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ECONOMIC EVALUATION OF BROILER DIETS SUPPLEMENTED WITH EITHER SELECTED HERBS OR THEIR ASSOCIATED ESSENTIAL OILS

Nadya MINCHEVA[1]*, Magdalena OBLAKOVA[1], Ivelina IVANOVA[1], Pavlina HRISTAKIEVA[1]

[1]*Agricultural Academy, Agricultural Institute, 6000, Stara Zagora, Bulgaria*

Abstract: In recent years, there has been a growing interest in incorporating phytogenic feed additives (PFAs) into broiler chicken diets as potential alternatives to traditional growth-promoting additives. This study evaluated the economics of individually incorporating either six different dried herbs or their essential oils into broiler diets: chamomile, rosemary, lavender, oregano, thyme, and St. John's wort. A total of 390 day-old male broiler chicks (Ross 308) were randomly divided into 13 groups of 30 chicks with three replicates (10 chicks/replicate). One group received a basal diet (control group), while the others received a basal diet supplemented with 2% of each dried herb (E1-E6 groups) or 0.02% of their essential oils (E7-E12 groups) for 39 days. The parameters measured were feed intake, body weight gain, feed conversion ratio, feed costs, economic efficiency and European Broiler Index (EBI). The results showed better economic efficiency with 2% dried St. John's wort herb, as well as 0.02% St. John's wort, rosemary, thyme or lavender essential oils compared to the other treatments (P<0.05), but not compared to the control group (P>0.05). Unsatisfactory results were observed with dry lavender herb and essential oils of chamomile or oregano, which resulted in a significant decrease in net income and economic efficiency due to higher feed costs per kilogram live weight (P<0.05). EBI values were not significantly increased in any of the treated groups compared to the control group (P>0.05). These results suggest that while certain PFAs can improve economic efficiency, their overall effect is variable and some may not outperform traditional growth promoters.

Keywords: Broiler performance, Phytogenic feed additives, Herbs, Essential oils, Economic efficiency

***Corresponding author:** Agricultural Academy, Agricultural Institute, 6000, Stara Zagora, Bulgaria
E mail: minchevan@yahoo.bg (N. MINCHEVA)
Nadya MINCHEVA https://orcid.org/0000-0002-0444-1255
Magdalena OBLAKOVA https://orcid.org/0000-0001-5746-7267
Ivelina IVANOVA https://orcid.org/0000-0002-9899-0684
Pavlina HRISTAKIEVA https://orcid.org/0000-0002-4981-4991

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1. Introduction

The global poultry industry is continuously searching for sustainable and economically viable strategies to enhance the efficiency of broiler production. Over the years, synthetic products, including antibiotic growth promoters, have been extensively used in broiler production to improve growth rate, feed efficiency, prevent diseases, and reduce mortality (Abd El-Hack et al., 2022; Mohamed and Hassan, 2023). However, increasing concerns about the emergence of antibiotic-resistant pathogenic bacteria, as well as antibiotic residues in poultry products, have led to the exploration of alternative, safe, and cost-effective additives that can maintain or even improve production performance without compromising the birds' health, the quality of poultry products, human health, and the environment (Alagawany et al., 2021).

Phytogenic feed additives (PFAs), derived from plant sources with bioactive compounds like aromatic and medicinal plants, their extracts, or essential oils, have gained attention due to their numerous biological and beneficial properties (Puvaĉa et al., 2015; Hassan and Awad, 2017; Giannenas et al., 2018; ; Kadhim, 2018; Singh et al., 2018; Jin et al., 2020). Previous studies indicate that the inclusion of PFAs in diets significantly impact various aspects of broiler performance. It has been reported to stimulate appetite and feed intake, promote the release of digestive enzymes, enhance nutrient utilization, improve gut morphology, modulate the immune system, as well as enhance resilience to heat stress (Omar et al., 2016; Galli et. al., 2020; El-Ashram and Abdelhafez, 2020; Moustafa et al., 2020; Alagawany et al., 2021; Ayalew et al., 2022; Phillips et al., 2023; Señas-Cuesta et al., 2023; Mahasneh et al., 2024). Some essential oils (EOs), such as oregano and thyme, have demonstrated potential in reducing the incidence of common poultry diseases, including coccidiosis and necrotic enteritis (Adhikari et al., 2020). Taken together, these findings suggest a range of potential benefits for maximizing the genetic potential of chickens and reducing mortality, thus increasing profitability (Puvaĉa et al., 2022). Additionally, some additives enhance nitrogen absorption, control excreta odor, and reduce ammonia concentration, thereby decreasing nitrogen excretion into the environment (Chowdhury et al., 2018). Moreover, phytogenic feed additives have shown potential in improving meat quality (fatty acid profile, flavor and shelf-life) which can positively impact consumer preference and marketability (Giannenas et al., 2013; Galli et. al., 2020; Mohamed and Hassan, 2023).

