Scientific Papers. Series D. Animal Science. Vol. LXIX, No. 1, 2026
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

EFFICIENCY OF USING LOCAL FEED RESOURCES IN TURKEY HYBRID NUTRITION

Răzvan UȚĂ[1], Minodora TUDORACHE[2], Ioan CUSTURĂ[2], Carmen CHELMEA[1], Maria ȘTEFAN[1], Ștefan-Teofil VLAD[2]

[1]National Institute of Research and Development for Potato and Sugar Beet Brasov, 2 Fundaturii Street, Brasov, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: minodora.tudorache@usamv.ro

Abstract

Feeding represents a key determinant of productive efficiency in turkey production systems, directly influencing growth performance, production costs, and overall sustainability. This study evaluated several dietary formulations designed for an interline turkey hybrid developed within the gene bank of INCDCSZ Braşov. The diets were optimized in terms of nutrient levels and incorporated local feed resources (peas, maize, wheat, sunflower meal) alongside medicinal plants with immunostimulatory potential (nettle, garlic, calendula). The results showed that balanced formulations based on local raw materials and supplemented with 2-4.5% medicinal plants ensured an optimal balance between productive performance, animal health, and economic efficiency. These feeding strategies also reduced reliance on imported feed ingredients and limited vulnerability to market price fluctuations. Although the average unit cost of the feed increased moderately, economic analysis indicated that the potential biological and preventive health benefits may partially compensate for these additional costs.

Key words*: economic efficiency, feed conversion ratio, local feed resources, medicinal plants, turkey hybrids.*

INTRODUCTION

The importance of feeding in meat production

Feeding represents the major component of any poultry production system, consistently accounting for 60-70% of total production costs. This reality is well documented in the scientific literature (Donohue & Cunningham, 2009; Zampiga et al., 2021). In the case of turkeys raised for meat production, the levels of crude protein (CP) and metabolizable energy (ME) are key determinants of growth performance, carcass quality, and the economic efficiency of production (Ognik et al., 2021).

In the current context, characterized by global fluctuations in feed raw material prices (FAO, 2024), diet optimization is no longer solely a matter of biological performance, but also of economic sustainability and efficient integration into the modern food chain, where product quality and requirements related to food safety and packaging are becoming increasingly important (Davidescu et al., 2025; Curea et al., 2023).

Numerous experimental studies have demonstrated the independent and significant effects of metabolizable energy (ME) and crude protein (CP) on turkey performance. For example, Sell et al. (1985) showed that both increasing protein and energy levels influence daily weight gain and slaughter yield; however, the additional benefits tend to plateau once certain nutritional thresholds are exceeded. More recent studies confirm that adjusting dietary energy levels affects not only growth rate but also meat quality (color, cooking losses), thereby directly linking feeding strategies to the commercial value of the final product (Abouelezz et al., 2019; Lungu et al., 2024; Moise et al., 2025).

Reference nutritional recommendations remain those published by the National Research Council (NRC, 1994); however, these have been expanded and updated by more recent reviews highlighting the importance of diet formulation not only in terms of total protein but also digestible amino acids (Lee et al., 2023; Konieczka et al., 2021). Targeted supplementation with essential amino acids-particularly lysine, methionine + cystine, and threonine-allows productive performance to be maintained

at moderate CP levels, while simultaneously reducing feed costs and nitrogen excretion (Abouelezz et al., 2019).

Moreover, the literature indicates that feed form and processing play an essential role in determining feed conversion efficiency. Pelleting and optimization of particle size increase feed intake and digestibility, aspects that are particularly important in young birds. In addition, the ratio between ME and CP can affect the yield of specific anatomical parts: inadequate ratios may reduce breast meat proportion, even when body weight gain appears satisfactory (Gous et al., 2023).

Thus, the scientific literature emphasizes that the efficiency of compound feeds in turkeys is not determined exclusively by protein or energy supply, but by a combination of factors: optimal levels of ME and CP, the profile of digestible amino acids, feed form, and appropriate adaptation to the different growth phases (NRC, 1994; Rostagno et al., 2017; Abdollahi et al., 2013; Aviagen Turkeys, 2022). All these aspects must be evaluated together with the unit cost of the finished feed, since nutritionally adequate formulations that are excessively expensive cannot be applied in practice (Donohue & Cunningham, 2009; OECD-FAO, 2023).

Contribution of local feed resources

The use of on-farm feed resources represents a fundamental strategy for reducing costs and increasing the sustainability of poultry farms (OECD-FAO, 2023; Mottet & Tempio, 2017). Locally available raw materials (maize, wheat, peas, and sunflower) form the basis of many compound feed formulations used in turkey production, providing both energy and protein supply (NRC, 1994; Ravindran, 2013).

Maize is one of the most widely used cereals in poultry feeds due to its high starch content and superior metabolizable energy value (NRC, 1994; Rostagno et al., 2017). At the same time, it contains relatively low levels of crude protein and essential amino acids, particularly lysine and tryptophan, which requires its combination with protein sources (Watson & Ramstad, 2003; Leeson & Summers, 2001; Rostagno et al., 2017). Under Romanian conditions, maize also benefits from wide availability and relatively competitive prices, making it a key ingredient in feed formulations (INSSE, 2023; OECD-FAO, 2023).

Wheat, compared with maize, has a higher protein content and provides appreciable amounts of amino acids such as methionine and tryptophan, although it supplies slightly lower metabolizable energy (Day et al., 2006; Shewry, 2009; NRC, 1994). In addition, the relatively high levels of antinutritional factors (arabinoxylans, NSP - non-starch polysaccharides) may reduce digestibility, which is why the use of exogenous enzymes is often recommended (Cowieson et al., 2006; Choct, 2006). Nevertheless, locally produced wheat remains an important resource for diversifying the cereal base and balancing feed costs (OECD-FAO, 2023).

Peas represent an alternative protein source to soybean meal, containing approximately 22-25% crude protein and a favorable starch composition (NRC, 1994; Rostagno et al., 2017). However, the relatively low level of methionine and the presence of certain antinutritional factors (tannins, trypsin inhibitors) require limiting the inclusion rate or applying technological treatments. Studies indicate that peas can partially replace soybean meal without compromising poultry performance, thereby reducing both feed costs and dependence on imported protein sources (Tufarelli et al., 2018).

Sunflower (seeds or meals) provides a valuable contribution of protein (28-38% CP depending on processing) and crude fiber, but it is deficient in lysine, which requires correction through the use of synthetic amino acids or other lysine-rich ingredients (González-Alvarado et al., 2007; NRC, 1994). In Romania, sunflower meal is widely available as a co-product of the oil industry, making it economically attractive for use in feed formulations (OECD-FAO, 2023; INSSE, 2023).

