ISUBU
Journal of Agriculture Faculty
Ziraat Fakültesi Dergisi
ISSN 1304-9984 e-ISSN 2687-3419
https://dergipark.org.tr/tr/pub/sduzfd
Issue 1, pp. 1-13, 2026
Araştırma Makalesi/Research Article

Effects of Peat and Feather-Based Feed Additives on Digestive and Reproductive Organ Development in Adler Silver Laying Hens

Alla CARA[1]
1 Comrat State University, Agro-Technological Faculty, Department of Production and Agro-Processing Technology COMRAT-REPUBLIC of MOLDOVA

Abstract
The purpose of this study was to investigate the effects of non-traditional organic feed additives derived from peat and feathers on the development of digestive and reproductive organs in Adler Silver laying hens. A total of 180 one-day-old hens were randomly allocated into three groups: a control group fed a basal compound feed, and two treatment groups receiving the basal diet supplemented with either a peat-based additive (1 kg/ton) or a feather-based additive (2 kg/ton). At 180 days of age, morphometric measurements of the digestive tract and reproductive organs were performed. Hens receiving both feed additives exhibited enhanced development of the digestive system, including increased length of the small intestine and duodenum compared with the control group. Furthermore, supplementation resulted in a significant increase in ovary mass and oviduct length, indicating improved reproductive system development and physiological readiness for egg production. No pathological alterations were observed in the examined organs, suggesting that the additives did not adversely affect the hens' health status. The findings demonstrated that peat and feather-based organic feed additives can positively influence digestive and reproductive organs development in laying hens, highlighting their potential as alternative components in poultry nutrition strategies.

Article Info
Received:26.12.2025
Accepted:10.03.2026

Keywords
Digestive organs
Hens
Oviduct

Turba ve Tüy Bazlı Yem Katkı Maddelerinin Adler Gümüş Yumurta Tavuklarında Sindirim ve Üreme Organlarının Gelişimine Etkileri

Öz
Bu çalışmanın amacı turba ve tüy kökenli geleneksel olmayan organik yem katkı maddelerinin Adler gümüşü yumurtacı tavuklarda sindirim ve üreme organlarının gelişimi üzerine etkilerini araştırmaktır. Toplam 180 adet bir günlük yaştaki civcivler, kontrol grubu (temel karma yem) ve iki deneme grubu olacak şekilde üç gruba ayrılmıştır. Araştırma gruplarına sırasıyla turba bazlı katkı maddesi (1 kg/ton) ve tüy bazlı katkı maddesi (2 kg/ton) içeren rasyonlar verilmiştir. Araştırmanın 180. gününde sindirim sistemi ve üreme organlarına ait morfometrik ölçümler yapılmıştır. Araştırma gruplarında, özellikle ince bağırsak ve duodenum uzunluğunda kontrol grubuna kıyasla belirgin artışlar tespit edilmiştir. Ayrıca, ovaryum ağırlığı ve ovidukt uzunluğu deneme gruplarında anlamlı düzeyde artmış olup, bu durum üreme sisteminin daha iyi geliştiğini ve yumurtlama dönemine fizyolojik olarak daha hazır olunduğunu göstermektedir. İncelenen organlarda herhangi bir patolojik değişikliğe rastlanmamış, kullanılan yem katkı maddelerinin hayvan sağlığı ve performans üzerinde olumsuz bir etki oluşturmadığı belirlenmiştir. Sonuç olarak, turba ve tüy bazlı organik yem katkı maddelerinin Adler gümüşü yumurtacı tavuklarda sindirim ve üreme organlarının gelişimini olumlu yönde etkileyebileceği ve kanatlı beslemede alternatif yem katkıları olarak değerlendirilebileceği ortaya konmuştur.

Anahtar Kelimeler
Ovidukt
Sindirim organları
Yumurtacı tavuklar

Corresponding Author
adimkara1@gmail.com

Introduction

The emerging trend in the production of environmentally friendly food products is an essential element in the technology for the production of poultry products and improving its quality, which requires the search for new types of non-traditional feed additives.

Poultry meat and eggs are especially in demand in the consumer market, as they have high taste characteristics and are relatively cheaper (Ivanov, 2014).

DOI: 10.54975/isubuzfd.1849385

Today, the poultry industry is under pressure to obtain maximum quantity of poultry meat and eggs while reducing the cost of production, as well as obtaining high-quality and environmentally friendly products (Kolesnik and Derkho, 2014).

Displaying the full genetic potential of poultry is possible only with the use of the latest scientific developments and their application in the form of supplements to the basic diet.

Use of non-traditional feed additives reduces the use of expensive feed, stimulates metabolic processes, increases the resistance of the poultry organism, and increases the productivity and quality of poultry products.

Taking the modern structure of the diets of poultry sector into account, a detailed study of the morphology and physiology of the digestive apparatus and egg-forming organs has now acquired particular relevance. The biological basis for the development and implementation of ways to increase the productivity of poultry is the knowledge of the patterns of development of digestion, as organs that directly provide metabolism in the body, and egg formation, as organs that directly determine the level of egg productivity.