The economic efficiency of diets containing these supplements is crucial in determining their viability and practicality for broiler production. Therefore, the objective of this study is to evaluate the economics of incorporating either six herbs or their essential oils as phytogenic feed additives in broiler chicken diets. The findings of this research will contribute to the existing knowledge on alternative feed additives and provide valuable information to poultry producers, feed manufacturers, and other stakeholders helping them make informed decisions regarding the incorporation of phytogenic feed additives in broiler chicken diets.

2. Materials and Methods

The present study was conducted at the Poultry farm of the Agricultural Institute, Stara Zagora. A total of 390 day-old Ross 308 male broiler chicks, with an initial body weight of 49.78±0.2 g, were randomly assigned to thirteen treatment groups. Each group, comprising 30 chicks, was further divided into three replicates (10 chicks/replicate). Subsequently, each replicate was allocated to a floor pen equipped with one feeder and drinker. Additionally, a continuous lighting program was implemented. The temperature was initially set at 33 °C during the first week and gradually decreased by 3 °C per week until stabilizing at 21 °C in the fourth week.

The dietary treatments included a control group fed basal diets without supplementation and twelve experimental groups. The experimental groups received basal diets supplemented with either 2% herbs (groups E1-E6) or 0.02% of their essential oils (groups E7-E12). The following herbs were used separately in dried powder form: chamomile (*Matricaria chamomilla*), rosemary (*Rosmarinus officinalis*), lavender (*Lavandula angustifolia*), oregano (*Origanum vulgare*), thyme (*Thymus vulgaris*), and St. John's wort (*Hypericum perforatum*). The essential oils were obtained from commercial companies (Nature Energies LTD; ALTEYA ORGANICS LTD, Bulgaria).

Chicks were fed a starter diet (1-10 days of age), a grower diet (11-28 days of age) and a finisher diet (29-39 days of age). The diets were formulated to meet the nutritional recommendations of the National Research Council (NRC, 1994). The composition and calculated nutritional value are shown in Table 1. Feed (in mash form) and water were provided ad libitum to the chicks throughout the experiment.

Table 1. Ingredients and calculated nutrient composition of starter (1-10 d), grower (11-28) and finisher (29-39 d) diets

Ingredients, %	Starter (1-10 days)	Grower (11-28 days)	Finisher (29-39 days)
Soybean meal	35.00	31.00	25.00
Wheat	30.00	29.69	35.87
Maize	21.22	25.00	24.00
DDGS	5.00	5.00	5.00
Sunflower oil	5.00	6.00	7.00
Dicalcium phosphate	2.05	1.80	1.65
Limestone	0.60	0.50	0.55
Salt	0.20	0.20	0.20
Premix*	0.20	0.20	0.20
Lysine	0.25	0.17	0.12
Methionine	0.18	0.14	0.11
Salgard	0.20	0.20	0.20
Optizim	0.10	0.10	0.10
Calculated nutrient composition, %			
Metabolizable energy, kcal/kg	2912.80	3042.19	3111.17
Crude protein	22.47	21.01	19.02
Ether extract	7.03	8.10	9.08
Crude fiber	3.99	3.77	3.48
Calcium	1.03	0.90	0.85
Available phosphorus	0.50	0.45	0.43
Lysine	1.44	1.25	1.05
Methionine	0.50	0.45	0.40
Methionine + cysteine	0.85	0.77	0.68

*Composition/kg of premix: Vit. A= 6 000 000 IU, Vit D3= 2 500 000 IU, Vit. E= 45 000 mg, Vit B1= 2 000 mg, Vit B2= 4 500 mg, Vit B6= 2 500 mg, Pantothenic acid= 10 000 mg, Biotin= 125 mg, Vit. K3= 2 000 mg, Folic acid= 1 100 mg, Nicotinic acid= 32 500 mg, Vit. B12= 10 mg, Selenium= 150 mg, Manganese= 60 000 mg, Iron= 12 500 mg, Zinc= 45 000 mg, Copper= 7 500 mg, Iodine= 500 mg

Performance parameters, including body weight and the feed consumed, were measured at the end of the starter, grower, and finisher periods. Then body weight gain, feed intake, and feed conversion ratio were calculated for specified periods, as well as for the entire fattening period of the chickens. Additionally, mortality rates were also recorded daily.

