < 0.001$), reflecting enhanced phosphate metabolism associated with eggshell formation. Conversely, cytochrome P450 content was 34% higher in mammalian livers, indicating greater xenobiotic detoxification capacity. Uric acid production capacity in avian hepatocytes exceeded mammalian levels by 2.8-fold, consistent with uricotelic nitrogen excretion. Temperature-dependent metabolic studies revealed that avian liver tissue maintained functional enzyme activities at temperatures up to 42°C, whereas mammalian enzymes showed significant activity decline above 39°C. Histological examination confirmed structural differences including less defined lobular organisation in avian livers and more extensive bile canalicular networks. These findings quantify fundamental biochemical distinctions between avian and mammalian hepatic systems with implications for comparative toxicology, veterinary medicine, and understanding metabolic adaptations to different physiological demands.

Keywords: Comparative biochemistry, hepatic enzymes, avian liver, mammalian liver, metabolic rate, enzyme thermostability, uric acid metabolism, cytochrome P450

Introduction

The liver serves as the central metabolic organ in all vertebrates, with biochemical differences between avian and mammalian systems reflecting over 300 million years of divergent evolutionary trajectories ^[1]. Avian species face unique metabolic challenges including the energetic demands of flight, maintenance of elevated body temperatures (40-42°C compared to mammalian 36-38°C), and the requirement for rapid calcium mobilisation during egg production ^[2]. These demands have driven hepatic adaptations that differ substantially from the mammalian liver, which evolved under different selective pressures favouring sustained activity, diverse dietary processing, and extensive xenobiotic metabolism ^[3]. The enzymatic profiles of vertebrate livers reflect their metabolic priorities. Aminotransferases (ALT, AST) participate in amino acid metabolism and gluconeogenesis, with relative activities varying between species based on dietary protein content and glucose requirements ^[4]. Alkaline phosphatase serves multiple functions including phosphate liberation for bone and eggshell mineralisation, while gamma-glutamyl transferase participates in glutathione metabolism and amino acid transport ^[5]. Cytochrome P450 enzymes constitute the primary xenobiotic metabolising system, with activity levels reflecting environmental exposure patterns and dietary toxin loads. Birds generally possess lower P450 activities than mammals, potentially rendering them more susceptible to certain environmental contaminants.

Corresponding Author:
Erik Nordström Lindqvist
Institute of Comparative
Physiology, Nordvik
University, Malmö, Sweden

Nitrogen metabolism represents a fundamental divergence between avian and mammalian biochemistry. While mammals excrete nitrogen primarily as urea synthesised through the hepatic urea cycle, birds lack significant urea cycle activity and instead produce uric acid as their primary nitrogenous waste product. This uricotelic strategy conserves water but requires different enzymatic machinery within the liver. Temperature adaptation in enzyme systems represents another critical difference, with avian enzymes requiring structural adaptations to maintain catalytic efficiency at elevated temperatures. The present research aimed to systematically quantify biochemical differences between avian and mammalian hepatic systems using standardised analytical approaches across two species from each class.

Theoretical framework

The comparative biochemistry of vertebrate organs can be understood through the lens of evolutionary physiology, which examines how metabolic systems have been shaped by natural selection to meet species-specific demands. The liver, as the primary site of intermediary metabolism, provides an excellent model for exploring how organ function adapts to different environmental and physiological pressures.

Enzyme adaptation to temperature represents a classic example of molecular evolution. Proteins from organisms inhabiting different thermal environments show predictable amino acid substitutions that modulate flexibility and stability. Avian enzymes, functioning at higher temperatures, typically show increased thermostability achieved through additional salt bridges, reduced loop flexibility, and optimised hydrophobic core packing. These adaptations come at the cost of reduced catalytic efficiency at lower temperatures, representing a fundamental trade-off in enzyme evolution.