In modern trends in the development of poultry farming, the possibility of increasing the level of implementation of the bioresource potential of poultry in the meat and egg direction of productivity by increasing the biological usefulness and efficiency of diets (Zelenkova and Pakhomov, 2010), through the use of new non-traditional feed additives individually and in combination, as methods for improving digestion processes (Zelenkova and Pakhomov, 2012), morpho-biochemical and immune status of blood, metabolism, egg productivity through earlier and better development of internal organs - digestion and egg formation, is currently an urgent scientific problem (Zelenkova and Gorlov, 2013; Pakhomova et al., 2013).

Humic substances, including humic acid, have been shown to positively affect poultry performance, feed conversion efficiency, gastrointestinal health, and immune status, making them promising components of poultry diets (Arif et al., 2019). Experimental data obtained from pheasant rearing further indicate that dietary supplementation with humic substances enhances body weight gain, improves feed utilization, and promotes the development of the digestive tract, thereby extending their applicability beyond intensive poultry systems to specialized poultry production (Hreško Šamudovská et al., 2025). Similarly, phytogenic feed additives demonstrate the capacity to improve gut health, intestinal microbiota, and immune functions in poultry; however, their efficacy is largely dependent on composition and dosage, highlighting the need for further research and standardization (Abdelli et al., 2021). Dietary fiber also plays a crucial role in maintaining intestinal functionality, as its optimal inclusion in poultry diets improves nutrient utilization and performance and may reduce the environmental impact of poultry production (Jha and Mishra, 2021). Recent studies confirm the high potential of natural feed additives as alternatives to antibiotic growth promoters in poultry production. Thus the purpose of this study was to investigate the effects of non-traditional organic feed additives derived from peat and feathers on the development of digestive and reproductive organs in Adler Silver laying hens.

Material and Method

Experimental Design

The studies were conducted in 2019 at the poultry farm SRL “Piliççik-Grup”, located in the city of Comrat, Comrat District. Laboratory analyses were carried out at the Department of Animal Resources and Food Safety of the Technical University of Moldova. The research materials included organic feed additives obtained through enzymatic processing of feathers and pre-treated peat. The animal material of the study was dual-purpose (meat-and-egg) laying hens of the Adler Silver breed.

 DOI: 10.54975/isubuzfd.1849385

Adler Silver chickens were placed at one day of age into three treatment groups by body weight and physiological status, as recommended in poultry physiological studies (Sklan, 2001; Uni et al., 2003) (Table 1).

Table 1. Treatments of the experiment.

Treatments	Feeding characteristics
Control (CG)	Basic compound diet (BCD)
Treatment 1 (TRT1)	BCD with inclusion of OFAP* 1 kg/ton
Treatment 2 (TRT2)	BCD with inclusion of OFAF** 2.0 kg/ton

* - OFAP- organic feed additive from peat
** - OFAF - organic feed additive from feather

According to the experimental design, one group served as the control; laying hens in this group were fed a standard compound diet used at the poultry farm. Laying hens in the first treatment group (TRT1) received an organic feed additive from peat at a dosage of 1 kg per ton of feed, whereas laying hens in the second treatment group (TRT2) were supplemented with an organic feed additive from feathers at a dosage of 2 kg per ton of feed.

Each group consisted of 60 laying hens. Throughout the entire experimental period, the laying hens were housed under a floor-rearing system. Microclimatic conditions in the poultry houses were maintained in accordance with the recommended standards for keeping Adler Silver laying hens.

Materials

The Adler Silver chicken breed was developed in 1965 through the crossbreeding of five breeds – Pervomayskaya, Russian White, Yurlov Crower, White Plymouth Rock, and New Hampshire – known for their high meat quality, intensive growth, and good egg-laying performance. Laying hens of this breed are characterized by stable egg production and high meat quality over a period of 3-4 years, which determines their prolonged productive lifespan (Sidorenko, 2016).

An organic feed additive from feather is a feed product obtained from feathers remaining after the slaughter of poultry through their technological processing and conversion. During production, feathers undergo hydrolysis, thermal treatment, drying, and grinding, which substantially improves protein digestibility and makes this product suitable for inclusion in compound feed formulations. Feather meal is a valuable source of nutrients, particularly sulfur-containing amino acids such as cystine and methionine. The crude protein content of feather meal exceeds 80%, which allows it to be considered a potentially effective feed component in poultry diets, provided that appropriate technological processing and dietary balance are ensured (Caisin et al., 2025).

An organic feed additive from peat represents a promising non-food raw material for use in feed production due to its rich and diverse chemical composition. It contains both organic and inorganic compounds that may exert a beneficial effect on the health and productivity of farm animals (Martynov, 2001). According to Caisin (2021), the effectiveness of peat-based organic feed additives in poultry production has been demonstrated. The high concentration of active components and the unique composition of the peat additive, which possesses adsorptive properties due to the presence of humic acids and lignin, contributed to the enhancement of the natural immune response in laying hens. As a result, increased egg production, improved product quality, and reduced feed costs were observed.

