Jakub URBAN[1] ORCID: 0000-0003-1686-894X; **Edward MAJEWSKI**[2] ORCID: 0000-0003-0886-6645;
Monika GĘBSKA[3] ORCID: 0000-0001-6196-5904; **Anna GRONTKOWSKA**[2] ORCID: 0000-0002-7286-8496;
Monika MICHALCZUK[1] ORCID: 0000-0002-8093-2822;
Anna RYGAŁO-GALEWSKA[4*] ORCID: 0000-0002-2770-6201

[1*] Department of Animal Husbandry and Nutrition, Institute of Animal Sciences, Warsaw University of Life Sciences – SGGW, Ciszewskiego St. 8, Warsaw, 02-786, Poland

[2] Department of Economics and Organization of Enterprises, Institute of Economics and Finance, Warsaw University of Life Sciences – SGGW, Nowoursynowska St. 166, 02-787 Warsaw, Poland

[3] Institute of Management, Warsaw University of Life Sciences – SGGW, Nowoursynowska St. 166, 02-787 Warsaw, Poland

[4*] Institute of Technology and Life Sciences – National Research Institute, Falenty, 3 Hrabska Avenue, 05-090 Raszyn, Poland

* corresponding author e-mail: a.rygalo-galewska@itp.edu.pl

DOI: 10.15199/180.2025.4.2

OPEN ACCESS

Submission received: 28 November 2025 / Revised: 3 December 2025 / Accepted: 23 December 2025 / Published: 30 December 2025

HEALTH, PRODUCTION, AND ECONOMIC EFFECTS OF PHYTOBIOTICS IN THE REARING OF BROILER CHICKENS

ZDROWOTNE, PRODUKCYJNE I EKONOMICZNE EFEKTY ZASTOSOWANIA FITOBIOTYKÓW W ODCHOWIE KURCZĄT BROJLERÓW

Summary: *TPhytobiotics, a diverse group of plant-derived bioactive compounds, are increasingly considered effective alternatives to coccidiostats and antibiotic growth promoters in broiler production. Due to their antimicrobial, antioxidant, digestive-stimulating, and immunomodulatory properties, they enhance gut function, improve feed efficiency, and support overall health. A large commercial-scale trial on Ross 308 broilers demonstrated that phytobiotic supplementation increased body weight, reduced mortality and improved feed conversion. These production effects were incorporated into a cost-benefit analysis using models of typical broiler farms of different sizes. Across all variants, phytobiotics lowered variable costs—mainly through reduced veterinary expenses and improved feed utilization—and increased revenues due to higher sale weights and, in selected scenarios, a price premium for antibiotic-free meat. Gross Margin improved in each of the analyzed farm types, with the greatest economic benefits observed in large-scale systems. The results confirm that phytobiotics provide measurable production and financial advantages, supporting their use as a sustainable and competitive solution in broiler farming.*

Keywords: *broiler chickens, phytobiotics, health effects, production effects, economic effects*

Streszczenie: Fitobiotyki, zróżnicowana grupa bioaktywnych związków pochodzenia roślinnego, są coraz częściej uważane za skuteczną alternatywę dla kokcydiostatyków i antybiotykowych stymulatorów wzrostu w produkcji brojlerów. Ze względu na swoje właściwości przeciwdrobnoustrojowe, antyoksydacyjne, stymulujące trawienie i immunomodulujące, poprawiają funkcjonowanie jelit, poprawiają wykorzystanie paszy i wspierają ogólny stan zdrowia. Duże badanie na skalę komercyjną na brojlerach Ross 308 wykazało, że suplementacja fitobiotykami zwiększyła masę ciała, zmniejszyła śmiertelność i poprawiła konwersję paszy. Te efekty produkcyjne uwzględniono w analizie kosztów i korzyści z wykorzystaniem modeli typowych ferm brojlerów o różnej wielkości. We wszystkich wariantach fitobiotyki obniżyły koszty zmienne — głównie poprzez zmniejszenie wydatków weterynaryjnych i lepsze wykorzystanie paszy — oraz zwiększyły przychody dzięki wyższej masie sprzedażnej. W wybranych scenariuszach dodatkowe korzyści finansowe skalkulowano przy założeniu premii cenowej za mięso bez antybiotyków. Marża brutto poprawiła się w każdym z analizowanych typów ferm, przy czym największe korzyści ekonomiczne zaobserwowano w systemach z dużą skalą produkcji. Wyniki potwierdzają, że fitobiotyki zapewniają wymierne korzyści produkcyjne i finansowe, co przemawia za ich stosowaniem jako zrównoważonego i konkurencyjnego rozwiązania w hodowli brojlerów.

Słowa kluczowe: kurczaki brojlery, fitobiotyki, wpływ na zdrowie, wpływ na produkcję, wpływ ekonomiczny

Introduction

Antibiotic growth promoters (AGPs) have been used in animal production for almost 50 years. [18, 39, 40, 49]. With the passage of time, attention has been drawn to the problem of the presence of antibiotic residues in milk, meat, and eggs and their harmful effects on human health (allergenic and toxic effects). The issue of using antibiotics as antibiotic growth promoters (AGPs) has been further exacerbated by the ever-increasing number of pathogens with antibiotic resistance, i.e., resistance to the bactericidal or bacteriostatic effects of antibiotics. As a result of this development, a total EU-wide ban on the use of antibiotics as antibiotic growth promoters (AGPs) in animal production was introduced on 1 January 2006 [7, 39]. Unfortunately, the

actions taken did not bring the expected results. Currently, only 30% of the world's antibiotic production is used in human treatment; the remaining 70% is used in animal treatment and to stabilize the composition of the digestive tract microbiota. Every year, over 700 thousand deaths are recorded in the world as a result of infections caused by pathogenic antibiotic-resistant microorganisms [39, 65], of which about 25 - 33 thousand people are in Europe. The widespread problem of antibiotic resistance in the EU also causes substantial economic losses of more than €1.5 billion per year, covering the additional costs of healthcare and hospitalization [8, 39].