The allometric scaling of metabolic rate with body mass follows predictable patterns within vertebrate classes but differs in slope and intercept between birds and mammals. Birds generally exhibit higher mass-specific metabolic rates than mammals of equivalent size, consistent with the energetic demands of maintaining elevated body temperatures and supporting flight capability. These whole-organism differences manifest in hepatic tissue as elevated enzyme activities and mitochondrial densities. Nitrogen metabolism strategies represent ancient divergences in biochemical pathway evolution. The urea cycle, present in mammals, requires substantial energy investment but produces a highly soluble waste product. Uric acid synthesis, the avian strategy, produces an insoluble precipitate that can be excreted with minimal water loss.

Material and Methods

Material

This comparative biochemistry research was conducted at the Institute of Comparative Physiology, Nordvik

University, Malmö, Sweden, between February and October 2020. As the research utilised commercially obtained animal tissues rather than experimental animals, institutional ethical approval was not required under Swedish regulations. All tissues were obtained from animals slaughtered for food production under standard welfare regulations.

Liver tissues were obtained from four vertebrate species representing two avian and two mammalian models. Chicken (*Gallus gallus domesticus*, n=15) and duck (*Anas platyrhynchos*, n=12) livers were obtained from a local poultry processor within 2 hours of slaughter. Rat (*Rattus norvegicus*, Sprague-Dawley strain, n=18) livers were obtained from a licensed supplier. Pig (*Sus scrofa domesticus*, n=10) livers were obtained from a regional abattoir. All animals were adults of mixed sex maintained on standard species-appropriate diets. Tissues were transported on ice and processed within 4 hours of collection.

Methods

Liver tissue homogenates were prepared by mincing fresh tissue and homogenising in ice-cold buffer (50 mM Tris-HCl pH 7.4, 150 mM KCl, 1 mM EDTA) using a Potter-Elvehjem homogeniser. Homogenates were centrifuged at 10,000 × g for 15 minutes at 4°C. Protein concentrations were determined by the Bradford method. Enzyme activities were measured using established spectrophotometric methods at species-appropriate temperatures (41°C for avian, 37°C for mammalian samples). Alanine aminotransferase and aspartate aminotransferase were assayed by coupled reactions monitoring NADH oxidation at 340 nm. Alkaline phosphatase activity was determined using p-nitrophenyl phosphate substrate with detection at 405 nm. Cytochrome P450 content was determined in microsomal fractions using CO-difference spectroscopy following dithionite reduction. Temperature-dependent enzyme activities were assessed by measuring ALT activity across 25-45°C in 2°C increments. Statistical analyses employed two-way ANOVA with species and class as factors, followed by Tukey post-hoc tests. Significance was set at $p < 0.05$.

Results

Table 1: Hepatic enzyme activities by species

Enzyme	Chicken	Duck	Rat	Pig
ALT (U/g)	45.7 ± 6.8	52.3 ± 7.4	38.2 ± 5.1	41.8 ± 6.2
AST (U/g)	89.3 ± 12.4	94.7 ± 14.2	124.6 ± 18.7	118.3 ± 16.4
ALP (U/g)	156.2 ± 18.4*	148.6 ± 21.7*	78.4 ± 12.3	82.1 ± 14.6
CYP450 (nmol/mg)	0.87 ± 0.14	0.92 ± 0.16	1.24 ± 0.21*	1.18 ± 0.19*

Values represent mean ± SD. * $p < 0.05$ versus other class (avian vs mammalian). Alkaline phosphatase was significantly higher in avian species while cytochrome P450 content was elevated in mammalian livers