The role of medicinal plants in turkey nutrition

The integration of medicinal plants into poultry feed formulations represents an innovative approach aimed at addressing current requirements for reducing the use of synthetic additives and increasing the sustainability of poultry production (Windisch et al., 2008; Greathead, 2003). Phytonutrients derived from plants such as nettle (*Urtica dioica*), garlic (*Allium sativum*), and calendula (*Calendula officinalis*) provide a range of nutritional and functional benefits, with positive effects on productive performance, animal health, and the quality of the products obtained (Amad et al.,

2011; Toghyani et al., 2011; Trifunschi et al., 2017; Surai et al., 2019).

Nettle is an important source of vitamins (A, C, K), minerals (Fe, Ca, Mg), and bioactive compounds with antioxidant and immunostimulatory properties (Bhusal et al., 2022; Chrubasik et al., 2007). In poultry diets, nettle contributes to the reduction of oxidative stress and the stimulation of immune responses, which may lead to greater disease resistance and more efficient nutrient utilization (Surai et al., 2019; Windisch et al., 2008).

Garlic contains organosulfur compounds (allicin, diallyl disulfide) with antimicrobial, antifungal, and immunomodulatory effects (Block, 1993; Amagase et al., 2001; Golubkina et al., 2024). In poultry feeding, the inclusion of garlic in diets has been associated with improved feed conversion, reduced mortality, and an improved lipid profile of meat (Karangiya et al., 2016; Toghyani et al., 2011).

Calendula is rich in carotenoids (lutein, zeaxanthin), flavonoids, and volatile oils with anti-inflammatory and antioxidant effects (Mishra et al., 2024; Preethi et al., 2009). In poultry nutrition, calendula contributes to improving skin and egg yolk quality by intensifying pigmentation, while also supporting overall health through the reduction of inflammatory and oxidative processes (Makinde, 2022; Surai et al., 2019).

Numerous studies have confirmed the beneficial effects of medicinal plants on productive performance and poultry health. For example, Ognik et al. (2021) demonstrated that supplementing turkey diets with plant extracts can modulate immune status and oxidative stress markers. Moreover, these authors highlighted the role of amino acids and plant-derived bioactive compounds in supporting intestinal health, suggesting a synergistic interaction between conventional nutrition and phytotherapeutic supplementation (Surai et al., 2019; Zhai et al., 2018; Lungu & Moise, 2025; Usturoi et al., 2023; Usturoi et al., 2025).

From a practical perspective, the partial replacement of synthetic additives with phytotherapeutic resources offers the advantage of reducing costs associated with veterinary treatments and producing meat with superior organoleptic properties, which is better appreciated by consumers. In addition, the use of medicinal plants in poultry nutrition aligns with current trends in the European Union aimed at reducing antibiotic use and promoting natural solutions for maintaining animal health (European Commission, 2019).

Economic rationale: cost-efficiency analysis

Feeding strategies for meat turkeys must be evaluated not only from the perspective of the biological value of feeds but also in terms of economic efficiency. Considering that feed represents the main component of production expenses (Donohue & Cunningham, 2009; Biofeed, 2020), it is essential to identify formulations that provide the best balance between nutritional parameters and the unit cost of the finished feed.

Cost-efficiency analysis involves comparing productive performance (average daily gain, feed conversion ratio, and slaughter yield) with the costs associated with producing each kilogram of feed. This approach allows the evaluation of the "real cost of performance" and the selection of formulations that, at a moderate cost, can ensure results comparable to or even superior to more expensive alternatives (Donohue & Cunningham, 2009; Pesti & Choct, 2023).

In recent years, numerous studies have shown that reducing the overall level of crude protein, combined with targeted supplementation of essential amino acids, does not compromise productive performance but reduces feed cost and nitrogen excretion, thereby contributing to both economic and environmental sustainability (Strifler et al., 2023; Woyengo et al., 2023; Lee et al., 2023). In this context, economic analysis goes beyond the simple comparison of ingredient prices, requiring the integration of biological results into the calculations.

In the Romanian market, where the prices of soybean meal and synthetic additives are strongly influenced by imports and fluctuations in international markets, the use of local resources (maize, wheat, peas, sunflower) and medicinal plants reduces dependence on external raw materials and provides farmers with greater financial stability.

From the farmers' perspective, the most relevant indicators in the economic evaluation of feeding strategies are the unit cost of the finished feed, the feed conversion ratio, the cost per kilogram of meat produced, and the added value of the final product, including meat quality and

consumer acceptability. These aspects are becoming increasingly important in the context of current requirements regarding food safety and the sustainability of the food supply chain (Pesti & Choct, 2023).

MATERIALS AND METHODS

Experimental design

The experimental design was developed to test the hypothesis that the use of feed resources available on small farms (peas, maize, wheat, sunflower) and the differentiated integration of medicinal plants into compound feed formulations can improve productive performance, with a favorable impact on production costs and the sustainability of farming systems.

Experimental conditions

The experimental groups were established immediately after hatching, using poults originating from the same hatchery and from parent flocks of the same age in order to minimize genetic influences on the results. The testing period lasted 20 weeks, during which growth parameters, mortality, and feed conversion were monitored.

Experimental structure

The interline turkey hybrid obtained by crossing the Diana and White Large breeds was used, as this combination is known to express heterosis effects, leading to superior growth performance, feed conversion efficiency, and disease resistance compared with pure breeds (Crawford, 1990; Besbes, 2009).

Four experimental groups were established as follows:

- Control (M) - standard diet, without the addition of medicinal plants;
- Group 1 (G1) - diet supplemented with 4.5% medicinal plants (nettle 3%, garlic 1%, calendula 0.5%);
- Group 2 (G2) - diet supplemented with 3% medicinal plants (nettle 1.5%, garlic 1%, calendula 0.5%);
- Group 3 (G3) - diet supplemented with 2% medicinal plants (nettle 0.5%, garlic 1%, calendula 0.5%).

Growth phases

Turkey feeding was organized into four technological phases (starter, grower 1, grower 2, and finisher). This approach reflects age-specific nutritional requirements:

- during the starter phase, protein requirements are high in order to support the development of organs and muscle tissue;
- subsequently, protein requirements decrease, but maintaining adequate energy and mineral intake remains essential for achieving the final body weight and ensuring carcass quality.

The four technological growth phases were as follows:

- starter (0-7 weeks): compound feed containing 24% crude protein (CP);
- grower 1 (8-11 weeks): diets containing 22% CP and variable levels of medicinal plants (0-4.5%);
- grower 2 (12-15 weeks): diets containing 20% CP and variable levels of medicinal plants (0-4.5%);
- finisher (16-20 weeks): diets containing 17% CP and variable levels of medicinal plants (0-4.5%).

The aim was to evaluate the effect of medicinal plant inclusion while maintaining a constant protein level, with moderate variations in energy density and structural fraction.

Integration of medicinal plants and justification of inclusion levels

The diets were formulated based on locally available feed resources (maize, wheat, peas, sunflower meal, soybean meal), supplemented with mineral additives (calcium carbonate, salt) and dried, ground medicinal plants.