Input-output analysis was used to assess the economic efficiency of the experimental diets, assuming other costs remained constant, as suggested by Hassan and Awad (2017), as follows:

1) Total feed cost = feed intake per bird x cost of 1 kg diet
2) Feed cost/kg weight gain = feed conversion x cost of 1 kg diet
3) Net revenue/kg gain = revenue/kg gain – feed cost/kg gain
4) Economic efficiency = net revenue/feed cost per kg gain.

Input costs data were collected by calculating the prices of feed ingredients available on the market at the time of the experiment. The additional costs of the tested dried herbs and essential oils were included in the feed price.

In the economic assessment, the total feed cost, feed cost per kg of weight gain for each feed period, as well as for the entire experimental period were taken into account. Total revenue per bird sell was also considered assuming 4.80 BGN/kg live body weight constant for all treatment birds.

The economic efficiency of growth was determined through the calculations of European Broiler Index (EBI) based on the following formula given in Equation 1 (Marcu et al., 2013):

$$EBI = \frac{\text{Viability (\%) x ADG (g/chick/day)}}{\text{FCR (kg feed/kg gain) x 10}} * 100 \qquad (1)$$

where, ADG= average daily gain; FCR= feed conversion ratio.

2.1. Statistical Analysis

The data were analyzed using General Linear Model procedure of SPSS (version 19.0). Means were compared using Duncan's Multiple Range Test, with the level of significance set at P<0.05. The replicate pens served as experimental units for all parameters.

3. Results

Table 2 presents the economics of cost in relation to the supplementation of dried herbs in broiler diets during the starter, grower, and finisher periods. The inclusion of the tested herbs in the basal diet resulted in an increase in the price of the dietary mixtures for all three phases, ranging from 0.10 to 0.40 BGN/kg. However, no significant differences in feed consumption and feed conversion were found during these periods (P>0.05). As a result, most of the groups given herbal diets had higher total feed costs and feed costs per kilogram of gain compared to the control group (P<0.05), except for those receiving rosemary (E2), thyme (E5) or St. John's wort herb (E6) during the starter and grower phases, which were comparable to the control birds (P>0.05). On the other hand, the starter diet containing lavender herb (E3) resulted in the highest total feed cost (34.48%) and feed cost per kilogram of gain (45.45%), a trend that continued in subsequent periods (P<0.05), followed by the group fed a diet supplemented with chamomile (E1) during both the grower and finisher periods compared to the control group.

Table 2. Cost effectiveness of broiler diets supplemented with 2% dried herbs

Parameters	Groups							SEM	*P*-value
	C	E_1	E_2	E_3	E_4	E_5	E_6		
Starter period (1-10 d)									
Feed price, BGN/kg	0.93	1.17	1.12	1.31	1.07	1.03	1.03	-	-
Feed intake, kg/bird	0.32	0.29	0.28	0.30	0.33	0.30	0.30	0.01	0.177
Total feed cost, BGN	0.29^{b}	0.34^{abc}	0.32^{bc}	0.39^{a}	0.36^{ac}	0.31^{bc}	0.31^{bc}	0.02	0.004
Feed conversion, kg/kg	1.78	1.71	1.94	1.83	1.85	1.89	1.86	0.09	0.672
Feed cost/kg gain, BGN	1.65^{c}	2.00^{b}	2.18^{ab}	2.40^{a}	1.99^{b}	1.94^{bc}	1.91^{bc}	0.10	0.004
Grower period (11-28 d)									
Feed price, BGN/kg	0.90	1.14	1.09	1.29	1.05	1.00	1.00	-	-
Feed intake, kg	1.57	1.56	1.47	1.58	1.58	1.64	1.48	0.07	0.610
Total feed cost, BGN	1.42^{c}	1.78^{b}	1.61^{bc}	2.03^{a}	1.66^{bc}	1.64^{bc}	1.48^{c}	0.08	0.002
Feed conversion , kg/kg	1.70	1.56	1.83	1.58	1.59	1.70	1.63	0.08	0.304
Feed cost/kg gain, BGN	1.53^{b}	1.78^{ab}	2.00^{a}	2.03^{a}	1.66^{b}	1.70^{b}	1.62^{b}	0.09	0.011
Finisher period (29-39 days)									
Feed price, BGN/kg	0.86	1.11	1.06	1.26	1.02	0.97	0.97	-	-
Feed intake, kg	1.10	1.05	0.88	0.97	1.06	1.08	0.95	0.05	0.080
Total feed cost, BGN	0.95^{b}	1.16^{a}	0.94^{b}	1.21^{a}	1.08^{ab}	1.04^{ab}	0.92^{b}	0.06	0.011
Feed conversion, kg/kg	2.04	2.06	1.74	2.12	2.19	2.14	1.71	0.13	0.114
Feed cost/kg gain, BGN	1.77^{b}	2.29^{ad}	1.86^{bc}	2.66^{a}	2.22^{cd}	2.07^{bcd}	1.65^{b}	0.13	0.001