The nutritional value of the diets used in the study is presented in Table 2. It reflects the differences in the energy supply of the diets among the treatment groups.

 DOI: 10.54975/isubuzfd.1849385

Table 2. Nutritional value of the feeds used in the experiment.

Parameters	Treatments		
	CG	TRT1	TRT2
Metabolizable energy (MJ/kg)	12.5	13.0	13.1
Poultry ME (kcal/100 g)	299	311	312
Crude protein (%)	21.8	20.5	20.0
Crude fat (%)	5.3	6.5	7.2
Crude fiber (%)	3.1	3.0	3.9
Lysine (%)	1.3	1.3	1.2
Methionine (%)	0.61	0.60	0.60
Methionine + cystine (%)	0.97	0.95	0.94
Threonine (%)	0.88	0.82	0.80
Tryptophan (%)	0.26	0.24	0.23
Calcium (+ phytase) (%)	1.05	0.96	0.91
Total phosphorus (+ phytase) (%)	0.80	0.75	0.75
Available phosphorus (%)	0.50	0.45	0.44
Sodium (%)	0.17	0.17	0.17
Vitamins			
Vitamin A (IU/kg)	12500	12500	12500
Vitamin D3 (IU)	5000	5000	5000
Vitamin E (mg)	75	70	70

The diets of TRT1 and TRT2 had a slight increase in energy value compared with the compound feed of the control group. The level of metabolizable energy in TRT1 and TRT2 increased by 0.50 and 0.60 MJ/kg, respectively, while the metabolizable energy content of the diet increased by 12-13 kcal per 100 g of feed. The crude protein content in the compound feeds of the TRT1 and TRT2 groups was lower by 1.3-1.8% compared with the control group, with an higher crude fat content by 1.2-1.9%. The crude fiber level in the compound feed of TRT2 exceeded that of the control group (CG) by 0.8%. The content of essential amino acids in TRT1 and TRT2 feed was lower: in lysine by 0.02-0.08%, threonine by 0.06-0.08%, and tryptophan by 0.02-0.03%. At the same time, the concentration of methionine and the total content of methionine and cystine remain practically unchanged. The mineral composition of the compound feeds of the TRT1 and TRT2 groups was characterized by a decrease in calcium content by 0.09-0.14% and available phosphorus by 0.05-0.06%, while the sodium level remains stable at 0.17%. Vitamin supplementation of the diets was balanced: the contents of vitamins A and D_3 remain unchanged, whereas the level of vitamin E in TRT1 and TRT2 was lower than in the control group by 5 mg/kg, corresponding to a decrease of 6.7%. Overall, the compound feeds used in the experiment differed in nutritional value as well as in protein, amino acid, and mineral supply.

Sampling Collection

Sample collection was performed on day 180 of the experiment. Prior to euthanasia, the live body weight of each bird was recorded with an accuracy of ±1 g. The birds were euthanized in accordance with accepted ethical and physiological guidelines for poultry research.

After euthanasia, the abdominal cavity was opened, and the following organs were carefully excised following classical anatomical procedures described by Sklan (2001) and Uni et al. (1998):

• Digestive system: esophagus, crop, glandular stomach (proventriculus), muscular stomach (gizzard), and small intestine;

• Reproductive system: ovary and oviduct.

Excised organs were freed from adhering connective tissue, rinsed in physiological saline solution (0.9% NaCl), and gently blotted dry with filter paper prior to measurements.

Morphometric Measurements of Digestive Organs

Morphometric evaluation of digestive organs was performed according to methods widely applied in poultry ontogenetic studies (Uni et al., 1998; Geyra and Uni, 2001; Sklan, 2001).

- Esophagus – measured from the pharyngeal region to the crop.
- Proventriculus and gizzard – measured along the longitudinal central axis.
- Small intestine – measured from the pyloric junction to the ileocecal junction.

Organs' length was measured using a flexible measuring tape with millimeter accuracy; short segments were measured using a metal ruler or digital caliper. Organs' mass was determined using a Radwag PS 1000.R2 electronic balance with an accuracy of 0.001 g.

Morphometric Assessment of Reproductive Organs

The development of the reproductive system was assessed using classical anatomical and morphometric approaches described by Etches (1996) and Johnson (2000).

- Ovary – total mass and visual assessment of follicular development
- Oviduct – carefully straightened and measured along its full length from the infundibulum to the cloaca

Measurements were conducted immediately after dissection to avoid post-mortem tissue changes.

Calculated Indices

The relative organ mass was calculated as a percentage of body weight, following standard morphophysiological methodology (Etches, 1996; Uni et al., 2000):

$$\text{Relative mass (\%)} = \frac{\text{Organ mass (g)}}{\text{Body mass (g)}} \times 100 \qquad (1)$$

Additional parameters included:

- organ index (organ mass to body mass ratio);
- length-to-body-mass ratio for digestive tract segments;
- wall thickness and lumen diameter, measured using a caliper or micrometer (Iji et al., 2001).