For each growth phase, four distinct formulations were developed (Control + G1 + G2 + G3), resulting in a total of 12 experimental diets. These formulations were balanced to ensure a constant crude protein level, with the only differences deriving from the proportion of medicinal plants included (Tables 1, 2, 3, and 4). Three levels of medicinal plant inclusion (4.5%, 3%, and 2%) were tested, compared with a control diet without plant supplementation. The selection of these inclusion levels was based on literature indicating beneficial effects of nettle, garlic, and calendula on digestibility, immune status, and meat quality (Rahimi et al., 2011; Bhusal et al., 2022). However, these effects are dose-dependent: excessively high inclusion levels may reduce palatability or affect nutritional balance, whereas moderate inclusion levels may exert stimulatory effects on intestinal health and metabolic processes.

Statistical analysis of the data

The experimental data were statistically processed using a one-factor model, in which the experimental factor was the nutritional treatment (Control, G1, G2, G3). The productive parameters evaluated (final body weight, average daily gain, feed conversion ratio, and viability) were expressed as the arithmetic mean (X) and the standard error of the mean (Sx). Differences between means were assessed using one-way analysis of variance (ANOVA). When significant differences were identified, pairwise comparisons of means were performed using Tukey's post-hoc test. The level of statistical significance was set at $p < 0.05$, with differences considered highly significant $p < 0.01$ and very highly significant at $p < 0.001$.

Table 1. Required feed formulations

Specification		CP (%)	MP* (%)	Nettle (%)	Garlic (%)	Calendula (%)
Starter		Compound feed containing 24% CP				
Grower 1 (8-11 weeks)	Control (Diet 1)	22.00	0.00	0.00	0.00	0.00
	Group 1 (Diet 2)	22.00	4.50	3.00	1.00	0.50
	Group 2 (Diet 3)	22.00	3.00	1.50	1.00	0.50
	Group 3 (Diet 4)	22.00	2.00	0.50	1.00	0.50
Grower 2 (12-15 weeks)	Control (Diet 5)	20.00	0.00	0.00	0.00	0.00
	Group 1 (Diet 6)	20.00	4.50	3.00	1.00	0.50
	Group 2 (Diet 7)	20.00	3.00	1.50	1.00	0.50
	Group 3 (Diet 8)	20.00	2.00	0.50	1.00	0.50
Finisher (16-20 weeks)	Control (Diet 9)	17.00	0.00	0.00	0.00	0.00
	Group 1 (Diet 10)	17.00	4.50	3.00	1.00	0.50
	Group 2 (Diet 11)	17.00	3.00	1.50	1.00	0.50
	Group 3 (Diet 12)	17.00	2.00	0.50	1.00	0.50

*MP - medicinal plants; Diet ingredients (feed resources available from household farms): peas; maize; wheat; sunflower.

RESULTS AND DISCUSSIONS

Feed formulations used

The analysis of the diets corresponding to the three technological phases highlights the maintenance of crude protein levels according to age-specific requirements (22% in Grower 1, 20% in Grower 2, and 17% in Finisher), while the inclusion of medicinal plants led to adjustments in energy density and in the structural fraction of the diets (Tables 2-4). In all phases, the groups supplemented with phytotherapeutic additives showed slightly lower metabolizable energy values and a moderate increase in crude fiber content compared with the control, thereby implicitly modifying the ME/CP ratio. Although moderate, these variations may influence nutrient utilization efficiency and voluntary feed intake, particularly during stages characterized by high growth intensity or by the optimization of final tissue deposition. Therefore, the interpretation of productive performance should be conducted in the context of these nutritional adjustments and not solely in terms of the effects of the bioactive compounds present in the medicinal plants.

Table 2. Compound Feed Formulations - Grower 1 Phase (8-11 weeks)

Raw materials	Control (Diet 1)	Group 1 (Diet 2)	Group 2 (Diet 3)	Group 3 (Diet 4)
	%	%	%	%
Wheat	30.18	22.56	25.19	27.08
Maize	25.00	25.00	25.00	25.00
Sunflower seeds	26.04	29.48	28.03	27.14
Soybean meal	10.00	9.70	10.00	10.00
Peas	5.00	5.00	5.00	5.00
Calcium carbonate	3.39	3.37	3.38	3.38
Salt	0.39	0.40	0.40	0.40
Nettle	0.00	3.00	1.50	0.50
Garlic	0.00	1.00	1.00	1.00
Calendula	0.00	0.50	0.50	0.50
Total	100	100	100	100
ME (MJ/kg)	11.05	10.49	10.68	10.72
CP (%)	22.00	22.00	22.00	22.00
CFat (%)	2.09	2.00	2.03	2.01
CF (%)	6.34	6.73	6.56	6.48
Ca (%)	1.44	1.44	1.44	1.45
TP (%)	0.55	0.55	0.55	0.55
Na (%)	0.17	0.17	0.17	0.17
Met (%)	0.40	0.41	0.40	0.40
Met + Cys (%)	0.78	0.79	0.79	0.78
Lys (%)	0.89	0.90	0.90	0.89
Thr (%)	0.76	0.77	0.77	0.76
Trp (%)	0.25	0.25	0.25	0.25

ME - metabolizable energy; CP - crude protein; CFat - crude fat; CF - crude fiber; Ca - calcium; TP - total phosphorus; Na - sodium; Met - methionine; Met + Cys - methionine + cystine; Lys - lysine; Thr - threonine; Trp - tryptophan.

Table 3. Compound Feed Formulations - Grower 2 Phase (12 – 15 weeks)

Raw materials	Control (Diet 5)	Group 1 (Diet 6)	Group 2 (Diet 7)	Group 3 (Diet 8)
	%	%	%	%
Wheat	37.61	30.62	34.09	33.59
Maize	25.00	25.00	25.00	25.00
Sunflower seeds	21.55	23.05	19.07	21.47
Soybean meal	7.00	8.00	10.00	9.10
Peas	5.00	5.00	5.00	5.00
Calcium carbonate	3.44	3.43	3.45	3.44
Salt	0.39	0.40	0.40	0.40
Nettle	0.00	3.00	1.50	0.50
Garlic	0.00	1.00	1.00	1.00
Calendula	0.00	0.50	0.50	0.50
Total	100	100	100	100
ME (MJ/kg)	11.37	10.86	11.13	11.04
CP (%)	20.00	20.00	20.00	20.00
CFat (%)	2.13	2.03	2.06	2.08
CF (%)	5.62	5.76	5.24	5.38
Ca (%)	1.44	1.44	1.44	1.44
TP (%)	0.51	0.50	0.49	0.50
Na (%)	0.17	0.17	0.17	0.17
Met (%)	0.35	0.36	0.35	0.35
Met + Cys (%)	0.70	0.71	0.69	0.69
Lys (%)	0.77	0.80	0.82	0.79
Thr (%)	0.67	0.68	0.68	0.67
Trp (%)	0.22	0.22	0.22	0.22

ME - metabolizable energy; CP - crude protein; CFat - crude fat; CF - crude fiber; Ca - calcium; TP - total phosphorus; Na - sodium; Met - methionine; Met + Cys - methionine + cystine; Lys - lysine; Thr - threonine; Trp - tryptophan.