The total ban on the use of antibiotics as growth promoters in feeding animals for slaughter has presented nutritionists with the challenging task of finding alternative feed additives. On the one hand, they had to protect the animal's digestive tract from colonization by pathogenic bacteria; on the other hand, they had to be inert within the animal's organism [39, 60]. Based on the results of numerous experiments, a group of natural, fully effective substitutes for AGPs has been developed. The wide range of natural substitutes for antibiotic growth stimulants most used in the poultry industry includes probiotics and prebiotics (including crude fibre) [6, 47, 48, 59, 61], enzymes, preparations stimulating the immune system, as well as herbs and plant preparations, m.in. in the form of essential oils [39, 67].

Since ancient times, plants, particularly herbs, have been utilized in the prevention and treatment of diseases in humans and livestock. The specific properties of herbs were used by people from all ancient civilizations, including those of the Egyptians, Chinese, Greeks, and Romans [3, 58, 60]. The use of specific herbs in treating a particular condition was initially based on observations from animals and traditional folk medicine practices. In relation to humans and animals, herbs are both spices and medicinal remedies [46]. Herbs used as

a nutritional additive in the rearing of chickens for fattening enhance taste sensations, stimulate appetite, and regulate the functioning of the digestive system (e.g. *Thymus vulgaris, Carum carvi*) and metabolism (e.g. *Trigonella foenum-graecum, Polygonum aviculare*). They perform protective functions, exhibiting antidiarrheal, antibacterial, and anti-inflammatory effects (e.g., *Allium, Allium cepa, Salvia officinalis*). They also have anabolic effects, reduce stress susceptibility, strengthen the immune system (*Allium, Allium cepa, Echinacea purpurea*), and eliminate the negative impact of anti-nutritional substances [37, 52, 58]. Factors that have a positive effect on the poultry body are biologically active compounds contained in herbs, such as flavonoids, anthocyanins, glycosides, tannins, mucilages, bitters, essential oils, alkaloids, terpenes, triterpenes, saponins, iridoids, naphthoquinones, anthraquinones, phenols, phenolic acids, and mineral salts [10]. All of these substances belong to the group of biologically active compounds, characterized by a high chemical diversity, known as phytobiotics (Table 1). Phytobiotics are a broad group of bioactive compounds derived from plants. They are synthesized naturally by plants to protect against various pathogens, including bacteria, viruses, and fungi. The tasks of phytobiotics also include protecting the genetic material and photosynthetic apparatus of plants from oxidative damage caused by ultraviolet radiation [29, 57, 58, 60].

Table 1. Bioactive properties of selected phytobiotics and their effect on the body of broiler chickens

Phytobiotic(s)	Biologically active effects	Impact on broiler production rates	Natural source of occurrence
Garlicin	They have an effect analogous to that of antiseptic antibiotics, improving immunity by increasing antibody titer, stimulating lysozyme activity, and enhancing the phagocytic activity of macrophages, as well as stimulating digestion and exhibiting a chemopreventive effect	The use of the additive in feed increases body weight, reduces the feed conversion rate, and reduces the adverse effects of environmental stress	Garlic (*Allium*)
Allicin			
Ajoene			
Phytosterols			
Pectins			
Mucilages			
Flavonoids			
Thymol	They reduce the number of harmful intestinal microorganisms and have antiseptic and antioxidant effects	They reduce the risk of diarrhea and improve body weight and feed conversion efficiency	Thyme (*Thymus vulgaris*)
Linalool			
Terpineol			
Borneol			
Cineole			
Bornyl octane			
Menthol	They stimulate digestion, increase appetite, and have antiseptic properties	They lower total cholesterol and triglycerides in the blood serum	Peppermint (*Mentha piperita*)
Menthon			
Neomentol			
Terpenes			