Egg Productivity

The parameters of egg productivity were determined according to the method of Lukashenko, 2015.

- Egg production was evaluated separately for each group. The total number of eggs laid during the experimental period was determined and divided by the average number of hens in the group over the same period. The value was calculated using the following formula:

$$EP = \frac{N}{H} \qquad (2)$$

where: EP – egg production, pcs.;
N – number of eggs during the experimental period, pcs.;
H – average number of hens during the entire experimental period, heads;

 DOI: 10.54975/isubuzfd.1849385

- The egg-laying intensity was calculated according to the formula:

$$I = \frac{N}{D} x\ 100\% \quad (3)$$

where: I – egg-laying intensity;
N – number of eggs laid during the experimental period;
D – number of feeding days.

- Egg weight. For each experimental group, egg weight was determined at 16-28 weeks of age. At least 20 eggs were weighed over three consecutive days, and the average egg weight was calculated.

Statistical Analysis

Each treatment group included 60 laying hens. For a detailed assessment of productive and morphological parameters, 10 hens from each group were selected using the analogue group method.

Statistical analysis of the data was performed using one-way analysis of variance (ANOVA). Differences between the mean values of each treatment group were assessed using Tukey's post-hoc test (HSD), with grouping according to Tukey's method at a 95% confidence level. Calculations were carried out using Minitab 17 (Minitab user's guide).

Data processing and graph construction were performed using Microsoft Excel 2017, included in the Microsoft Office 2017.

Results and Discussion

During the experiment, it was noted that the hens were active, had a good appetite, and had dense and shiny plumage, which indicated good condition and egg productivity.

The physiological state of the body and the readiness of the hens for the period of egg production were controlled by the degree of development of the digestive organs and egg production at 180 days of age.

Weight and linear dimensions of the digestive organs and egg formation were studied in the age period of 180 days. The results are presented in Table 3.

Table 3. Influence of organic feed additives on the mass of digestive and reproductive organs in adler silver laying hens (180 days of age).

Treatments	Parameters																	
	Body weight, g			Mass of liver, g			Muscular stomach, g			Glandular stomach, g			Pancreas, g			Ovary, g		
CG	2538	±5	c	34.5	±0.8	b	39.0	±1.2	a	11.4	±0.2	a	4.08	±0.04	a	45.0	±0.3	b
TRT1	2625	±6	a	34.8	±1.1	b	36.3	±1.2	a	10.2	±0.1	b	4.04	±0.03	a	46.3	±0.4	b
TRT2	2584	±6	b	41.5	±1.2	a	39.5	±1.3	a	10.4	±0.1	b	3.84	±0.03	b	48.6	±0.5	a
Mean	2582	±7		36.9	±0.8		38.3	±0.7		10.7	±0.1		3.99	±0.03		46.6	±0.3	
ANOVA																		
F_{group}	*55.2****			*14.8****			*2.0ns*			*20.1****			*14.5****			*22.5****		

The effects were determined by one-way analysis of variance (ANOVA). Differences between means were assessed using Tukey test. Values are expressed as mean ± standard error (SE; n=10). Means marked with different letters indicate statistically significant differences. Significance levels are ns: not significant, *: significant at p≤0.05, **: significant at p≤0.01, ***: significant at p≤0.001

It was found that the weight of the liver in chickens of TRT1 and TRT2 was slightly larger compared to the CG and ranged from 34.8±1.1 to 41.5±1.2 g, which corresponds to the limits of physiological fluctuations. The absolute mass of the muscular stomach in the TRT2 increased by 8.8% and amounted to 39.5±1.3 g in relation to the CG 36.3±1.2.

The weight of the glandular stomach of the CG (11.4 g) exceeded those of the TRT1 (10.2) by 10.6%, and the TRT2 (10.4) by 8.8%, but this excess was minimal. The absolute mass of the pancreas was also within the limits of physiological fluctuations from 3.84±0.03 to 4.08±0.04 g. In the digestive organs of chickens of the control and treatment groups, no pathological changes characteristic of the inflammatory process was found.

The oviduct performs a very complex function. It serves not only as a conducting channel for eggs, but also as a place where their formation ends. The oviduct is a long, winding tube. In laying hens, it occupies most of the left side of the abdominal cavity. Near the ovary, it forms a funnel-shaped expansion. The lower part of the oviduct opens into the cloaca. The mass of the ovary is not constant, it increases with the age of the bird and reaches a significant value by the beginning of oviposition. In laying chickens, the length is 11-18 cm, and the diameter is 0.4-7.0 mm. During intensive oviposition, the length of the oviduct reaches 40-85 cm, and the diameter increases to several centimeters (Bochenkova, 1974; Bogdanov, 1976).