$^{a-d}$ -Means in the same row with different superscripts are significantly different P<0.05, C = Control group, E1 = 2% *Matricaria*, E2 = 2% *Rosmarinus officinalis*, E3 = 2% *Lavandula*, E4 = 2% *Origanum vulgare*, E5 = 2% *Thymus*, E6 = 2% *Hypericum perforatum*.

Data on the economic efficiency of feeding different experimental diets over a period of 39 days, influenced by dried herbs, are presented in Table 3. There were no significant (P>0.05) differences in total feed consumption and feed efficiency between the groups. However, the total feed cost showed a significant (P<0.05) increase of 36% in the diet supplemented with lavender herb (E3), followed by the diets supplemented with either chamomile herb (E1) by 23.5% or oregano herb (E4) by 16 % compared to the control group. This indicates that the choice of herb supplementation in the diets had a notable impact on the overall feed cost. In terms of feed cost per kilogram of gain, data analysis revealed the most significant (P<0.05) increase of 39 % in the lavender supplemented group (E3). In contrast, the St. John's wort supplemented group demonstrated the lowest value (10-26%) compared to the other treated groups (P<0.05), which were comparable to those of the control group (P>0.05). The economic efficiency values observed in the study were not influenced by the specific properties of each herb, including its potential effects on feed consumption and broiler growth, but rather by the different market prices of the herbs used.

According to the input-output analysis (Table 3), the economic efficiency (EE) values varied among the treatments, with the highest value of 1.96 observed for broilers fed the control diet, followed by 1.88 for chicks fed diets supplemented with St. John's wort, while the lowest value of 1.13 was recorded for the lavender supplementation (P<0.05).

The cost economics related to dietary supplementation of essential oils (EOs) in broiler diets during the starter, grower, and finisher periods are shown in Table 4. The inclusion of essential oils in broiler diets during the starter period had a significant effect on all the parameters studied (P<0.05). Although feed intake was reduced in the groups supplemented with rosemary (E8) or lavender (E9) essential oil (P<0.05), no significant difference in feed utilization was observed compared to the control group (P>0.05).

Table. 3. Economic efficiency of broiler diets supplemented with 2% dried herbs

Parameters	Groups							SEM	*P*-value
	C	E_1	E_2	E_3	E_4	E_5	E_6		
Average feed price, BGN/kg	0.90	1.14	1.09	1.29	1.05	1.00	1.00	-	-
Feed intake, kg	2.99	2.90	2.63	2.84	2.98	3.02	2.73	0.09	0.069
Total feed cost, BGN	2.68^{d}	3.31^{b}	2.88^{cd}	3.65^{a}	3.11^{bc}	3.01^{bcd}	2.72^{d}	0.10	0.000
Feed conversion, kg/kg	1.80	1.75	1.81	1.75	1.79	1.85	1.67	0.05	0.251
Feed cost / kg gain, BGN	1.62^{c}	2.00^{b}	1.97^{b}	2.25^{a}	1.87^{b}	1.85^{b}	1.67^{c}	0.05	0.000
Net revenue/ kg gain, BGN	3.18^{a}	2.80^{b}	2.83^{b}	2.55^{c}	2.93^{b}	2.95^{b}	3.14^{a}	0.05	0.000
Economic efficiency (EE)	1.96^{a}	1.40^{b}	1.44^{b}	1.13^{c}	1.57^{b}	1.59^{b}	1.88^{a}	0.07	0.000
Relative EE	100^{a}	71.43^{b}	73.47^{b}	57.65^{c}	80.10^{b}	81.12^{b}	95.92^{a}	3.31	0.000

$^{a-d}$ -Means in the same row with different superscripts are significantly different P<0.05, C = Control Group, E1 = 2% *Matricaria chamomilla*, E2 = 2% *Rosmarinus officinalis*, E3 = 2% *Lavandula angustifolia*, E4 = 2% *Origanum vulgare*, E5 = 2% *Thymus vulgaris,* E6 = 2% *Hypericum perforatum*.