Piperine	It mainly exhibits antioxidant, anticancer, anti-inflammatory, and immunomodulatory properties	It has a beneficial effect on improving digestion and feed conversion	Black pepper (*Piper nigrum*)
Cineole	Stimulates digestion and enhances nutrient absorption, while also exhibiting antiseptic, antioxidant, antibacterial, and immunostimulating effects	Increases weight gain and improves feed conversion	Rosemary (*Salvia Rosmarinus*)
[4, 12, 16, 19, 24, 27, 30, 31, 35, 36, 41, 44, 45, 55, 56, 60, 62–64, 66]			
Polysaccharides Flavonoids Chlorogenic acid Caffeic acid Alkylamides Polyacetylenes	They show immunomodulatory properties (stimulating the phagocytic activity of macrophages), antibacterial, anticancer, antidiabetic, and antioxidant properties, and increase lysozyme activity and antibody titers	Stimulate digestion and increase body weight, and reduce FCR	Coneflower (*Echinacea purpurea*)
[1, 2, 15, 20, 23, 25, 31, 32, 42, 60, 62]			
Chlorogenic acid Caffeic acid Ascorbic acid Flavonoids Phenolics Carotenoids	They exhibit anticancer and antioxidant effects	The use of the additive reduces the feed conversion rate	Moringa oleifera (*Moringa oleifera*)
[5, 31, 34, 38, 43, 51, 60]			
Hydrocarbons Ketones Aldehydes Oxides Coumarins esters Organic acids	They stimulate digestion by increasing bile acid synthesis, which can directly improve digestion and lipid absorption, as well as lower total cholesterol	They have a positive effect on the processes involved in the digestion and absorption of nutrients in feed	Lavender (*Lavandula angustifolia*)
[31, 32, 60]			
Curcuminoids Turmerones	They have antioxidant, anticancer, chemopreventive, antihepatotoxic, and immunomodulatory effects (they stimulate interferon production)	Improves blood lipid profile; increase appetite and improve digestion through choleretic effects	Tumeric (*Curcuma longa*)
Anthraquinones Acemannan Salicylic acid	They exhibit immunomodulatory properties by stimulating the activity of granulocytes and granulocyte enzymes (myeloperoxidase, peroxidase); mitigate the adverse effects of environmental stress; they are also characterized by antidiabetic properties. And antioxidant effects - reducing lipid peroxidation and increasing antioxidant status	They stimulate digestion, improving the absorption of nutrients from the intestines and the composition of the intestinal microbiota, and enhancing yield and feed conversion rate. Additionally, they can protect important organs, such as the liver and kidneys	Aloe vera (*Aloe vera* L.)
[9, 14, 31, 50, 53, 54, 60]			
Shogaol Gingerol α-zingiberene α-fernazen Geraniol Citral β-selenide Neridol α-myrcene β-bisabolol Camphene	The mixture of essential oils obtained through steam distillation exhibits analgesic, antipyretic, anti-inflammatory, immunostimulating, anticancer, and antioxidant properties	The impact on production results has not been confirmed	Ginger (*Zingiber officinale*)
[26, 60]			

Phytobiotics can be used in various forms:

- **Dried fruits or plants** are intended for food, medicinal, or feed purposes, used in an amount of 0.5 to 5%.
- **Dried extracts** are concentrated plant preparations obtained by extracting the raw vegetable material with a solvent (such as water, ethanol, or their mixtures). Then, properly concentrated, they achieve the consistency of a loose powder (with a water content of up to 5%) and are dosed at a rate of up to 0.5 kg/t of feed.
- **Essential oils** are mixtures of volatile organic compounds (e.g., esters, ketones, aldehydes) characterized by an intense smell that occurs in various parts of plants, such as roots, fruits, and bark. The recommended amount is 0.05 %/t of feed [58, 60].

The content and composition of the phytobiotic mixture in herbs are primarily influenced by environmental conditions such as:

- geographical region,
- type of soil,
- the date and method of harvesting,
- processing and maintenance techniques,
- storage method [46, 58].

In addition, herbs used to obtain phytobiotics should be collected from areas free of pollution, e.g., heavy metals and pesticides, and their cultivation should be carried out with a significant reduction in chemical inputs. It is also recommended to grow native herb species [46, 58].

Economic analysis of the experiment aimed at substituting coccidiostats with phytobiotics

Outline of the methodology

The experiment was conducted in a commercial chicken coop. Ross 308 chickens were placed in two groups: control and experimental. The number of broiler chickens in each group was 65,000. During the 39-day rearing period, the chickens were fed cereal-based feed mixtures ad libitum. In the experimental group, a plant-based product was added to the feed at a rate of 100 g per ton. During rearing, production indicators (FCR, body weight, mortality) were controlled [39].

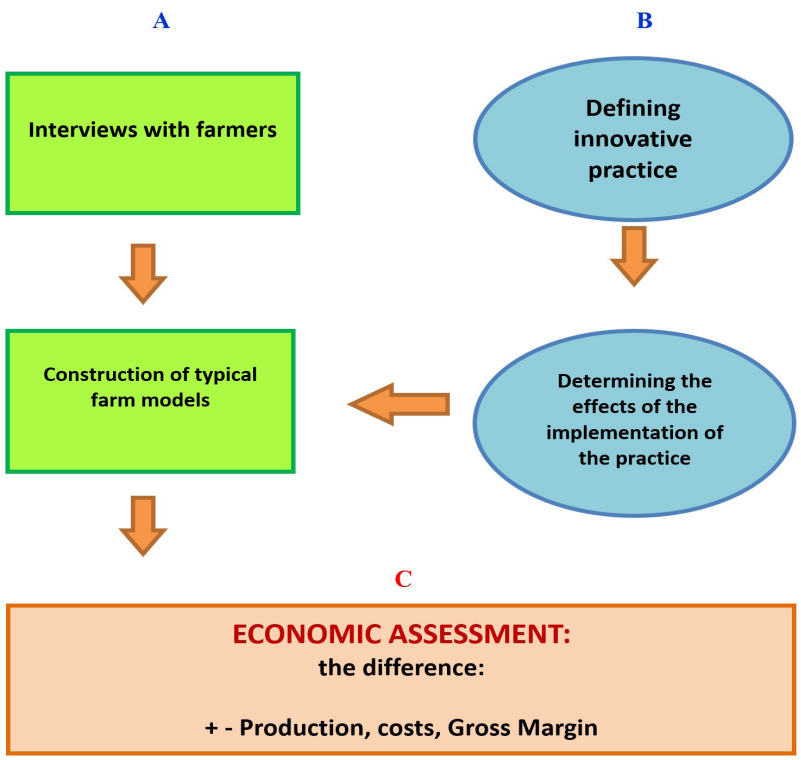
Economic evaluation methodology

To assess the economic effects of changing the method of coccidiosis control in broiler production, a Cost-Benefit Analysis (CBA) was applied. The methodology adopted from the Horizon Europe project[1] focuses on estimating the potential benefits and additional costs related to the implementation of innovative practices in broiler production. The result of the assessment is the change of the financial outcome represented by Gross Margin (GM), which is a difference between value of production and variable costs.