Table 4. Compound Feed Formulations - Finisher Phase (16-20 weeks)

Raw materials	Control (Diet 9)	Group 1 (Diet 10)	Group 2 (Diet 11)	Group 3 (Diet 12)
	%	%	%	%
Wheat	17.38	10.00	12.39	13.66
Maize	50.00	50.00	50.00	50.00
Sunflower seeds	18.72	21.68	20.72	20.45
Soybean meal	5.00	5.00	5.00	5.00
Peas	5.00	5.00	5.00	5.00
Calcium carbonate	3.50	3.42	3.49	3.49
Salt	0.40	0.40	0.40	0.40
Nettle	0.00	3.00	1.50	0.50
Garlic	0.00	1.00	1.00	1.00
Calendula	0.00	0.50	0.50	0.50
Total	100	100	100	100
ME (MJ/kg)	11.76	11.22	11.40	11.33
CP (%)	17.00	17.00	17.00	17.00
CFat (%)	2.63	2.54	2.57	2.55
CF (%)	5.12	5.45	5.35	5.39
Ca (%)	1.44	1.42	1.44	1.44
TP (%)	0.46	0.47	0.47	0.47
Na (%)	0.17	0.17	0.17	0.17
Met (%)	0.32	0.33	0.32	0.32
Met + Cys (%)	0.63	0.64	0.63	0.63
Lys (%)	0.65	0.66	0.66	0.65
Thr (%)	0.59	0.61	0.60	0.59
Trp (%)	0.18	0.18	0.18	0.18

ME - metabolizable energy; CP - crude protein; CFat - crude fat; CF - crude fiber; Ca - calcium; TP - total phosphorus; Na - sodium; Met - methionine; Met + Cys - methionine + cystine; Lys - lysine; Thr - threonine; Trp - tryptophan.

Analysis of productive performance

The results showed a slight decrease in final body weight in the groups supplemented with medicinal plants compared with the control (4.335 kg in M vs. 4.060-4.206 kg in G1-G3 variants), although these differences were not statistically significant ($p > 0.05$). This trend suggests that the inclusion of phytogenic additives within the range of 2-4.5% did not substantially affect the growth potential of the hybrid, but may be associated with the concurrent nutritional adjustments of the diets, particularly the slight reduction in energy density and the increase in the structural fraction.

The scientific literature indicates that the effects of medicinal plants on productive performance are dose-dependent and influenced by the composition of the basal diet. Studies conducted on meat-type poultry have reported either moderate improvements in growth at low inclusion levels or the absence of significant differences at higher doses when the dietary energy density is reduced (Windisch et al., 2008; Toghyani et al., 2011). Similarly, Ognik et al. (2021) showed that supplementation with plant extracts may modulate physiological parameters without inducing significant increases in body mass.

Therefore, in the case of the hybrid analyzed, the absence of statistically significant differences suggests that phytotherapeutic supplementation does not compromise growth performance, but neither does it generate a direct increase in body weight under conditions of a slight reduction in metabolizable energy. From a practical perspective, this result indicates that the use of medicinal plants can be implemented without significant losses in final body weight; however, their benefits should be evaluated in relation to feed efficiency and the associated production costs.

Table 5. Final production performance

Specification	Treatment							
	Control		Group 1		Group 2		Group 3	
	X	S_X	X	S_X	X	S_X	X	S_X
Live body weight (kg)	4.335	0.1548	4.206	0.1681	4.156	0.1621	4.060	0.1732
Average daily gain (kg)	0.031	0.0011	0.030	0.0012	0.029	0.0012	0.029	0.0012
Feed conversion ratio (kg)	4.448	0.1612	4.797	0.1881	5.123	0.1972	5.532	0.2320
Viability (%)	100		100		95.00		95.00	

Table 6. Testing the statistical significance of the observed differences in final body weight

Specification		Treatment			
		C	G1	G2	G3
Treatment	C	-	0.5652	0.7989	1.1844
	G1	NS	-	0.2138	0.6048
	G2	NS	NS	-	0.4049
	G3	NS	NS	NS	-

NS - statistically non-significant differences ($p > 0.05$)

Table 7. Testing the statistical significance of the observed differences in feed conversion ratio

Specification		Treatment			
		C	G1	G2	G3
Treatment	C	-	1.4083	2.6518	3.8407
	G1	NS	-	1.1981	2.4646
	G2	*	NS	-	1.3453
	G3	**	*	NS	-

NS - statistically non-significant differences ($p > 0.05$)
* - significant differences ($p < 0.05$)
** - significant differences ($p < 0.01$)

With regard to feed conversion, the results revealed a progressive increase in FCR values with the inclusion of medicinal plants, from 4.448 kg feed/kg gain in the control group to 4.797 kg in G1, 5.123 kg in G2, and 5.532 kg in G3. The differences compared with the control were statistically significant for groups G2 ($p < 0.05$) and G3 ($p < 0.01$), indicating a reduction in feed conversion efficiency at inclusion levels of 2–3% medicinal plants.

This trend may be explained by the slight reduction in dietary energy density and the increase in the structural fraction, which may lead to compensatory feed intake in order to meet the birds' energy requirements. The literature indicates that phytogenic additives may improve feed conversion when used at moderate levels and under conditions of constant dietary energy density; however, their effects may become neutral or even negative when their inclusion alters the energy balance of the diet (Windisch et al., 2008; Zhai et al., 2018). Furthermore, studies conducted on meat-type poultry indicate that plant-based additives rich in fiber may influence intestinal transit and nutrient digestibility, with a direct impact on FCR (Choct, 2006).

In the present case, the results suggest that the tested inclusion levels, particularly 2-3%, resulted in reduced feed efficiency without generating a significant advantage in weight gain. From a practical perspective, this aspect is essential, since feed conversion represents the main determinant of the cost per kilogram of meat produced. Therefore, the use of medicinal plants should be calibrated so that potential functional benefits are not offset by a reduction in nutritional efficiency.

The viability of the flock remained high across all experimental groups, reaching 100% in the control and G1 groups and 95% in G2 and G3. The absence of major differences suggests that the inclusion of medicinal plants at levels of up to 4.5% did not have adverse effects on the overall health status or on the birds' capacity to adapt to the experimental conditions.

The literature indicates that phytogenic additives based on plants with antioxidant and antimicrobial properties may contribute to maintaining physiological balance and reducing oxidative stress without necessarily affecting growth parameters (Windisch et al., 2008; Surai et al., 2019). In agreement with these observations, the results obtained in the present study suggest that the tested supplements are biologically safe; however, their effects on productive performance remain dependent on their interaction with the nutritional structure of the diet.

Analysis of the costs of the compound feeds used

The analysis of the costs associated with the compound feeds used highlights clear differences between the control group (M) and the experimental groups supplemented with phytotherapeutic additives (G1-G3), both in

terms of the average cost and the phase-specific costs across the growth stages. For the control group, the weighted average unit cost of the compound feed, calculated over the entire growth cycle, was 0.279 €/kg, representing the lowest value among the variants analyzed.