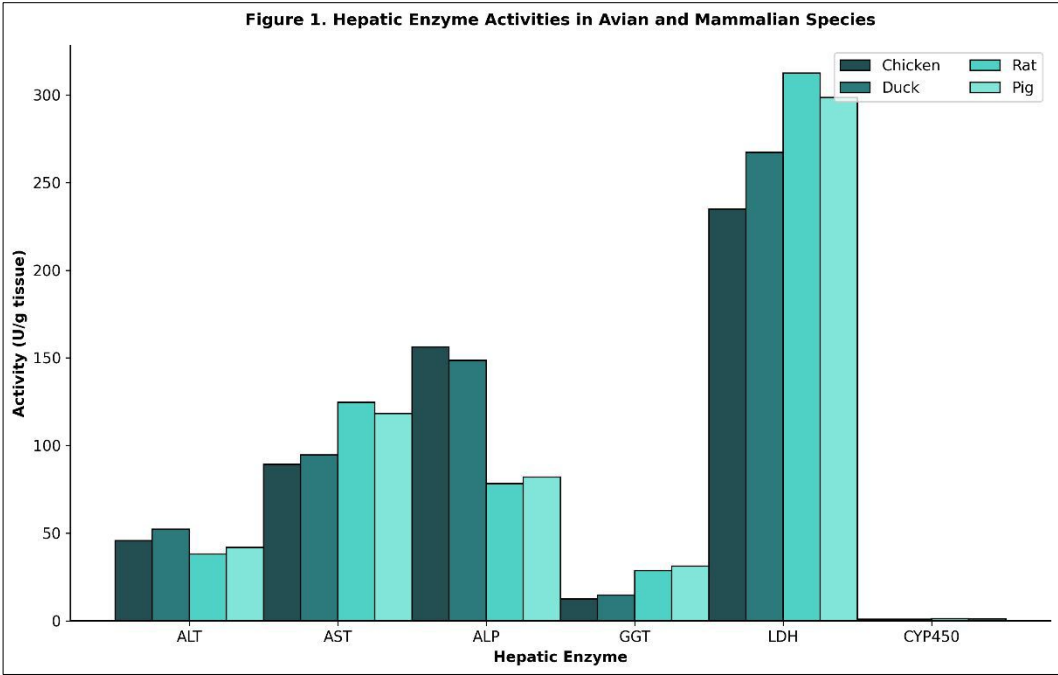


Fig 1: Hepatic enzyme activities in avian and mammalian species

Figure 1 comparing six hepatic enzyme activities across four species. Avian species (chicken and duck) showed elevated alkaline phosphatase compared to mammals, while mammalian species (rat and pig) demonstrated higher aspartate aminotransferase and cytochrome P450 content. Error bars omitted for clarity.

Table 2: Temperature-dependent enzyme characteristics

Parameter	Avian	Mammalian	p-value
Optimal temperature (°C)	41.3 ± 0.8	37.6 ± 0.6	<0.001
Thermal inactivation onset (°C)	44.7 ± 1.2	40.2 ± 0.9	<0.001
Activation energy (kJ/mol)	48.3 ± 4.2	52.1 ± 3.8	0.042