The study of the weight characteristics of the egg-forming organs in hens showed that their best development was observed in the hens of the treatment groups. It can be seen from Table 3 that the absolute weight of the ovary in the CG was 45.0±0.3 g, whereas in TRT2 it was 48.6±0.5 (EG 2) g and 46.3±0.4 g in TRT1, the difference was 3.6 g and 1.3 g, or 8.0 and 2.9%. From the data obtained, it can be concluded that non-traditional feed additives have a positive effect on the increase in ovary weight.

Influence of Organic Feed Additives on the Linear Dimensions of Digestive Organs and the Reproductive System in Adler Silver Laying Hens is provided in Table 4.

The results of the morphometric analysis of the digestive and reproductive organs of laying hens revealed pronounced intergroup differences in parameters of the studied organs.

Table 4. Influence of organic feed additives on the linear dimensions of digestive organs and the reproductive system in adler silver laying hens (180 days of age).

Treatments	Parameters								
	Oviduct, cm			Small intestine, cm			Duodenum, cm		
CG	60.8	±0.8	b	95.8	±1.0	c	21.4	±0.2	c
TRT1	80.3	±1.0	a	122.5	±1.1	a	24.5	±0.3	a
TRT2	78.1	±1.0	a	109.3	±1.0	b	23.2	±0.2	b
Mean	73.1	±1.7		109.2	±2.1		23.0	±0.3	
ANOVA									
F_{group}	135.2^{***}			168.1^{***}			45.2^{***}		

The effects were determined by one-way analysis of variance (ANOVA). Differences between means were assessed using Tukey test. Values are expressed as mean ± standard error (SE; n=10). Means marked with different letters indicate statistically significant differences. Significance levels are ns: not significant, *: significant at p≤0.05, **: significant at p≤0.01, ***: significant at p≤0.001

The length of the oviduct ranged from 60.8 ± 0.8 cm in CG to 80.3 ± 1.0 cm in TRT1, which exceeded the control value by 32.1%. TRT2 had an intermediate value of 78.1 ± 1.0 cm, surpassing the CG by 28.5%. The mean value across all treatments was 73.1 ± 1.7 cm. The increase in oviduct length in the treatment groups indicates enhanced morpho functional development of the reproductive system under the influence of the tested feed additives, creating prerequisites for increased egg production intensity.

A similar pattern was observed for the length of the small intestine, which reached a maximum of 122.5 ± 1.1 cm in TRT1, exceeding the CG (95.8 ± 1.0 cm) by 27.9%. In TRT2, this parameter amounted to 109.3 ± 1.0 cm, which was 14.1% higher than the CG. The mean of all treatments for small intestine length was 109.2 ± 2.1 cm. An increase in intestinal length indicates hypertrophy of the digestive tract, which expands the absorptive surface and, consequently, improves the efficiency of nutrient absorption from feed.

The length of the duodenum varied from 21.4 ± 0.2 cm in the CG to 24.5 ± 0.3 cm in TRT1 (an increase of 14.5%), with an average value of 23.0 ± 0.3 cm. TRT2 showed an intermediate value of 23.2 ± 0.2 cm, which was 8.4% higher than the CG. Elongation of the duodenum is of important physiological significance, as this segment is the site of intensive enzymatic digestion of nutrients under the action of pancreatic and intestinal enzymes.

Analysis of variance (ANOVA) revealed a significant effect of the feeding regimes on all studied morphometric parameters (F = 135.2***, 168.1***, and 45.2*** respectively at $p<0.001$), confirming the statistical significance of the observed differences. The most pronounced effect of the experimental factor was noted in TRT1, which exceeded both the CGl and TRT2 in all linear parameters.

The morphological characteristics of the digestive organs and egg formation in hens were studied, and it was established that their optimal development was observed in the treatment groups supplemented with peat and feather additives. No structural changes associated with the development of toxic processes were detected in the internal organs of the treatment groups, indicating that the use of non-traditional feed additives did not exert a negative effect on the physiological state of the hens. Obtained results are consistent with data on viability, live weight, and growth rates in chickens. The digestive organs play a key role in metabolic processes and, through their function, regulate the level of subsequent productivity of the hens.