In the case of the replacement of cocidiostatics with phytobiotics the partial budgeting technique was used - only those items in the GM calculation were considered which change their value (increases or reductions) after implementing this alternative.

For the purpose of the study four models of typical broiler farms were constructed. The typical farm (real or virtual) is usually defined as a farm that represents the most common type(s) of farm. Farm type, in turn, is a term indicating groups of farms that meet specific criteria, such as production type (e.g., raising broilers breeding), the scale of production, and the production system [11, 33]. This paper presents results of economic assessments for farms with the conventional production system, and the criterion for differentiating farm types is the flock size (small, medium, large, and very large).

The models of typical farms were constructed based on data and information obtained through interviews with selected farmers representing respective farm types (three farms per farm type).



** Gross Margin = revenue (sales) minus variable costs*

Fig. 1. General scheme of cost-benefit analysis – evaluation stages

[1] Deliverable 5.1.

The economic effects of introducing phytobiotics were estimated using the results of the experiment presented in the first part of the study. Based on this, four sets of assumptions were prepared (Table 2) to simulate costs and benefits in model farms. The basic variant (A1) directly refers to the experimental results. In the other three, selected parameters of the calculation were modified to check the model's response to more or less favourable assumptions as part of the model's sensitivity analysis:

- Variant A2 is a variation of the basic one, assuming a premium price for antibiotic-free broilers might be achieved;
- Variants B and C assume, respectively, less optimistic assumptions regarding the level of benefits.

Results

Prior to the cost-benefit analysis the baseline models for each farm type considered were constructed. In these models production and financial results were calculated for the technology based on the use of coccidiostatics. In the next step, the variants of models introducing a system of feeding broilers with feed supplemented with coccidiostats were constructed, based on assumptions presented in Table 2. The results of assessments were in the next step compared with the baseline model, which serves as a reference.

Table 3 presents the basic production parameters characterising individual model variants, indicating differences from the basic models.

Apart from the apparent differences in the scale of production in individual types of model farms, some differences in the size of selected production parameters were revealed. In the "small" farm model, the number of production cycles was significantly lower (5.6), while, at the same time, with a slightly longer cycle, broilers were fattened to a higher weight (3.0 kg) than in other types. On the contrary, in the model of "very large" farms, the average broiler weight was the lowest (2.4), but the cycle was the shortest (41 days), and the number of production cycles was the largest (6.5). In farms with smaller-scale production (small and medium-sized), FCR was significantly lower.

Changes in the selected production parameters (number of broilers, sales volume, FCR) in the phytobiotics models reflect the impact of the cost-benefit analysis assumptions. According to the assumptions, the most favourable in terms of production results were variants A and A1. Variants B and C were also more favourable than the baseline model, albeit to a lesser extent, due to less optimistic assumptions about the scale of the benefits of phytobiotic use.

Models of typical farms were characterised by a similar structure of variable production costs[2] (Table 4), with a dominant share of feed and chicken rearing costs, totaling 84–90%.

[2] Variable costs increase with the increase in production volume, while fixed costs (e.g. depreciation of fixed assets, administrative costs) do not change in a specific range of production scale. In the analysis presented, the use of phytobiotics has no impact on fixed costs, so they were omitted from the cost-benefit calculations.

Table 2. Assumptions for the cost-benefit analysis of the use of a phytobiotic supplement in broiler feeding chickens

Parameters	Variants			
	A1	A2	B	C
Benefits				
Higher weight gain [g/broiler]	72.5	72.5	50*	40*
Price premium [%]	lack	2.5	2.5	2.5
Reduction of veterinary costs [%]	2.0	2.0	1.5	1.5
Lower chicken mortality [percentage points]	0.5	0.5	0.5	0.5
Lower feed consumption due to better use of feed with phytobiotic [kg/kg increase of body weight]	0.065	0.065	0.06	0.05
Additional Input/Costs				
Dosage of phytobiotic	0.5 kg per tonne of feed**			

Source: own study.
** expert evaluations using literature data [13, 17, 21, 22, 28, 40].*
*** price of phytobiotic: 30 PLN/kg*

Table 3. Selected production parameters of the analyzed model solutions

Specification	Types of model farms			
	Small	**Average**	**Large**	**Very large**
Sale of broilers [pieces] in basic models	140 160	302 400	778 073	10 342 230
Sale of broilers [pieces] in variants A1/A2/B/C	140 831	303 937	781 784	10 392 413
Number of production cycles	5.6	6.0	6.0	6.5
Cycle Length (days)	43.2	42.4	42.3	41.0
Average broiler weight in the base model [kg live weight]	3.0	2.9	2.8	2.4
Sale of broilers [tons]				
Base Model = 100	**408.7**	**843.4**	**2126.8**	**24333.9**
A1 and A2	103.4	103.4	103.4	103.4
B	102.5	102.5	102.5	102.5
C	102.1	102.1	102.1	102.1
Feed Conversion Rate (FCR)				
Base Model = 100	**1.766**	**1.769**	**1.638**	**1.699**
A1 and A2	97.5	95.6	96.2	99.0
B	98.5	96.6	97.2	99.5
C	99.1	97.2	97.8	99.8

Source: own study

Table 4. Changes in the structure of variable production costs in relation to the base model (base = 100)

