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BIOCHEMICAL CAPACITY AND *IN SILICO* ANALYSIS OF THE LIPID MATRIX IN HEN EGG YOLK

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Introduction

The chicken (Gallus gallus domesticus) egg is a unique biological system, combining the properties of a high-quality food product and an autonomous reproductive unit (Vaillant & Vuma, 2015; Sah & Mishral, 2018; Scanes et al., 2020).

The yolk is the primary source of energy, structural lipids, and bioactive compounds (Vieira, 2007). For humans, it provides phospholipids, choline, polyunsaturated fatty acids, and fat-soluble vitamins (Patil et al., 2022), while for the developing embryo, it is the main nutritional reserve with albumin (Hatta et al., 2007).

During embryogenesis, yolk contents are degraded by enzymes into absorbable molecules (Gilbert & Barresi, 2018). Extraembryonic tissues – yolk sac, amnion, allantois – also utilize yolk resources (Ramos et al., 2022; Zhao et al., 2024).

Limited studies link the yolk lipid profile to egg quality and embryonic support (Duan et al., 2013), especially in unfertilized, healthy eggs.

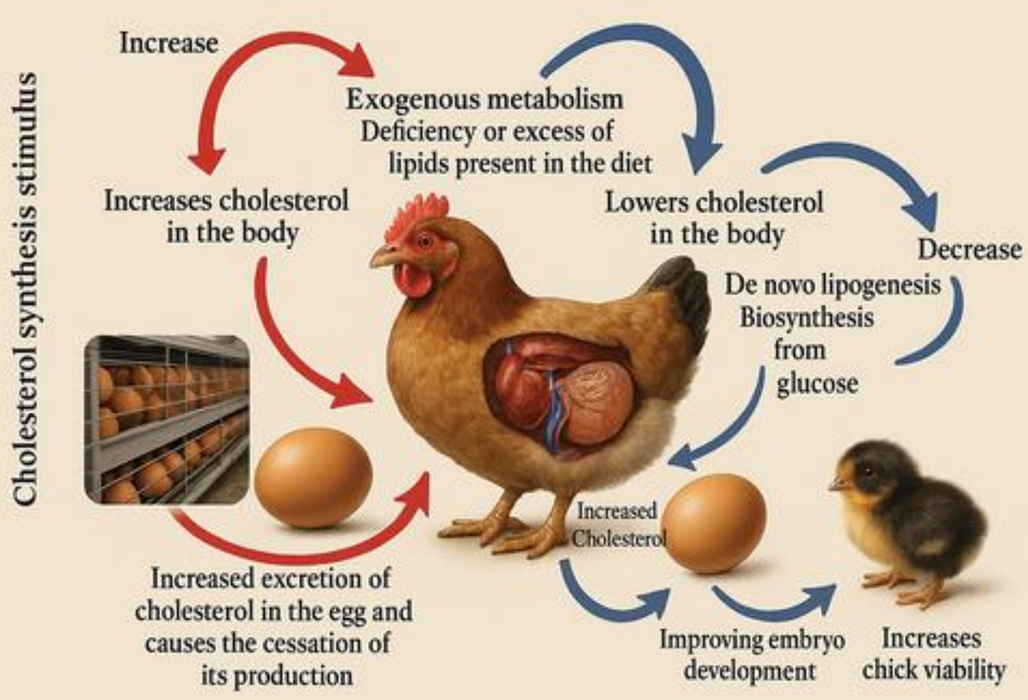

Fig.1. Conceptual model of dietary lipid metabolosim in laying hens and its influence on egg cholesterol and embryo viability (Noble & Cocchi, 1990).

Materials and Methods

The study was conducted on 60 chicken eggs obtained from a commercial hatchery. Eggs were produced by laying hens of the Line Brown breed, raised under standard conditions. Samples with similar weight and without visible defects were selected. All eggs were unfertilized and served as a baseline biological system for evaluating the yolk lipid matrix prior to embryonic development.

Lipids were extracted from egg yolks and analyzed for total lipids, cholesterol, phospholipids, and neutral lipids (triglycerides). Total lipid content was determined using chloroform–methanol extraction (2:1 v/v) according to Ahn et al. (2006). Cholesterol and phospholipids were quantified following the methods of Hwang et al. (2003) and Zhou et al. (2010), respectively. Absorbance was measured at 206 nm using a UV-1800 spectrophotometer.

An *in silico* model implemented in Python (v. 3.9) was used to simulate lipid flux and calculate a Structural Support Index (Iss) based on lipid parameters and a metabolic utilization coefficient (σ = 0.85) (Noble & Cocchi, 1990).