Table 4. Cost effectiveness of broiler diets supplemented with 0.02% essential oils

Parameters	Groups							SEM	*P*-value
	C	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}		
Starter 1-10 d									
Feed price, BGN/kg	0.93	1.41	0.97	0.97	1.37	1.12	0.97	-	-
Feed intake, kg	0.32^{a}	0.32^{a}	0.27^{bc}	0.25^{c}	0.28^{abc}	0.31^{ab}	0.30^{ab}	0.01	0.010
Total feed cost, BGN	0.29^{d}	0.45^{a}	0.26^{de}	0.24^{e}	0.39^{b}	0.34^{c}	0.29^{d}	0.01	0.000
Feed conversion, kg/kg	1.78^{ab}	2.03^{a}	1.59^{b}	1.63^{b}	1.63^{b}	1.85^{ab}	1.76^{ab}	0.09	0.048
Feed cost/kg gain, BGN	1.65^{c}	2.85^{a}	1.55^{c}	1.58^{c}	2.13^{b}	2.06^{b}	1.71^{c}	0.10	0.000
Grower 11-28 d									
Feed price, BGN/kg	0.90	1.38	0.95	0.95	1.35	1.09	0.95	-	-
Feed intake, kg	1.57	1.55	1.61	1.67	1.63	1.39	1.46	0.10	0.443
Total feed cost, BGN	1.42^{b}	2.14^{a}	1.53^{b}	1.59^{b}	2.19^{a}	1.52^{b}	1.38^{b}	0.11	0.000
Feed conversion , kg/kg	1.70	1.64	1.60	1.65	1.61	1.46	1.50	0.10	0.600
Feed cost/kg gain, BGN	1.53^{b}	2.26^{a}	1.52^{b}	1.57^{b}	2.17^{a}	1.60^{b}	1.42^{b}	0.11	0.000
Finisher 29-39 d									
Feed price, BGN/kg	0.86	1.35	0.91	0.91	1.31	1.05	0.91	-	-
Feed intake, kg	1.10	1.00	1.03	1.03	1.19	1.05	1.10	0.06	0.412
Total feed cost, BGN	0.95^{c}	1.35^{b}	0.94^{c}	0.91^{c}	1.55^{a}	1.10^{c}	1.00^{c}	0.06	0.000
Feed conversion, kg/kg	2.04	1.86	1.77	1.93	2.31	1.95	2.18	0.20	0.530
Feed cost/kg gain, BGN	1.77^{c}	2.50^{ab}	1.61^{c}	1.76^{c}	3.02^{a}	2.06^{bc}	1.98^{bc}	0.22	0.005

$^{a-d}$ -Means in the same row with different superscripts are significantly different P<0.05, C = Control group , E7 = 0.02% *Matricaria chamomilla* oil, E8 = 0.02% *Rosmarinus officinalis* oil, E9 = 0.02% *Lavandula angustifolia* oil, E10 = 0.02%*, Origanum vulgare* oil, E11 = 0.02% *Thymus vulgaris* oil, E12 = 0.02% *Hypericum perforatum* oil.

However, there was an improvement in feed conversion compared to the chamomile oil treated group (P<0.05). The corresponding total feed cost was significantly lower for the diet supplemented with lavender oil (E9) compared to the other groups, which was attributed to reduced feed intake (P<0.05). However, there was a significant increase (P<0.05) in total feed cost in the chamomile oil diet (E7) due to the higher cost of chamomile oil. No significant difference (P>0.05) was observed between the control group and the rosemary (E8) or St. John's wort (E12) dietary supplement groups. Similar trends were observed for feed cost per kg gain. During the next two fattening periods, feed consumption and feed conversion ratio remained unaffected by the addition of essential oils (P>0.05). However, due to the higher prices of chamomile and oregano oil, total feed costs and feed costs per kg of gain were highest in these groups compared to the other groups (P<0.05). Specifically, they were between 30-35% higher during the grower phase and 30-41% higher during the finisher phase compared to the control group.