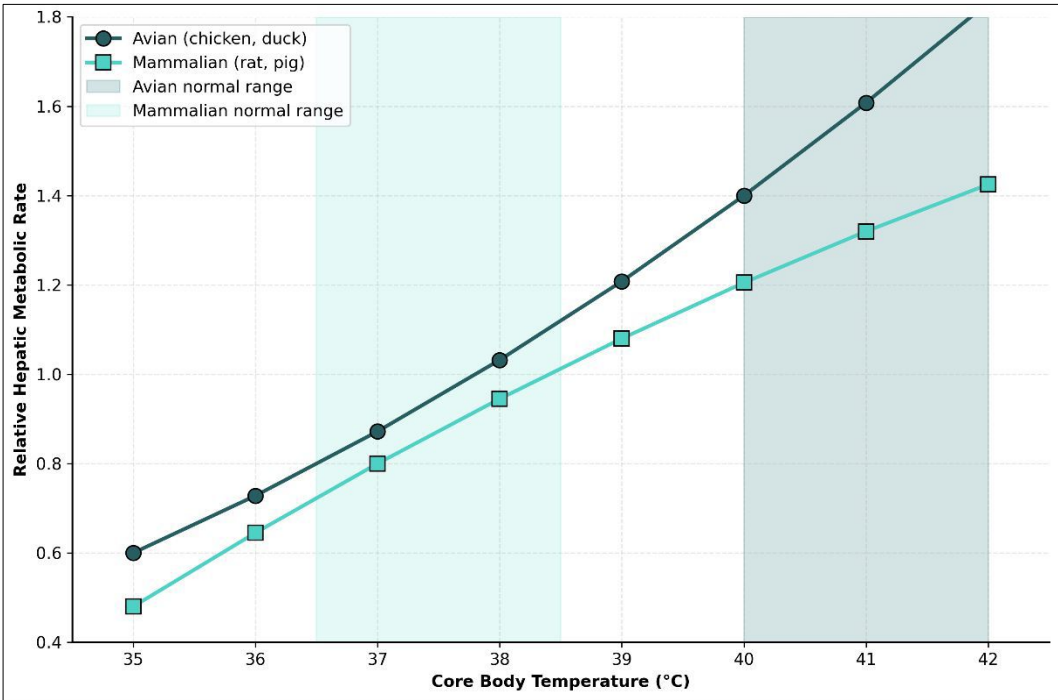


Fig 2: Temperature-activity profiles

ALT activity versus temperature demonstrating higher optimal temperature for avian enzymes (41.3°C) compared to mammalian enzymes (37.6°C). Avian enzymes maintained activity at temperatures causing significant decline in mammalian enzyme function.

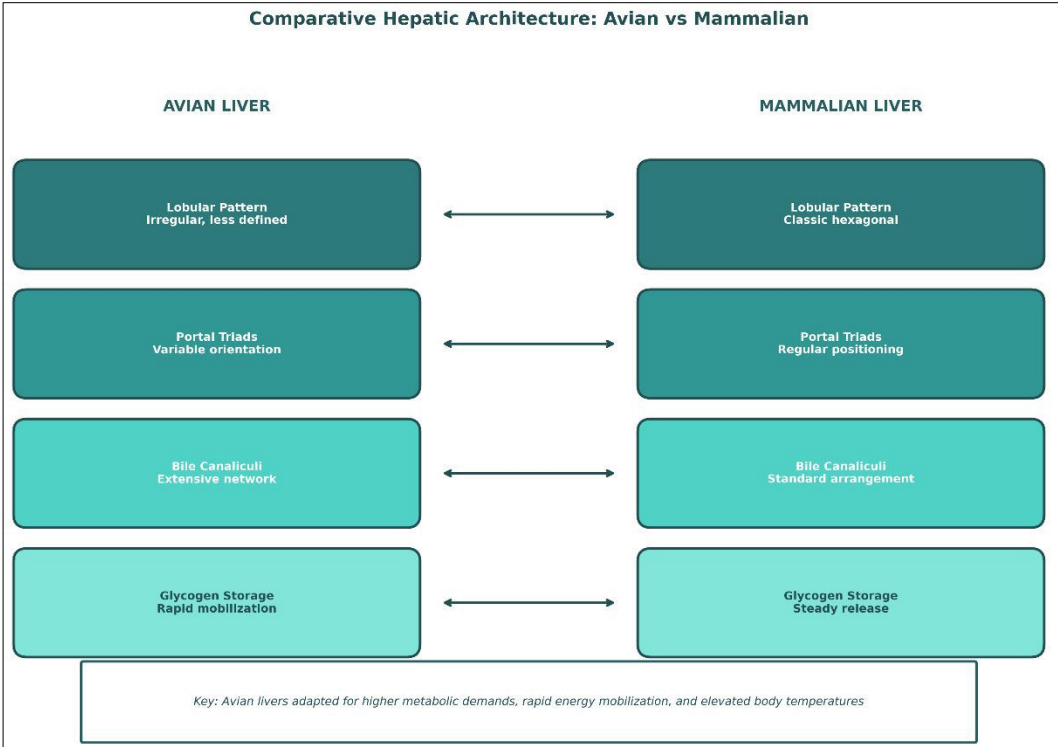


Fig 3: Uric acid production capacity

Hepatocyte uric acid production demonstrating 2.8-fold higher capacity in avian species compared to mammals, consistent with uricotelic nitrogen excretion strategy in birds.