From the perspective of phase-specific costs, a decreasing trend can be observed with advancing age: from 0.694 €/kg in the starter phase to 0.282 €/kg (Grower 1), 0.264 €/kg (Grower 2), and 0.244 €/kg (Finisher). This profile is characteristic of poultry feed formulations, in which nutrient density (particularly protein supply, amino acids, and premixes) is higher at early ages, generating higher costs during the starter and early growth phases, followed by a gradual reduction as the formulation becomes simpler and the proportion of cereals increases in the later stages. This evolution is consistent with the principles of phase feeding described by Leeson & Summers (2001) and Rostagno et al. (2017), who emphasize that protein requirements and digestible amino acid levels are higher during early growth, resulting in higher starter feed costs, while finisher diets allow a greater inclusion of cereals and less expensive energy ingredients.

In the groups receiving medicinal plants (G1-G3), the average unit cost of compound feed increased substantially compared with the control, reaching 0.375 €/kg (G1), 0.375 €/kg (G2), and 0.375 €/kg (G3). The difference compared with the control is approximately +34%, indicating a substantial economic impact associated with the inclusion of phytotherapeutic components and the reformulation of the diets. The percentage increase reflects the difference relative to the weighted average cost across the entire production cycle, rather than the phase-specific costs.

The literature indicates that the introduction of unconventional ingredients or natural additives can modify the economic structure of feed formulations, even when included at moderate levels, due to their higher unit cost and the adjustments required to maintain nutritional balance (Donohue & Cunningham, 2009; Pesti & Choct, 2023). In intensive poultry production systems, any change in the cost per kilogram of feed is directly reflected in the total budget of the production cycle, given that feeding accounts for the largest share of overall production costs (Zampiga et al., 2021).

It is important to note that although the inclusion levels of the medicinal plant mixture differ among G1-G3, the resulting average costs are practically identical. This suggests that the increase in cost is not strictly proportional to the percentage of plant additives, but is mainly determined by the overall structure of the formulation and by the way in which the phytotherapeutic ingredients replace or complement other components of the diet.

At the level of phase-specific costs, the same decreasing trend is maintained in the phytotherapeutic groups; however, the values remain higher than in the control group, particularly during the growth phases, where costs reach 0.383 €/kg (Grower 1) and 0.366 €/kg (Grower 2), respectively 0.345 €/kg in the Finisher phase. Therefore, in phases characterized by high feed intake (Grower 2 and Finisher), even relatively small differences in cost per kilogram have the potential to significantly increase the total feeding expenditure, since these stages account for the largest share of cumulative feed consumption.

From this perspective, the economic relevance of the unit cost of feed should be interpreted not only through its absolute value, but also through the distribution of feed intake across growth phases. An increase in feed cost during periods of maximum consumption has a disproportionately large impact on the total feed budget of the production cycle. In modern poultry production, economic efficiency is largely determined by the relationship between feed cost and feed conversion performance, as feeding accounts for approximately 60-70% of total production expenses, and fluctuations in the prices of energy and protein ingredients directly influence the farm's profit margin (Donohue & Cunningham, 2009; Mottet & Tempio, 2017; OECD-FAO, 2023).

Although the starter phase records the highest specific cost per kilogram (0.694 €/kg in all variants), its impact on the total cost of the production cycle is limited by the relatively low feed intake (0.975-1.150 kg/bird). In contrast, the Grower 2 and Finisher phases account for the largest volume of feed consumption (6.45-6.70 kg and 8.75-11.00 kg/bird, respectively),

thereby becoming the most decisive stages in determining the overall structure of feeding costs.

In the control group, the majority of feed consumption is distributed across the Grower 2 and Finisher phases, where the specific feed costs are lower (0.264 €/kg and 0.244 €/kg), thus favoring a balanced economic relationship between nutrient density and feed cost. In the phytotherapeutic variants, however, the specific costs during these phases increase to 0.366 €/kg (Grower 2) and 0.345 €/kg (Finisher), and this difference becomes economically significant due to the volume effect.

For example, a difference of 0.101 €/kg in the Finisher phase, applied to a feed intake of 8.75-11.00 kg/bird, generates an additional cost of approximately 0.880-1.120 €/bird in this stage alone. The same principle applies to the Grower 2 phase, where cost differences are amplified by the high level of feed consumption. Consequently, even though the percentage differences in cost per kilogram may appear moderate, their cumulative economic impact becomes substantial, particularly during stages characterized by maximum feed intake.

This phenomenon is explained by the concept of "consumption-weighted cumulative cost", commonly used in economic evaluations of compound feeds, according to which the financial impact of a price difference is proportional not only to the unit value of the feed but also to the total volume consumed during the respective production phases (Donohue & Cunningham, 2009; OECD-FAO, 2023).

Overall, the analysis of the unit cost of compound feed confirms that the inclusion of medicinal plants modifies the economic structure of the formulations not only through the intrinsic cost of the phytotherapeutic ingredients themselves, but also through the adjustments required to maintain a constant crude protein level.

The specialized literature emphasizes that the economic evaluation of feed formulations should be carried out in an integrated manner, by correlating the unit feed cost with productive performance and with the distribution of feed intake across the different growth phases (Pesti & Choct, 2023; Zampiga et al., 2021). This approach is essential because seemingly moderate differences in cost per kilogram may generate significant cumulative effects at the level of the entire production cycle.

Table 8. Average unit cost of the compound feed

Specification		Duration (weeks)	Compound feed intake (g)	Production cost (€/kg)	Average unit cost (€/kg)
C	Starter	0-7	0.975	0.694	0.279
	Grower 1	8-11	2.950	0.282	
	Grower 2	12-15	6.450	0.264	
	Finisher	16-20	8.750	0.244	
G 1	Starter	0-7	0.975	0.694	0.375
	Grower 1	8-11	2.900	0.383	
	Grower 2	12-15	6.450	0.366	
	Finisher	16-20	9.250	0.345	
G 2	Starter	0-7	1.035	0.694	0.375
	Grower 1	8-11	3.200	0.383	
	Grower 2	12-15	6.700	0.366	
	Finisher	16-20	9.750	0.345	
G 3	Starter	0-7	1.150	0.694	0.375
	Grower 1	8-11	2.850	0.383	
	Grower 2	12-15	6.700	0.366	
	Finisher	16-20	11.000	0.345	

Analysis of the unit cost of the live weight meat (€/ton)

The unit cost of the product "live meat" increased progressively across the experimental treatments, reaching a maximum in G3, from 2638.659 €/ton in the control group (M) to 3209.752 €/ton (G1), 3389.219 €/ton (G2), and 3565.177 €/ton (G3). The absolute differences compared with the control group were +571.093 €/ton for G1, +750.560 €/ton for G2, and +926.518 €/ton for G3, corresponding to relative increases of approximately +21.6%, +28.4%, and +35.1%, respectively. This profile indicates a cumulative economic pressure associated with the experimental treatments, with the highest impact observed in G3.