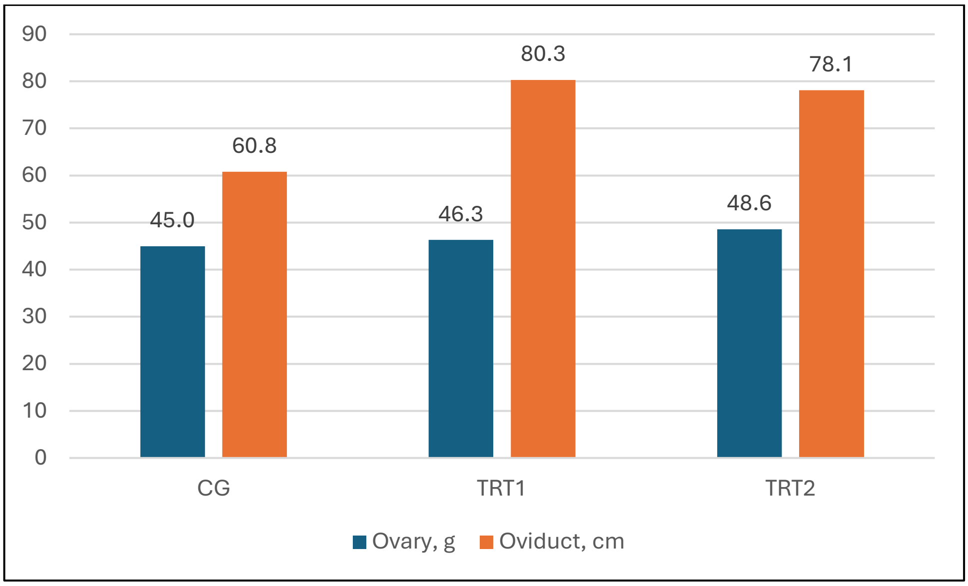

Figure 1. Morphometric relationship between ovary weight and oviduct length in adler silver laying hens.

The morphometric analysis of the reproductive system in laying hens demonstrated significant differences between the control group (CG) and experimental groups (TRT1 and TRT2) in ovary mass and oviduct length. In TRT1, which received the peat supplement, ovary mass increased to 48.6 g (+8.0% vs. CG) and oviduct length to 80.3 cm (+32.1%), while in TRT2, ovary mass reached 46.3 g (+3.0%) and oviduct length 78.1 cm (+28.6%) relative to the CGl (Figure 1).

An association was observed between ovary mass and oviduct length, indicating the role of the ovary in regulating oviduct development and maintaining egg-laying performance. These findings suggest that the peat supplement effectively enhanced reproductive productivity by stimulating growth and development of reproductive organs in laying hens.

Thus, the development of the digestive organs was significantly influenced by the use of peat- and feather-based organic feed additives in the hens' diet. An increase in the size of the muscular stomach, duodenum and the entire small intestine provides an increase in the digesting and absorbing surface of the mucous membrane, which in turn leads to an increase in metabolism and an increase in the productivity and safety of the bird. By adsorbing mycotoxins entering the body, the peat additive contained in the feed prevents the development of toxicological and inflammatory processes in these organs, as evidenced by the condition of the gastric and intestinal mucosa.

The development of the digestive organs and the reproductive system of laying hens directly affects egg production and the morphometric characteristics of eggs (Table 5).

 DOI: 10.54975/isubuzfd.1849385

Table 5. Influence of organic feed additives on the ratio of egg components adler silver laying hens (180 days of age).

Treatments	Egg weight, g			Albumen, g			Yolk, g			Shell, g		
CG	54.0	±0.1	b	31,7	±0.2	b	15.0	±0.1	c	7.186	±0.049	b
TRT1	55.5	±0.2	a	32.3	±0.2	b	15.8	±0.1	a	7.461	±0.053	a
TRT2	56.0	±0.1	a	33.3	±0.2	a	15.4	±0.1	b	7.315	±0.050	ab
Mean	55.2	±0.2		32.4	±0.2		15.4	±0.1		7.321	±0.035	
ANOVA												
F_{group}	*60.5****			*24.3****			*25.3****			*7.5***		
Group	Albumen (%)			Yolk (%)			Shell (%)			Albumen/yolk mass ratio		
CG	58.8	±0.2	ab	27.9	±0,1	b	13.4	±0.1	a	2.108	±0.019	a
TRT1	58.2	±0.2	b	28.5	±0.1	a	13.5	±0.1	a	2.042	±0.006	b
TRT2	59.5	±0.3	a	27.6	±0.1	b	13.1	±0.1	b	2.159	±0.022	a
Mean	58.8	±0.2		28.0	±0.1		13.3	±0.1		2.103	±0.013	
ANOVA												
F_{group}	*9.6****			*22.5****			*10.9****			*11.7****		

The effects were determined by one-way analysis of variance (ANOVA). Differences between means were assessed using Tukey test. Values are expressed as mean ± standard error (SE; n=10). Means marked with different letters indicate statistically significant differences. Significance levels are ns: not significant, *: significant at p≤0.05, **: significant at p≤0.01, ***: significant at p≤0.001

The inclusion of feed additives in the diets of the treatment groups resulted in statistically significant changes in the morphometric characteristics of eggs (Table 5). Significant differences among the studied groups were observed for all major parameters (p<0.05).

The average egg weight in TRT1 was 55.5 g, which exceeded the CG by 2.8%, whereas in TRT2 it reached 56.1 g, providing an increase of 3.8%. The highest egg and albumen weights were recorded in TRT2 (56.1 and 33.3 g, respectively), indicating more favorable conditions for protein metabolism in hens of this treatment.