Type of farm and variants of model solutions	Cost share [%]					
	Feed	**Chicks**	**Labour**	**Veterinary**	**Energy**	**Other**
Small – the base model	**72.18**	**13.09**	**2.78**	**4.28**	**4.20**	**3.46**
Small [A1, A2, B, C]	100.5	98.9	98.9	97.0	98.9	98.9
Medium – base model	**70.87**	**13.70**	**1.98**	**3.98**	**5.84**	**3.64**
Average [A1, A2, B, C]	100.6	98.9	98.9	96.9	98.9	98.9
Large – base model	**72.74**	**13.28**	**1.54**	**3.44**	**5.22**	**3.78**
Large [A1, A2, B, C]	100.5	98.9	98.9	96.9	98.9	98.9
Very large – base model	**75.35**	**14.71**	**2.15**	**2.04**	**4.46**	**1.29**
Very large [A1, A2, B, C]	100.4	98.8	98.8	96.8	98.8	98.8

Source: own study

The cost structure in the individual variants of the model solutions changed slightly compared to the baseline models. Because the differences in the cost structure between scenarios of phytobiotic models were almost negligible, for simplicity only averaged, rounded aggregate indicators for all variants are presented.

Only the share of feed costs increased because of a higher average feed price with phytobiotics, but also a higher feed consumption due to the decreasing mortality and a greater number of broilers raised. The share of all other items in the cost structure was reduced.

The benefits - higher sales due to lower mortality, higher production and potentially premium prices, and some cost reductions in accordance with the assumptions for modelling resulted with positive changes of economic indicators (Table 5).

In each variant solution, the economic parameters are more favourable compared to the base model. The total economic effect is the Gross Margin, which is higher across all variant solutions than in the baseline model.

In the A1 variant, the increase in revenues from the sale of broilers is the smallest, which is only the result of better weight gains and a larger number of broilers sold due to reduced

Table 5. Selected economic indicators in broiler chicken production after the use of phytobiotics (baseline model = 100)

Model/variant	Revenue [PLN/kg]	Variable costs [PLN/kg]	Gross Margin [PLN/kg]
Small – the base model	**5.60**	**5.23**	**0.37**
Small A1	100.5	97.7	132.0
Small A2	102.9	97.7	169.7
Small B	102.9	98.6	157.6
Small C	102.5	99.0	144.6
Medium – base model	**5.63**	**5.11**	**0.51**
Medium A1	100.5	97.7	122.9
A2 Medium	103.0	97.7	150.2
Medium B	103.0	98.6	141.6
Medium C	102.5	99.0	132.3
Large – base model	**5.45**	**4.64**	**0.81**
Large A1	100.5	97.8	113.1
Large A2	103.0	97.8	130.1
Capital B	103.0	98.7	125.1
Capital C	102.5	99.0	119.5
Very large – base model	**5.53**	**4.69**	**0.84**
Very large A1	100.5	97.9	112.3
Very Large A2	103.0	97.9	128.7
Very Large B	103.0	98.7	123.9
Very Large C	102.5	99.1	118.5

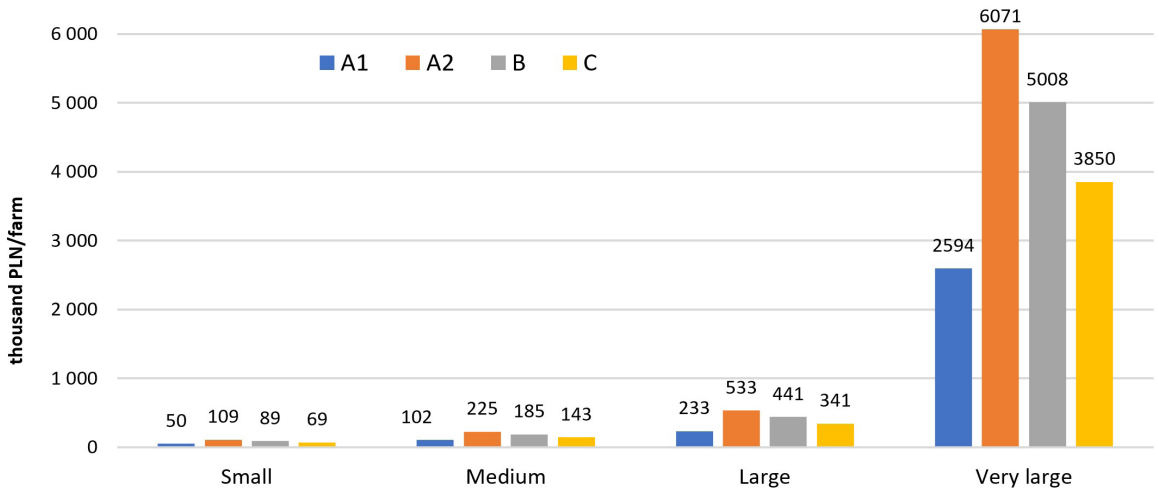
Source: own study

[1] *Variable costs increase with the increase in production volume, while fixed costs (e.g. depreciation of fixed assets, administrative costs) do not change in a specific range of production scale. In the analysis presented, the use of phytobiotics has no impact on fixed costs, so they were omitted from the cost-benefit calculations*

Table 6. Additional income from the use of phytobiotics in broiler chicken farming per model farm [PLN thousand]

Farm type	Model variants			
	A1	A2	B	C
Small	50.0	108.9	89.2	68.8
Average	102.3	224.7	184.7	142.8
Large	233.0	532.9	440.9	340.7
Very large	2 593.6	6 070.5	5 008.4	3 849.8

Source: own study



Source: own study

Figure 2. Increase in income from the use of phytobiotics in broiler chicken farming in relation to baseline models in various variant solutions [PLN thousand/farm]

mortality. In other variants, the increase in revenues is significantly higher, due to the assumption of a price premium (2.5%) for broilers produced without coccidiostats. From the perspective of the profitability of production, the most advantageous is the A2 solution due to the most optimistic assumptions. Although the assumed premium is relatively small, it generates a significant increase in the direct surplus (variant A2) compared to variant A1, without an increased price. In accordance with the assumptions made, variable production costs are lower in variant solutions.