Structure of the total cost and determining factors

The breakdown of total cost by components shows that the main determinant of the differences between treatments is the expenditure on feed, while labor costs remained constant (97.366 €/ton) and therefore cannot explain the observed variations. In the control group, feed costs amounted to 1242.682 €/ton, whereas in the groups supplemented with medicinal plants these costs increased substantially: 1797.696 €/ton (G1), 1920.895 €/ton (G2), and 2073.203 €/ton (G3). Consequently, the differences compared with the control group were +555.014 €/ton (G1), +678.213 €/ton (G2), and +830.521 €/ton (G3).

Analysis of the cost difference structure confirms the dominant role of feed expenditure: 97.184% of the total increase observed in G1 is attributed to feed costs, while in G2 and G3 the contribution of feed remains predominant (90.361% and 89.639%, respectively). Increases in the cost of biological material contribute only secondarily (approximately 4-10% of the total difference), whereas "other expenses" have a marginal contribution (including

slightly negative values compared with the control, which are negligible in magnitude). These findings are consistent with the literature emphasizing that, in poultry production systems, feeding represents the decisive component of production costs, and any changes in feed cost and/or feed conversion efficiency are immediately reflected in the cost per unit of product (Donohue & Cunningham, 2009; Pesti & Choct, 2023).

Economic interpretation integrated with biological performance

From an economic standpoint, the increase in feeding costs reflects a combined effect: a higher unit cost of compound feed in the phytotherapeutic groups and a reduced feed efficiency (higher FCR), both of which amplify the cost per unit of product. In intensive poultry production systems, even relatively small variations in the feed conversion ratio can generate significant economic differences at the level of the final product, given the dominant share of feeding in the overall cost structure (Donohue & Cunningham, 2009; Zampiga et al., 2021).

In practical terms, although differences in feed cost per kilogram may appear moderate, they are multiplied by the total feed intake and by the feed conversion ratio, becoming the main mechanism explaining the differences in the cost of the product "live meat." From this perspective, evaluating the economic feasibility of using medicinal plants cannot be based solely on the cost of the feed formulation, but requires the strict integration of feed cost per kilogram with FCR and with the cost per ton of final product.

Table 9. Comparative unit cost of the live weight meat (€/ton)

Specification		Biological material	Feed	Labor costs	Other expenses	Total production costs
Treatment	C	780.254	1242.682	97.366	518.357	2638.659
	G1	804.204	1797.696	97.366	510.486	3209.752
	G2	856.694	1920.895	97.366	514.263	3389.219
	G3	876.951	2073.203	97.366	517.657	3565.177

Table 10. Structure of the unit cost difference for live meat

Specification		Total difference	Biological material	Other expenses	Feed
G1	Value - €	571.093	23.950	-7.87	555.014
	Structure - %	100	4.194	-1.378	97.184
G2	Value - €	750.560	76.440	-4.094	678.213
	Structure - %	100	10.184	-0.545	90.361
G3	Value - €	926.518	96.697	-0.700	830.521
	Structure - %	100.000	10.437	-0.076	89.639

CONCLUSIONS

The study conducted on the interline hybrid Diana × White Large demonstrated that the use of locally available feed resources allows the formulation of nutritionally balanced diets with adequate crude protein levels, adapted to the specific requirements of each technological growth phase, in accordance with current nutritional recommendations (NRC, 1994; Rostagno et al., 2017).

The inclusion of medicinal plants (*Urtica dioica*, *Allium sativum*, *Calendula officinalis*) at levels of 2-4.5% did not produce significant changes in final body weight and did not affect flock viability, confirming the biological safety of these supplements, in agreement with findings reported in the scientific literature (Windisch et al., 2008; Surai et al., 2019).

However, the tested inclusion levels were associated with a progressive increase in the feed conversion ratio, statistically significant at inclusion rates of 2-3%, which ultimately led to an increase in the cost per unit of product. The economic analysis demonstrated that more than 89-97% of the cost difference observed in the product "live meat" is explained by feed expenditure, confirming the decisive role of feeding within the cost structure of poultry production systems (Donohue & Cunningham, 2009; Pesti & Choct, 2023).

The results suggest that the use of medicinal plants at moderate levels can be integrated into production systems based on local feed resources without negative effects on flock viability. Nevertheless, optimizing the balance between potential functional benefits and economic efficiency requires maintaining an

adequate dietary energy density. Under the experimental conditions analyzed, the tested supplements did not generate a direct economic advantage for the Diana × White Large hybrid, highlighting the importance of calibrating the inclusion level according to the nutritional structure of the diet and the economic objectives of the farm.

Overall, the use of locally available feed resources and medicinal plants may represent a sustainable nutritional strategy for turkey production systems, contributing to the reduction of dependence on imported feed ingredients and increasing resilience to market price fluctuations.

ACKNOWLEDGEMENTS

The study was carried out with the support of the Ministry of Agriculture and Rural Development and was funded through the ADER 815/2023 project.

REFERENCES

Abdollahi, M. R., Ravindran, V., & Svihus, B. (2013). Pelleting of broiler diets: An overview with emphasis on pellet quality and nutritional value. *Animal Feed Science and Technology*, *179*(1-4), 1-23, https://doi.org/10.1016/j.anifeedsci.2012.10.011.

Abouelezz, K. F. M., Wang, Y., Wang, W., Lin, X., Li, L., Gou, Z., Fan, Q., & Jiang, S. (2019). Impacts of graded levels of metabolizable energy on growth performance and carcass characteristics of slow-growing yellow-feathered male chickens. *Animals, 9*(7), 461, https://doi.org/10.3390/ani9070461.

Amad, A. A., Männer, K., Wendler, K. R., Neumann, K., & Zentek, J. (2011). Effects of a phytogenic feed additive on growth performance and ileal nutrient digestibility in broiler chickens. *Poultry Science, 90*(12), 2811-2816, https://doi.org/10.3382/ps.2011-01515.

Amagase, H., Petesch, B. L., Matsuura, H., Kasuga, S., & Itakura, Y. (2001). Intake of garlic and its bioactive components. *Journal of Nutrition, 131*(3), 955S-962S, https://doi.org/10.1093/jn/131.3.955S.

Aviagen Turkeys. (2019). *Management guidelines for commercial turkeys*. Aviagen Turkeys Ltd., Tattenhall, United Kingdom.

Besbes, B. (2009). Genotype evaluation and breeding of poultry for performance under sub-optimal village conditions. *World's Poultry Science Journal, 65*(2), 260-271, https://doi.org/10.1017/S0043933909000221.

Bhusal, K. K., Magar, S. K., Thapa, R., Lamsal, A., Bhandari, S., Maharjan, R., Shrestha, S., & Shrestha, J. (2022). Nutritional and pharmacological importance of stinging nettle (*Urtica dioica* L.): A review. *Heliyon, 8*(6), e09717, https://doi.org/10.1016/j.heliyon.2022.e09717.

Biofeed (2020). *Optimizing Feed Cost in Poultry Production*, https://www.biofeed.ca/publications/feed-cost-in-poultry-production.