Analysis of egg structure demonstrated a simultaneous increase in the mass of its main components. The albumen weight in TRT2 was 33.3 g, which was 4.9% higher than that of the CG (31.7 g). The maximum yolk weight was observed in TRT1 (15.8 g), exceeding the CG by 5.0% (15.0 g). The shell weight in TRT1 reached 7.461 g, which was 3.8% higher than the CG (7.186 g), whereas in TRT2 it amounted to 7.315 g (+1.8%). These differences indicate intensification of nutrient deposition processes and shell mineralization in the treatment groups.

Relative parameters also underwent statistically significant changes. The proportion of albumen in TRT2 reached the highest value (59.5%), exceeding the CG by 1.2%, whereas the yolk proportion in this group was the lowest (27.6%). In contrast, TRT exhibited the highest relative yolk proportion (28.5%), which was 2.1% higher than the CG. These features may be associated with differences in the intensity of metabolic processes and in the direction of nutrient utilization in birds from different groups.

The albumen-to-yolk ratio varied from 2.042 to 2.159. The maximum value of this indicator was recorded in TRT2 (2.159), which was 2.4% higher than the CG (2.108) and reflects a preferential increase in the albumen fraction of the egg. Despite the highest absolute yolk weight in TRT1, the albumen-to-yolk ratio in this group was the lowest, which can be explained by a proportional increase in albumen mass.

The relative shell weight remained stable across all treatments (13.1-13.5%), indicating preservation of egg mechanical strength and the absence of any negative effect of the feed additives on shell formation. The F-test values for all morphological parameters confirm that the observed differences are not random but are attributable to the action of the experimental feed additives.

DOI: 10.54975/isubuzfd.1849385

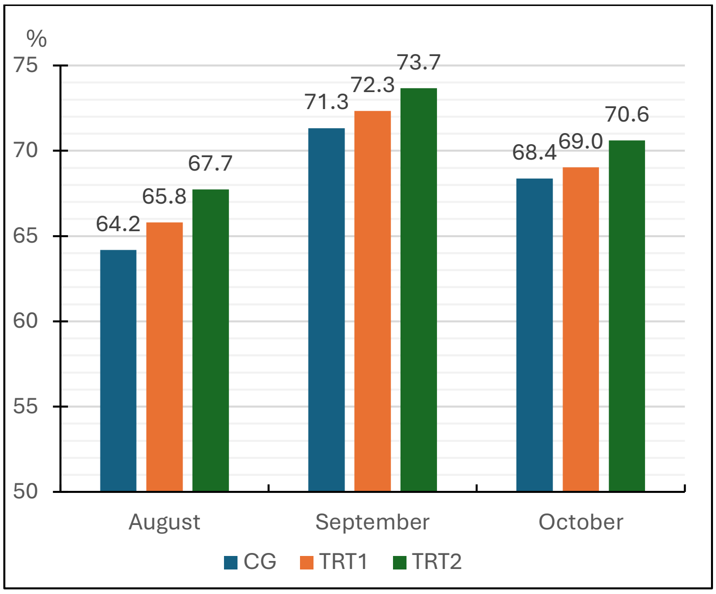

Figure 2. Influence of organic feed additives on egg production of adler silver laying hens, %

Egg production in laying hens is one of the most important economically valuable traits determining the efficiency of both industrial and small-scale poultry farming (Leeson et al., 2005). The onset of laying in pullets was recorded at 15 weeks of age. Egg production was analyzed over a three-month period (August, September, and October), when the hens were 16-28 weeks old (Figure 2).

The experiment showed that egg production in the experimental groups (TRT1 and TRT2) consistently exceeded that of the control group (CG), indicating a positive effect of the applied feed additives.

In August (16-19 weeks of age), egg production in the control group was 64.2%, whereas it reached 65.8% in TRT1 and 67.7% in TRT2. The increase compared with the control amounted to 1.6 and 3.6 percentage points, respectively.

In September (20-24 weeks of age), a general increase in productivity was observed in all treatments. Egg production was 71.3% in the CG, 72.3% in TRT1, and 73.7% in TRT2. The difference relative to the control reached to 1.0 and 2.3 percent in TRT1 and TRT2, respectively.

In October (25-28 weeks of age), a slight decline in egg production compared with September was noted; however, the experimental groups continued to outperform the control. Thus, egg production amounted to 68.4% in CG, 69.0% in TRT1, and 70.6% in TRT2, exceeding the CG by 0.7 and 2.2 percentage points, respectively.

Throughout the entire study period, the highest values were observed in the TRT2, indicating a more pronounced effect of the feather-based feed additive at a dosage of 2 kg/t of feed. The maximum level of egg production (peak productivity) in all treatments was recorded at 20-24 weeks of age (September), followed by a gradual declining trend.