At a farm scale, substituting coccidiostatics with phytobiotics enables to generate significant additional income, especially on farms with larger numbers of broilers (Table 6 and Figure 1).

It seems that even a small financial benefit in "small" farms, basically exclusively family farms with their own workforce, can be a sufficient incentive to use phytobiotics. A graphical presentation of the economic effects of using phytobiotics highlights the importance of implementing this practice on farms with larger-scale production (Figure 1).

Conclusions

- The results of the experiment, confirmed by literature reports, indicate positive production effects of phytobiotics use, primarily resulting in improved feed efficiency.
- The qualitative effect of broiler breeding without coccidiostats is also essential, and, in view of consumers' growing expectations, may be conducive to sales with a price premium.
- The cost-benefit analysis clearly indicates that the use of phytobiotics enables positive economic effects across all types of farms and variants of model solutions. The best results were shown by the "A2" variant, due to a cumulative effect of increased weight gains and the assumed price premium, in addition to reduced mortality and lower veterinary costs.
- The economic effects of phytobiotics use are particularly evident on large and very large farms, where even small changes in costs or revenues can yield significant income

differences given the scale of production. Nevertheless, in small and medium-sized farms, the benefits of reducing veterinary costs and improving feed efficiency can provide sufficient incentives to implement this practice.

- In the long term, replacing coccidiostats with phytobiotics could be a significant factor in enhancing the competitiveness of the Polish poultry sector

Bibliography

[1] Abd El-Hack ME, Alagawany M, Abdel-Moneim A-ME, Mohammed NG, Khafaga AF, Bin-Jumah M, Othman SI, Allam AA, Elnesr SS (2020) Cinnamon (*Cinnamomum zeylanicum*) Oil as a Potential Alternative to Antibiotics in Poultry. Antibiotics 9:210. doi: 10.3390/antibiotics9050210

[2] Abudabos AM, Alyemni AH, Dafalla YM, Khan RU (2017) Effect of organic acid blend and *Bacillus subtilis* alone or in combination on growth traits, blood biochemical and antioxidant status in broilers exposed to *Salmonella typhimurium* challenge during the starter phase. J. Appl. Anim. Res. 45:538–542. doi: 10.1080/09712119.2016.1219665

[3] Aftab K, Sial AA (1999). Phytomedicine: New and old approaches. Hamdard Med 42:11–15

[4] Akyildiz S, Denli M (2016) Application of plant extracts as feed additives in poultry nutrition. Animal Science LIX:71–74

[5] Al-Kassie GA (2009) Influence of Two Plant Extracts Derived from Thyme and Cinnamon on Broiler Performance. Pak Vet John 29:169–173

[6] Al-Khalaifah H, Al-Nasser A, Al-Surrayai T, Sultan H, Al-Attal D, Al-Kandari R, Al-Saleem H, Al-Holi A, Dashti F (2022). Effect of Ginger Powder on Production Performance, Antioxidant Status, Hematological Parameters, Digestibility, and Plasma Cholesterol Content in Broiler Chickens. Animals 12:901. doi: 10.3390/ani12070901

[7] Anadón A (2006) WS14 The EU ban of antibiotics as feed additives (2006): alternatives and consumer safety. J Vet Pharmacol Ther 29:41–44. doi: 10.1111/j.1365-2885.2006.00775_2.x

[8] Anderson M, Panteli D, Mossialos E (2023) Policy Brief 51 How Can the EU Support Sustainable Innovation and Access to Effective Antibiotics? Policy Options for Existing and New Medicines. In: https://www.ncbi.nlm.nih.gov/books/NBK594074 (accessed on 1 July 2024).

[9] Babak D, Nahashon SN (2014) A Review on Effects of Aloe Vera as a Feed Additive in Broiler Chicken Diets. Annals of Animal Science 14:491 500. doi: 10.2478/aoas-2014-0026

[10] Budny A., Kupczyński R., Sobolewska S., Korczyński M., Zawadzki W. (2012). Self-medication and herbal medicine in the Prevention and Treatment of Livestock. Acta Scientiarum Polonorum Medicina Veterinaria 11:5–24

[11] Chibanda C, Agethen K, Deblitz C, Zimmer Y, Almadani MohamadI, Garming H, Rohlmann C, Schütte J, Thobe P, Verhaagh M, Behrendt L, Staub DanielT, Lasner T (2020) The Typical Farm Approach and Its Application by the Agri Benchmark Network. Agriculture 10:646. doi: 10.3390/agriculture10120646

[12] Deminicis RG da S, Meneghetti C, Oliveira EB de, Garcia Júnior AAP, Farias Filho RV, Deminicis BB (2021) Systematic review of the use of phytobiotics in broiler nutrition. Revista de Ciências Agroveterinarias 20:098–106. doi: 10.5965/223811712012021098

[13] Deminicis RG da S, Meneghetti C, Oliveira EB de, Garcia Júnior AAP, Farias Filho RV, Deminicis BB (2021) Systematic review of the use of phytobiotics in broiler nutrition. Revista de Ciências Agroveterinarias 20:098–106. doi: 10.5965/223811712012021098

[14] Ebrahim AA, Elnesr SS, Abdel-Mageed MAA, Aly MMM (2020) Nutritional significance of aloe vera (*Aloe barbadensis Miller*) and its beneficial impact on poultry. Worlds Poult Sci J 76:803–814. doi: 10.1080/00439339.2020.1830010