Block, E. (1994). Flavorants from garlic, onion, and other alliums and their cancer-preventive properties. In: Huang, M.T., Osawa, T., Ho, C.T., & Rosen, R.T. (Eds.), Food Phytochemicals for Cancer Prevention *I. ACS Symposium Series, American Chemical Society, Washington, DC*, 84-96, https://doi.org/10.1021/bk-1994-0546.ch005.

Choct, M. (2006). Enzymes for the feed industry: Past, present and future. *World's Poultry Science Journal, 62*(1), 5-16, https://doi.org/10.1079/WPS200480.

Chrubasik, J. E., Roufogalis, B. D., Wagner, H., & Chrubasik, S. A. (2007). A comprehensive review on nettle effect and efficacy profiles, Part I: *Herba urticae*. *Phytomedicine, 14*(6), 423-435, https://doi.org/10.1016/j.phymed.2007.03.004.

Chrubasik, J. E., Roufogalis, B. D., Wagner, H., & Chrubasik, S. (2007). A comprehensive review on the stinging nettle effect and efficacy profiles, Part II: *Urticae radix*. *Phytomedicine, 14*(7-8), 568-579, https://doi.org/10.1016/j.phymed.2007.03.014.

Cowieson, A. J., Acamovic, T., & Bedford, M. R. (2006). Phytic acid and phytase: Implications for protein utilization by poultry. *Poultry Science, 85*(5), 878-885, https://doi.org/10.1093/ps/85.5.878.

Crawford, R.D. (1990). Heterosis. In: Crawford, R.D. (Ed.), *Poultry Breeding and Genetics*. Amsterdam, ND: Elsevier Publishing House, 913-933.

Curea, C.D., Usturoi, M., Custură, I., Radu-Rusu, R.M., Ratu, N., Prisacaru, M., & Usturoi, A. (2023). Efficiency of growing of chicken broilers under conditions of compliance with EU rules of welfare. *Scientific Papers. Series D. Animal Science, 66*(1), https://animalsciencejournal.usamv.ro/pdf/2023/issue_1/Art36.pdf.

Davidescu, M. A., Pânzaru, C., Mădescu, B. M., Poroşnicu, I., Simeanu, C., Usturoi, A., Matei, M., & Doliş, M. G. (2025). Advances and challenges in smart packaging technologies for the food industry: Trends, applications, and sustainability considerations. *Foods, 14*(24), 4347, https://doi.org/10.3390/foods14244347.

Day, L., Augustin, M. A., Batey, I. L., & Wrigley, C. W. (2006). Wheat-gluten uses and industry needs. *Trends in Food Science & Technology, 17*(2), 82-90, https://doi.org/10.1016/j.tifs.2005.10.003.

Donohue, M., & Cunningham, D. L. (2009). Effects of grain and oilseed prices on the costs of US poultry production. *Journal of Applied Poultry Research, 18*(2), 325-337, https://doi.org/10.3382/japr.2008-00134.

European Commission. (2019). *Regulation (EU) 2019/6 on veterinary medicinal products and repealing Directive 2001/82/EC*. Official Journal of the European Union, https://eur-lex.europa.eu/eli/reg/2019/6/oj/eng.

FAO. (2024). *Food Price Index*. Food and Agriculture Organization of the United Nations,

https://www.fao.org/worldfoodsituation/foodpricesindex/en/.

Golubkina, N., Kharchenko, V., Moldovan, A., Antoshkina, M., Ushakova, O., Sekara, A., Stoleru, V., Murariu, O.C, Tallarita, A.V., Sannino, M., & Caruso G. (2024). Effect of Selenium and Garlic Extract Treatments of Seed-Addressed Lettuce Plants on Biofortification Level, Seed Productivity and Mature Plant Yield and Quality. *Plants (13)*,1190 1-15. https://doi.org/10.3390/plants13091190.

González-Alvarado, J. M., Jiménez-Moreno, E., Lázaro, R., & Mateos, G. G. (2007). Effect of type of cereal, heat processing of the cereal, and inclusion of fiber in the diet on productive performance and digestive traits of broilers. *Poultry Science, 86*(8), 1705-1715, https://doi.org/10.1093/ps/86.8.1705.

Gous, R. M., Fisher, C., Tůmová, E., Machander, V., & Chodova, D. (2023). Dietary energy:protein ratio influences the efficiency of utilisation of dietary protein by growing turkeys. *British Poultry Science, 64*(1), 116-121, https://doi.org/10.1080/00071668.2022.2116696.

INSSE (2023). *Anuarul Statistic al României - Agricultură*. Institutul Național de Statistică, București, https://insse.ro/cms/ro/content/statistica-agriculturii.

Karangiya, V. K., Savsani, H. H., Patil, S. S., Garg, D. D., Murthy, K. S., Ribadiya, N. K., & Vekariya, S. J. (2016). Effect of dietary supplementation of garlic, ginger and their combination on feed intake, growth performance and economics in commercial broilers. *Veterinary World, 9*(3), 245-250, https://doi.org/10.14202/vetworld.2016.245-250.

Konieczka, P., Mikulski, D., Ognik, K., Juśkiewicz, J., Zduńczyk, Z., & Jankowski, J. (2021). Increased dietary inclusion levels of lysine are more effective than arginine in supporting the functional status of the gut in growing turkeys. *Animals, 11*(8), 2351, https://doi.org/10.3390/ani11082351.

Lee, J. T., Rochell, S. J., Kriseldi, R., Kim, W. K., & Mitchell, R. D. (2023). Functional properties of amino acids: Improve health status and sustainability. *Poultry Science, 102*(1), 102288, https://doi.org/10.1016/j.psj.2022.102288.

Leeson, S., & Summers, J. D. (2001). *Nutrition of the chicken (4th ed.)*. University Books, Guelph, Canada.

Lungu, V. D., & Moise, A. E. (2025). The impact of supplementing feed with omega-3 fatty acids on the nutritional and technological characteristics of poultry meat: A review. *Scientific Papers. Series D. Animal Science, 68*(1), 234-240, https://animalsciencejournal.usamv.ro/pdf/2025/issue_1/Art29.pdf.

Lungu, V. D., Zinca, A. I., Moise, A. E., & Dragotoiu, D. (2024). Nutritional quality of poultry meat according to breeding systems. *Scientific Papers. Series D. Animal Science, 67*(1), 260-264, https://www.animalsciencejournal.usamv.ro/pdf/2024/issue_1/Art33.pdf.

Makinde T.O. (2022). The effect of a botanical extract blend on behaviour, enrichment use, stress response, production performance, and egg quality of laying hens housed in a furnished cage system, *Submitted in partial fulfillment of the requirements for the degree of Master of Science*, Dalhousie University, Halifax, Nova Scotia, https://dalspace.library.dal.ca/bitstreams/a044ab8d-afcf-4157-9923-2cf4ea471851/download.

Mishra, D. K., Singh, S., & Singh, P. (2024). Therapeutic benefits and processing of marigold (*Tagetes* species): A review. *Indian Journal of Health Care, Medical & Pharmacy Practice, 5*(1), https://doi.org/10.59551/IJHMP/25832069/2024.5.1.190.