Table 5 shows the results of the economic efficiency of the dietary supplementation of essential oils in broiler diets. The total feed consumption of the treated groups was comparable to that of the control group (P>0.05). Throughout the experimental period, the broilers fed the diets supplemented with essential oils did not utilize the feed more efficiently than those in the control group (P>0.05). However, there was a highly significant difference between treatments in total feed cost, feed cost per kg gain, net revenue per kg gain and economic efficiency (P<0.001). It is evident that the inclusion of either chamomile or oregano oil in the diet increased the total feed cost by 47-55% and the feed cost per kg gain by 48-55% compared to the control group, resulting in the lowest economic and relative efficiency values, which were 0.98-1.00 and 50-51%, respectively. On the other hand, no significant (P>0.05) differences were found between the control group and the other supplemented groups.

The values for the economic efficiency of growth were obtained by calculating the European Broiler Index (EBI) and are shown in Figure 1(a,b). Typically, improvements in the European Broiler Index (EBI) result from better body weight gain, liveability and a lower feed conversion ratio. A high EBI value indicates good overall technical efficiency of the broiler operation and is desirable for optimal returns (Samarakoon and Samarasinghe, 2012). In our study, the European Broiler Index was not significantly affected by dietary supplementation with either dried herbs or their essential oils, with values ranging from 207.52 to 251.39 for dried herbs and 236.80 to 273.85 for essential oils, respectively. Based on our results, a trend can be observed that supplementing the birds' diet with either St. John's wort herb or rosemary essential oil was more economical than the other treatment groups. Contrary to our results, several authors have stated that the addition of dried herbs or essential oils to broiler diets may have a beneficial effect on EBI (Arczewska-Wlosek and Swiatkiewicz, 2012; Salama et al., 2023).

4. Discussion

In broiler rearing, feed is the major component of input costs, accounting for up to 70% of the total production costs (Shahin et al., 2020). Many efforts have been made to improve growth, enhance feed conversion, and reduce feed costs by supplementing broiler diets with phytogenic feed additives (PFAs), such as herbs and essential oils. Puvaĉa et al. (2020) noted that the cost per diet may increase depending on the specific natural additive used. While some studies have documented the economic benefits of PFAs, the results are not always consistent, suggesting that profitability may depend on factors such as feed prices and broiler’s growth response to the additives. According to Mohamed and Hassan (2023), PFA supplementation has shown economic advantages. Similarly, Omar et al. (2016) found that diets containing herbal extracts proved more economical than control diets, potentially due to enhanced feed conversion efficiency or a reduction in the amount of feed required to produce a unit of meat. Other research has reported similar findings and documented that PFA supplementation in broiler diets led to improved economic efficiency, increasing returns and gross margins in broiler production systems (EL-Faham et al., 2014; Oleforuh-Okoleh et al., 2014; Salama et al., 2023).

Table 5. Economic efficiency of broiler diets supplemented with 0.02% essential oils

Parameters	Groups							SEM	*P*-value
	C	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}		
Average feed cost, BGN/kg	0.90	1.38	0.95	0.95	1.34	1.09	0.94	-	-
Feed intake, kg	2.99	2.87	2.91	2.95	3.09	2.75	2.86	0.14	0.694
Total feed cost, BGN	2.68 ^{b}	3.95 ^{a}	2.75 ^{b}	2.79 ^{b}	4.15 ^{a}	2.99 ^{b}	2.69 ^{b}	0.16	0.000
Feed conversion, kg/kg	1.80	1.74	1.65	1.74	1.81	1.66	1.73	0.08	0.752
Feed cost / kg gain, BGN	1.62 ^{b}	2.40 ^{a}	1.56 ^{b}	1.64 ^{b}	2.43 ^{a}	1.80 ^{b}	1.63 ^{b}	0.10	0.000
Net revenue/ kg gain, BGN	3.18 ^{a}	2.40 ^{b}	3.24 ^{a}	3.16 ^{a}	2.37 ^{b}	3.00 ^{a}	3.17 ^{a}	0.10	0.000
Economic efficiency (EE)	1.96 ^{ab}	1.00 ^{c}	2.08 ^{a}	1.93 ^{ab}	0.98 ^{c}	1.67 ^{b}	1.94 ^{ab}	0.12	0.000
Relative EE	100.0 ^{ab}	51.02 ^{c}	106.12 ^{a}	98.47 ^{ab}	50.00 ^{c}	85.20 ^{b}	98.98 ^{ab}	5.93	0.000