[15] El-Ghousein SS, Al-Beitawi NA (2009) The Effect of Feeding of Crushed Thyme (Thymus valgaris L) on Growth, Blood Constituents, Gastrointestinal Tract and Carcass Characteristics of Broiler Chickens. J Poult Sci 46:100–104. doi: 10.2141/jpsa.46.100

[16] Frankić T, Volić M, Salobir J, Rezar V (2009) Use of herbs and spices and their extracts in animal nutrition. Acta Agric Slov 94. doi: 10.14720/aas.2009.94.2.14834

[17] Gheisar MM, Im YW, Lee HH, Choi Y Il, Kim IH (2015). Inclusion of phytogenic blends in different nutrient density diets of meat-type ducks. Poult Sci 94:2952–2958. doi: 10.3382/ps/pev301

[18] Greathead H (2003). Plants and plant extracts for improving animal productivity. Proceedings of the Nutrition Society 62:279–290. doi: 10.1079/PNS2002197

[19] Haque MdH, Sarker S, Islam MdS, Islam MdA, Karim MdR, Kayesh MEH, Shiddiky MJA, Anwer MS (2020) Sustainable Antibiotic-Free Broiler Meat Production: Current Trends, Challenges, and Possibilities in a Developing Country Perspective. Biology (Basel) 9:411. doi: 10.3390/biology9110411

[20] Hernández F, Madrid J, García V, Orengo J, Megías MD (2004) Influence of two plant extracts on broilers performance, digestibility, and digestive organ size. Poult Sci 83:169-174. doi: 10.1093/ps/83.2.169

[21] Ismail IE, Alagawany M, Taha AE, Puvača N, Laudadio V, Tufarelli V (2021) Effect of dietary supplementation of garlic powder and phenyl acetic acid on productive performance, blood haematology, immunity and antioxidant status of broiler chickens. Anim Biosci 34:363–370. doi: 10.5713/ajas.20.0140

[22] Iwiński H, Chodkowska KA, Drabik K, Batkowska J, Karwowska M, Kuropka P, Szumowski A, Szumny A, Różański H (2023) The Impact of a Phytobiotic Mixture on Broiler Chicken Health and Meat Safety. Animals 13:2155. doi: 10.3390/ani13132155

[23] Jankowski J, Zduńczyk Z, Juśkiewicz J, Kozłowski K, Lecewicz A, Jeroch H. (2009) Gastrointestinal tract and metabolic response of broilers to diets with the Macleaya cordata alkaloid extract. Archive für Geflugelkunde 73:95–101

[24] Jerzsele A, Szeker K, Csizinszky R, Gere E, Jakab C, Mallo JJ, Galfi P (2012) Efficacy of protected sodium butyrate, a protected blend of essential oils, their combination, and *Bacillus amyloliquefaciens* spore suspension against artificially induced necrotic enteritis in broilers. Poult Sci 91:837–843. doi: 10.3382/ps.2011-01853

[25] Kapica M, Kwiecień M, Puzio I, Bieńko M, Radzki R, Pawłowska M (2006) Influence of some herbs on the activity of digestive enzymes in chickens. Vet Med 62:1048–1050

[26] Kędzia A, Kędzia AW (2019) Antifungal effects of ginger oil (*Oleum Zingiberis*). Phytotherapy Progress 20th doi: 10.25121/PF.2019.20.3.175

[27] Khattak F, Ronchi A, Castelli P, Sparks N (2014) Effects of natural blend of essential oil on growth performance, blood biochemistry, cecal morphology, and carcass quality of broiler chickens. Poult Sci 93:132–137. doi: 10.3382/ps.2013-03387

[28] Khatun A., Das S.C., Ray B.C., Ahmed T., Hashem M.A., Khairunnesa M., Roy B.C. (2023) Effects of feeding phytobiotics on growth performance, breast meat quality, blood biochemical indices, and liver enzymes of broiler chickens. European Poultry Science (EPS) 87th doi: 10.1399/eps.2023.374

[29] Kikusato M (2021) Phytobiotics to improve health and production of broiler chickens: functions beyond the antioxidant activity. Anim Biosci 34:345–353. doi: 10.5713/ab.20.0842

[30] Kirubakaran A, Moorthy M, Chitra R, Prabakar G (2016) Influence of combinations of fenugreek, garlic, and black pepper powder on production traits of the broilers. Vet World 9:470–474. doi: 10.14202/vetworld.2016.470-474

[31] Krauze M (2021) Phytobiotics, a Natural Growth Promoter for Poultry

[32] Krauze M, Cendrowska-Pinkosz M, Matusevičius P, Stępniowska A, Jurczak P, Ognik K (2021) The Effect of Administration of a Phytobiotic Containing Cinnamon Oil and Citric Acid on the Metabolism, Immunity, and Growth Performance of Broiler Chickens. Animals 11:399. doi: 10.3390/ani11020399

[33] Lasner T, Brinker A, Nielsen R, Rad F (2017) Establishing a benchmarking for fish farming - Profitability, productivity and energy efficiency of German, Danish and Turkish rainbow trout grow-out systems. Aquac Res 48:3134–3148. doi: 10.1111/are.13144

[34] Leone A, Spada A, Battezzati A, Schiraldi A, Aristil J, Bertoli S (2015) Cultivation, Genetic, Ethnopharmacology, Phytochemistry and Pharmacology of Moringa oleifera Leaves: An Overview. Int. J. Mol. Sci. 16: 12791–12835. doi: 10.3390/ijms160612791