Moise, A. E., Pet, I., Panici, G., Stan, E. G., Lungu, D. V., Zinca, A. I., Enea, D. N., & Dragotoiu, D. (2025). Analysis of technological, sensory and food safety characteristics of semi-prepared products made from chicken inner filet. *Scientific Papers. Series D. Animal Science, 68*(1), 448–461, https://animalsciencejournal.usamv.ro/pdf/2025/issue_1/Art54.pdf.

Mottet, A., & Tempio, G. (2017). Global poultry production: Current state and future outlook and challenges. *World's Poultry Science Journal, 73*(2), 245–256, https://doi.org/10.1017/S0043933917000071.

National Research Council (NRC). (1994). *Nutrient requirements of poultry (9th revised ed.)*. National Academy Press, Washington, DC.

OECD-FAO. (2023). *Agricultural Outlook 2023–2032*. OECD Publishing, https://www.oecd.org/en/publications/oecd-fao-agricultural-outlook-2023-2032_08801ab7-en.html.

Ognik, K., Mikulski, D., Konieczka, P., Tykałowski, B., Krauze, M., Stępniowska, A., Nynca, A., & Jankowski, J. (2021). The immune status, oxidative and epigenetic changes in tissues of turkeys fed diets with different ratios of arginine and lysine. *Scientific Reports, 11*, 15975, https://doi.org/10.1038/s41598-021-95529-y.

Pesti, G. M., & Choct, M. (2023). The future of feed formulation for poultry: Toward more sustainable production of meat and eggs. *Animal Nutrition, 15*, 71-87, https://doi.org/10.1016/j.aninu.2023.02.013.

Preethi, K. C., Kuttan, G., & Kuttan, R. (2009). Anti-inflammatory activity of flower extract of Calendula officinalis Linn. and its possible mechanism of action. *Indian Journal of Experimental Biology, 47*(2), 113-120, PMID: 19374166.

Rahimi, S., Teymouri Zadeh, Z., Karimi Torshizi, M.A., Omidbaigi, R., & Rokni, H. (2011). „Effect of the Three Herbal Extracts on Growth Performance, Immune System, Blood Factors and Intestinal Selected Bacterial Population in Broiler Chickens. *Journal of Agricultural Science and Technology, 13*, 527-539.

Ravindran, V. (2013). Feed enzymes: The science, practice, and metabolic realities. *Journal of Applied Poultry Research, 22*(3), 628-636. https://doi.org/10.3382/japr.2013-00739.

Rostagno, H. S., et al. (2017). *Brazilian Tables for Poultry and Swine: Composition of Feedstuffs and Nutritional Requirements (4th ed.)*, UFV, Brazil.

Sell, J. L., Hasiak, R. J., & Owings, W. J. (1985). Independent effects of dietary metabolizable energy and protein concentrations on performance and

carcass characteristics of tom turkeys. *Poultry Science, 64*(8), 1527-1535, https://doi.org/10.3382/ps.0641527.

Shewry, P. R. (2009). Wheat. *Journal of Experimental Botany, 60*(6), 1537-1553. https://doi.org/10.1093/jxb/erp058.

Strifler, P., Horváth, B., Such, N., Farkas, V., Wágner, L., Dublecz, K., & Pál, L. (2023). Effects of feeding low protein diets with different energy-to-protein ratios on performance, carcass characteristics, and nitrogen excretion of broilers. *Animals, 13*(9), 1476, https://doi.org/10.3390/ani13091476.

Surai, P. F., Kochish, I. I., Fisinin, V. I., & Kidd, M. T. (2019). Antioxidant defence systems and oxidative stress in poultry biology: An update. *Antioxidants, 8*(7), 235, https://doi.org/10.3390/antiox8070235.

Toghyani, M., Toghyani, M., Gheisari, A., Ghalamkari, G., & Eghbalsaied, S. (2011). Evaluation of cinnamon and garlic as antibiotic growth promoter substitutions on performance, immune responses, serum biochemical and haematological parameters in broiler chicks. *Livestock Science, 138*(1-3), 167-173, https://doi.org/10.1016/j.livsci.2010.12.018.

Trifunschi, S., Munteanu M.., Pogurschi, E., & Gligor R. (2017). Characterisation of Polyphenolic Compounds in *Viscum album* L. And *Allium sativum* L. Extracts. *Revista de Chimie*, 68, 1677-1680.

Tufarelli, V., Ragni, M., & Laudadio, V. (2018). Feeding forage in poultry: A promising alternative for the future of production systems. *Agriculture, 8*(6), 81, https://doi.org/10.3390/agriculture8060081.

Usturoi, A., Doliș, M.-G., Rațu, R.-N., Simeanu, C., Baltag, F., Nistor, C.-E., Pânzaru, C., Radu-Rusu, R.-M., Davidescu, M.-A., & Usturoi, M.-G. (2025). Effects of ecological sea buckthorn powder supplementation on egg production and quality in free-range Moravia Black hens. *Agriculture, 15*(1), 104, https://doi.org/10.3390/agriculture15010104.

Usturoi A., Usturoi M.G., Avarvarei B.V., Pânzaru C., Simeanu C., Usturoi M.I., Spătaru M., Radu-Rusu R.M., Doliș M.G., & Simeanu D. (2023). Research Regarding Correlation between the Assured Health State for Laying Hens and Their Productivity. *Agriculture, 13*(1), 86, https://doi.org/10.3390/agriculture13010086.

Watson, S. A. Ramstad, M. (2003). Description, development, structure and composition of the corn kernel. In: *Corn Chemistry and Technology*. American Association of Cereal Chemists, https://www.cabidigitallibrary.org/doi/full/10.5555/20033163536

Windisch, W., Schedle, K., Plitzner, C., & Kroismayr, A. (2008). Use of phytogenic products as feed additives for swine and poultry. *Journal of Animal Science, 86*(Suppl. 14), E140-E148, https://doi.org/10.2527/jas.2007-0459.

Woyengo, T. A., Bach Knudsen, K. E., & Børsting, C. F. (2023). Low-protein diets for broilers: Current knowledge and potential strategies to improve performance and health, and to reduce environmental impact. *Animal Feed Science and Technology*, 297, 115574, https://doi.org/10.1016/j.anifeedsci.2023.115574.

Zampiga, M., Calini, F., & Sirri, F. (2021). Importance of feed efficiency for sustainable intensification of chicken meat production: Implications and role for amino acids, feed enzymes and organic trace minerals. *World's Poultry Science Journal, 77*(3), 639-659, https://doi.org/10.1080/00439339.2021.1959277.

Zhai, H., Liu, H., Wang, S., Wu, J., & Kluenter, A.-M. (2018). Potential of essential oils for poultry and pigs. *Animal Nutrition, 4*(2), 179-186, https://doi.org/10.1016/j.aninu.2018.01.005.

REPRODUCTION, PHYSIOLOGY, ANATOMY