$^{a\text{-}d}$ -Means in the same row with different superscripts are significantly different P<0.05, C = Control Group , E7 = 0.02% *Matricaria chamomilla* oil, E8 = 0.02% *Rosmarinus officinalis* oil, E9 = 0.02% *Lavandula angustifolia* oil, E10 = 0.02*%, Origanum vulgare* oil, E11 = 0.02% *Thymus vulgaris* oil, E12 = 0.02% *Hypericum perforatum* oil

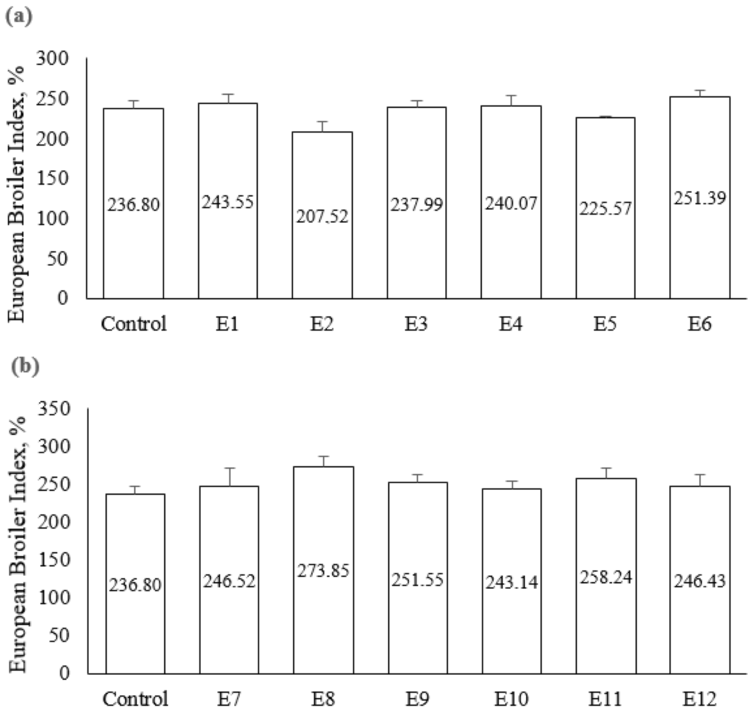

Figure 1. European Broiler Index in relation to dietary supplementation with dried herbs (a) and essential oils (b). C = Control Group, E1 = 2% *Matricaria chamomilla*, E2 = 2% *Rosmarinus officinalis*, E3 = 2% *Lavandula angustifolia*, E4 = 2% *Origanum vulgare*, E5 = 2% *Thymus vulgaris,* E6 = 2% *Hypericum perforatum, E7 = 0.02% Matricaria chamomilla oil, E8 = 0.02% Rosmarinus officinalis oil, E9 = 0.02% Lavandula angustifolia oil, E10 = 0.02%, Origanum vulgare oil, E11 = 0.02% Thymus vulgaris oil, E12 = 0.02% Hypericum perforatum* oil.