Results

The lipid composition of chicken egg yolks was analyzed to evaluate their quality as a functional nutritional matrix and baseline for potential embryonic development. Measured parameters included total lipids, phospholipids, cholesterol, and triglycerides. The experimentally determined values for total lipids and phospholipids were in good agreement with international reference databases (USDA, FAO, EFSA), often at the upper range of reported values, confirming the physiological completeness of the material. Cholesterol showed moderate individual variability, while triglycerides dominated as the primary energy reserve. These parameters indicate the structural stability of the yolk lipid matrix, essential for membrane organization and energy supply during early embryogenesis. Structural Support Index (Iss), integrating ratios between major lipid fractions, was calculated as 1.42 ± 0.27, reflecting the structural and metabolic readiness of the yolk lipid matrix (Table. 1).

Table.1 Lipid composition of egg yolk: Empirical data and international reference values.

Notes: 1.Reference values are taken from established international databases; ranges are indicated where available;
2.“–” indicates that the database does not provide a specific value for the parameter.

Parameter	Empirical data	USDA FoodData Central (fdc.nal.usda.gov)	FAO/INFOODS (fao.org)	EFSA Food Composition (efsa.europa.eu)
Total lipid (g /100 g yolk)	32.50 ± 1.78	26.5	31.9	32–33
Phospholipids (% of total lipid)	7.80 ± 0.74	–	7.5	7.0–8.0
Cholesterol (g /100 g yolk)	1.591 ± 0.22	1.085	1.850	1.5–2.0
Triglycerides (% of total lipid)	65.10 ± 2.00	–	65	64–66

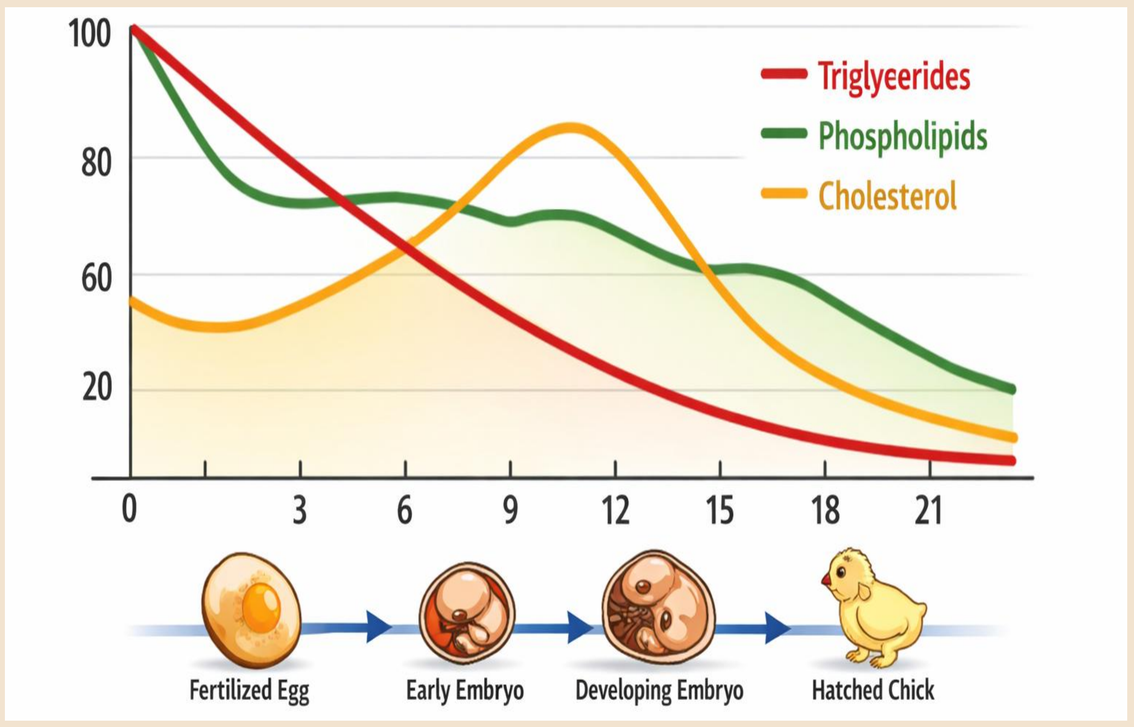

Fig.2. Functional resource for embryonic growth and membrane formation. The ratio of triglycerides, phospholipids, and cholesterol reflects the complex organization of the yolk lipid system, in which energy and structural components are balanced in a way that allows both stability and functional flexibility.

In conclusion, the chicken egg yolk represents a functionally integrated biological system with a dual role: as a primary nutritional matrix for human consumption and as a potential source of energy and structural substrates for embryonic development. Our results show that yolks from unfertilized eggs have a well-organized lipid profile, with balanced proportions of triglycerides, phospholipids, and cholesterol, consistent with established international reference values. The relatively high phospholipid content indicates a structurally stable lipid matrix, supporting the integrity and functional organization of the yolk. The proposed *in silico* Structural Support Index (Iss) integrates major lipid fractions and provides a framework for assessing the structural and metabolic readiness of the yolk lipid matrix. This approach offers a tool for interpreting experimental data and lays the groundwork for future studies on the effects of diet, production conditions, and biological variability on egg quality and embryonic potential.

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