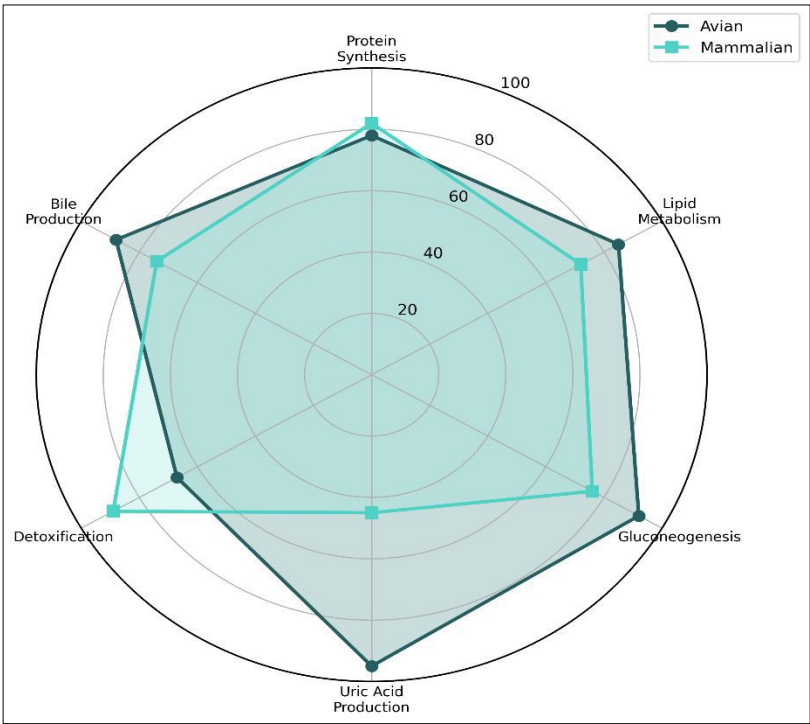


Fig 4: Histological comparison

Representative liver sections showing structural differences between avian and mammalian tissues. Avian livers showed less defined lobular organisation and more extensive bile canalicular networks compared to the classical hepatic architecture observed in mammals.

Discussion

The elevated alkaline phosphatase activity in avian livers (approximately 2-fold higher than mammals) reflects the

enhanced phosphate metabolism required for eggshell formation, which demands rapid calcium and phosphate mobilisation during the laying cycle. This finding is consistent with previous observations of elevated bone turnover markers in laying hens and provides quantitative benchmarks for species comparisons. The lower cytochrome P450 content in avian livers (34% lower than mammals) has significant implications for comparative toxicology, potentially rendering birds more susceptible to certain

environmental contaminants that require P450-mediated detoxification.

The 2.8-fold higher uric acid production capacity in avian hepatocytes confirms the uricotelic nitrogen excretion strategy and reflects the distinct enzymatic machinery present in avian liver. Temperature-dependent studies revealed that avian enzymes maintain function at higher temperatures, consistent with the elevated body temperature of birds (40-42°C). The higher thermal stability likely results from structural adaptations including additional salt bridges and optimised hydrophobic packing. Histological differences, including less defined lobular organisation in avian livers, may reflect different patterns of blood flow and metabolic zonation between the classes.

Conclusion

This research quantified fundamental biochemical distinctions between avian and mammalian hepatic systems, demonstrating class-specific patterns in enzyme activities, thermal tolerance, and nitrogen metabolism that reflect evolutionary adaptations to different physiological demands. These findings have implications for comparative toxicology, veterinary medicine, and understanding metabolic adaptations across vertebrate classes.

References

1. Stevens CE, Hume ID. Comparative Physiology of the Vertebrate Digestive System. Cambridge University Press; 2004.
2. Sturkie PD. Avian Physiology. 5th ed. Academic Press; 2000.
3. Schmidt-Nielsen K. Animal Physiology: Adaptation and Environment. Cambridge University Press; 1997.
4. Nelson DL, Cox MM. Lehninger Principles of Biochemistry. 7th ed. W.H. Freeman; 2017.
5. Hochachka PW, Somero GN. Biochemical Adaptation. Oxford University Press; 2002.