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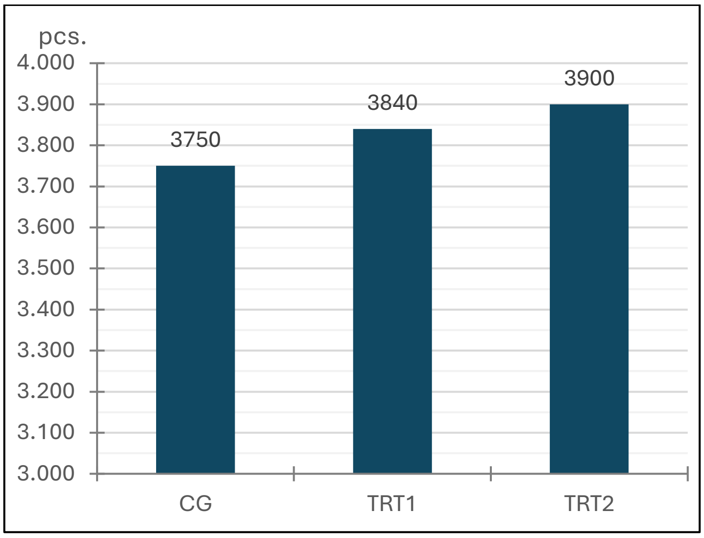

Figure 3. Influence of Organic Feed Additives on Total Egg Production of Adler Silver Laying Hens, %

Total egg production is an integral indicator that objectively reflects the overall productivity of a flock over a certain period and allows assessment of the economic efficiency of the applied technological solutions in poultry farming (North and Bell, 1990). During the study, covering the age of birds from 16 to 28 weeks, total egg production in TRT1 and TRT2 significantly exceeded that of the CG (Figure 3).

In the CG, 3,750 eggs were obtained, whereas 3,810 eggs were collected in TRT1, which is 60 eggs more (an increase of 1.6%), and 3,900 eggs in TRT2, exceeding the control by 150 eggs (an increase of 4.0%).

The increase in total egg production in the experimental groups indicates a positive effect of the applied feed additives on reproductive function and overall bird productivity. The most pronounced improvement was observed in TRT2, where the increase reached a maximum of 4.0% compared with the control. This suggests that the feeding strategy applied in TRT2 was the most optimal.

It is important to note that the increase in total egg production remained stable throughout the entire experimental period, confirming not only a short-term stimulating effect but also a prolonged influence of the feed additives on the physiological condition of laying hens. When extrapolated to annual productivity, the additional 150 eggs obtained from laying hens in TRT2 may represent a substantial economic benefit on an industrial scale. The obtained results indicate the feasibility of implementing the tested feed additives in poultry farming practice to enhance egg production in laying hens.

The experimental results indicate a direct relationship between the adequacy of the diet, the development of the digestive and reproductive organs, the level of egg production, and the volume of total egg output. Deficiency or imbalance of dietary nutrients, especially during critical periods of growth and onset of lay, negatively affects the morphofunctional state of organs and, consequently, the productive performance of hens.

Conclusion

The use of organic feed additives based on peat and feathers had no negative effect on the physiological condition of laying hens; no clinical signs of disorders or pathological changes in the digestive and reproductive systems were detected. The application of feed additives promoted pronounced development of the digestive system: the length of the small intestine increased by 27.9% in TRT1 (122.5 ± 1.1 cm) and by 14.1% in TRT2 (109.3 ± 1.0 cm) compared with the CG (95.8 ± 1.0 cm); the length of the duodenum increased by 14.5% and 8.4%, respectively.

Morphometric parameters of the reproductive system improved significantly: ovarian weight increased by 8.0% in TRT1 and by 2.9% in TRT2, while oviduct length increased by 32.1% and 28.5%, respectively, compared with the CG ($p<0.01$).

Feed additives had a positive effect on the morphometric characteristics of eggs: the average egg weight increased by 2.8% in TRT1 and by 3.8% in TRT2; albumen weight increased to 33.3 g (+4.9%), the maximum yolk weight reached 15.8 g (+5.0%), and shell weight reached 7.46 g (+3.8%).

Egg productivity of laying hens in the experimental groups consistently exceeded that of the control group throughout the entire study period (16–28 weeks), and the total egg production increased by 1.6% in TRT1 and by 4.0% in TRT2, which corresponds to an additional yield of 150 eggs during the experimental period.

The most pronounced biological and productive effect was observed in the TRT2 when using a feather-based feed additive at a dose of 2 kg/t of feed, which allows this option to be recommended as optimal for practical application.

Acknowledgments

This study is part of the Doctoral Thesis in Agricultural Sciences entitled “Scientific Substantiation of the Effective Use of Organic Feed Additives to Improve Laying Hen Productivity”. The author expresses sincere gratitude to the scientific supervisor, Doctor Habilitat, Professor Larisa CAISIN of the Technical University of Moldova, for comprehensive scientific and methodological support, valuable consultations, and guidance at all stages of the planning, implementation, and analysis of the experimental research.

Author Contributions

Alla CARA: Resource/Material/Instrument Supply, Observation, Data Curation.

Conflict of Interest

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics Committee Approval

The study was approved by the Ethics Committee of the Agro-Technological Faculty, Comrat State University (Decision No. 3, dated December 2, 2019).

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