Wang et al. (2024) found that supplementing broiler diets with 2% rosemary powder resulted in a lower average daily gain over a 1–42 day period, despite an increase in daily feed intake. Rosemary's strong aroma, combined with its high crude fiber, tannins, and other potential interfering compounds, may limit its efficacy when used in large amounts. Yesilbag et al. (2013) also reported that rosemary affected average daily gain and feed conversion, though better outcomes were observed with rosemary essential oil rather than the whole herb. Dried *Hypericum perforatum* (St John's Wort) positively impacted broiler body weight at slaughter and feed conversion efficiency, while its powdered form did not significantly affect live weight or feed utilization. Similarly, İlhan et al. (2024) found that a *Hypericum perforatum* extract, with low production costs and environmental benefits, showed variable impacts on growth performance. The inclusion of thyme as a feed additive in broiler diets demonstrated the lowest cost per kilogram of weight gain, with the highest economic efficiency observed compared to unsupplemented diet (Osman et al., 2010). In duck diets, chamomile (*Matricaria chamomilla* L.) supplementation at low levels (0.25%, 0.50%, and 0.75%) significantly increased economic efficiency by 37%, 40%, and 64%, respectively, compared to the control group (Ibrahim et al., 2014). Diets containing 1.0 g/kg of chamomile flower powder for both ducklings and duck breeders demonstrated improved economic efficiency, likely due to enhanced feed conversion ratios and body weight gain (Gad et al., 2018; EL-Shhat et al., 2021). However, the tannin concentration in chamomile can impact feed intake and conversion rates, as highlighted by Dada et al. (2015), which suggests that careful attention to herbal composition is necessary when using this herb. Oregano, another widely studied herb, has also demonstrated specific advantages and limitations. Ismail et al. (2017) observed that providing dried oregano leaves to broiler chickens reduced feed intake, resulting in lower average body weight and daily weight gain. However, the feed conversion ratio improved, particularly in birds fed higher levels (9 g/kg diet) of dried oregano leaves, suggesting that the herb enhances gut efficiency, enabling broilers to convert feed into body mass more effectively despite lower overall intake. Ri et al. (2017) suggested that the positive effects of oregano powder supplementation were particularly beneficial during the grower phase of broiler development, indicating that specific growth phases may influence the efficacy of herbal additives. However, these findings were not observed in the present study. Some researchers found a significant reduction in net revenue and economic efficiency when thyme powder was added at the level of 8 g/kg, while statistically similar values were observed in birds fed diets supplemented with 2 and 5 g/kg thyme compared to the control group (Hassan and Awad, 2017). This was due to the fact that the improvement in growth occurred along with a significant concurrent increase in total feed cost. Similar to our results, Singh et al. (2018) reported that supplementing broiler diets with phytogenic feed additives did not improve economic efficiency.

Although the addition of essential oils to broiler diets did not provide economic benefits in our study, they remain important from the perspective of consumers seeking high-quality meat, as they contain numerous bioactive compounds with antioxidant potential (Vlaicu et al., 2022). Adaszynska-Skwirzynska and Szczerbinska (2018) highlighted the advantage of supplementing lavender essential oil (EO) in broiler drinking water, particularly during the second rearing period (days 22–42), when the impact on production performance was more favorable. Additionally, Popović et al. (2016) found that a combination of thyme, rosemary, and oregano essential oils at concentrations of 0.05% and 0.1% improved broiler production performance, suggesting that specific EO blends may offer advantages over individual essential oils.

These inconsistencies in phytogenic feed additives responses across studies are often attributed to the variability of active compounds in herbs, which may be affected by factors such as plant species, harvest time, drying techniques, storage duration, and extraction methods (Hippenstiel et al., 2011). Furthermore, dosage, dietary interactions, and management conditions play significant roles in influencing PFA effectiveness (Behboodi et al., 2021). Research has also indicated that combining specific herbs or essential oils can produce synergistic effects, potentially enhancing the benefits beyond those observed with individual components (Hippenstiel et al., 2011).

5. Conclusion

The economic evaluation indicated better economic efficiency with the dietary supplementation of 2% dried St. John's wort herb, as well as 0.02% St. John's wort, rosemary, thyme, or lavender essential oil supplemented group compared to the corresponding other treated groups (P<0.05), but not when compared to the control group (P>0.05). Unsatisfactory results were observed when using dry herb lavender or essential oil of chamomile or oregano, expressing in a significant decrease in net revenue and economic efficiency due to the highest feed cost to produce 1 kg of live weight compared to other treatments (P<0.05). The European Broiler Index (EBI) values in the groups treated with dry herbs or corresponding essential oils did not show a significant increase compared to the control group (P>0.05). These results underline the need for a comprehensive evaluation of the economic implications associated with the inclusion of phytogenic feed additives in broiler diets.

Author Contributions

The percentage of the author(s) contributions is presented below. The author reviewed and approved the final version of the manuscript.

	N.M.	M.O.	I.I.	P.H.
C	25	25	25	25
D	25	25	25	25
S	25	25	25	25
DCP	25	25	25	25
DAI	25	25	25	25
L	25	25	25	25
W	25	25	25	25
CR	25	25	25	25
SR	100			
PM		100		
FA		100		

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. All procedures, including the use of birds, management and care, were in compliance with the European Council Directive regulations on the protection of animals used for experimental and other scientific purposes (2010/63/EU), and national protocol (approval date: November 01, 2012, protocol code: 20).

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