[35] Li HL, Zhao PY, Lei Y, Hossain MM, Kim IH (2015). Phytoncide, phytogenic feed additive as an alternative to conventional antibiotics, improved growth performance and decreased excreta gas emission without adverse effect on meat quality in broiler chickens. Livest Sci 181:1–6. doi: 10.1016/j.livsci.2015.10.001

[36] Makała H (2022) Herbs and phytogenic feed additives in poultry nutrition. Med Weter 77:6589–2023. doi: 10.21521/mw.6592

[37] Makała H (2023) Herbs and phytogenic feed additives in poultry nutrition. Med Weter 77:6589–2023. doi: 10.21521/mw.6592

[38] Martínez Y, Tobar L, Lagos H, Parrado C, Urquía A, Valdivié M (2021) Phytobiotic Effect of Anacardium occidentale L. Leaves Powder on Performance, Carcass Traits, and Intestinal Characteristics in Broilers. Brazilian Journal of Poultry Science 23. doi: 10.1590/1806-9061-2020-1362

[39] Michalczuk M, Abramowicz-Pindor P, Urban J, Bień D, Ciborowska P, Matuszewski A, Zalewska A, Opacka E, Wojtasik-Kalinowska I (2024) The Effect of Phytogenic Additive in Broiler's Diet on Production Results, Physicochemical Parameters, and the Composition of Volatile Organic Compounds of Broiler Meat Assessed by an Electronic Nose System. Animals 14:2428. doi: 10.3390/ani14162428

[40] Mohammadi Gheisar M, Kim IH (2018) Phytobiotics in poultry and swine nutrition – a review. Italian J Anim Sci 17:92–99. doi: 10.1080/1828051X.2017.1350120

[41] Mpofu DA, Marume U, Mlambo V, Hugo A (2016) The effects of Lippia javanica dietary inclusion on growth performance, carcass characteristics and fatty acid profiles of broiler chickens. Animal Nutrition 2:160–167. doi: 10.1016/j.aninu.2016.05.003

[42] Najafi P, Torki M (2010) Performance, Blood Metabolites and Immunocompetaence of Broiler Chicks Fed Diets Included Essentioal Oils of Medicinal Herbs. Journal of Animal and Veterinary Advances 9:1164–1168. doi: 10.3923/javaa.2010.1164.1168

[43] Ogbunugafor HA, Eeneh FU, Ozumba AN, Igwoezikpe MN, Okpuzor J, Igwilo IO, Adenekan SO, Onyekwelu OA (2011) Physicochemical and antioxidant properties of Moringa oleifera seed oil. Pakistan Journal of Nutrition 10:409–414

[44] Peng QY, Li JD, Li Z, Duan ZY, Wu YP (2016) Effects of dietary supplementation with oregano essential oil on growth performance, carcass traits and jejunal morphology in broiler chickens. Anim Feed Sci Technol 214:148–153. doi: 10.1016/j.anifeedsci.2016.02.010

[45] Pirgozliev V, Bravo D, Mirza MW, Rose SP (2015) Growth performance and endogenous losses of broilers fed wheat-based diets with and without essential oils and xylanase supplementation. Poult Sci 94:1227–1232. doi: 10.3382/ps/peu017

[46] Radkowska I. (2013) The use of herbs and phytogenic feed additives in livestock nutrition. Zootechnical News 4:117–124

[47] Ricke SC (2021) Prebiotics and alternative poultry production. Poult Sci 100:101174. doi: 10.1016/j.psj.2021.101174

[48] Ricke SC, Van Der Aar PJ, Fahey GC, Berger LL Influence of Dietary Fibers on Performance and Fermentation Characteristics of Gut Contents from Growing Chicks

[49] Rochfort S, Parker AJ, Dunshea FR (2008) Plant bioactives for ruminant health and productivity. Phytochemistry 69:299–322. doi: 10.1016/j.phytochem.2007.08.017

[50] Sinha S, Muzamil S, Ahmad B, Rehman MU, Quadri A (2017) Ameliorative effect of *Aloe vera* Supplementation in Poultry Feed. Journal of Animal Research 7:85. doi: 10.5958/2277-940X.2017.00012.2

[51] Sofidiya MO, . OAO. OBF, . SII-A (2006) Free Radical Scavenging Activity of Some Nigerian Medicinal Plant Extracts. Pakistan Journal of Biological Sciences 9:1438–1441. doi: 10.3923/pjbs.2006.1438.1441
[52] Stajnder E. (2019) The use of high-protein crops in poultry nutrition. Department of Agricultural Production Technology and Experimentation. MODR from Karniowice 1–14
[53] Taraneh J.F.K. (2016) A study on the effects of supplementing Aloe vera gel and garlic powder on immune response of broiler. Global Journal of Poultry Farming and Vaccination 4:238–242
[54] Tariq H RRPMBMB (2014) Effect of Aloe Vera (Aloe barbadensis) and Clove (Syzigium aromaticum) Supplementation on Immune Status, Haematological and Serum Biochemical Parameters in Japanese Quails. Indian Journal of Animal Nutrition 313:293–296
[55] 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. Livest Sci 138:167–173. doi: 10.1016/j.livsci.2010.12.018
[56] Truchliński J, Krauze M, Cendrowska-Pinkosz M, Modzelewska-Banachiewicz B (2006) Influence of garlic, synthetic 1,2,4-triasole derivative and herbal preparation echinovit C on selected indices of turkey-hens non-specific immunity. Paul J Vet Sci 9:51–5
[57] Tsao R, Deng Z (2004) Separation procedures for naturally occurring antioxidant phytochemicals. Journal of Chromatography B 812:85–99. doi: 10.1016/j.jchromb.2004.09.028
[58] Urban J., Bień D., Matuszewski A., Ciborowska P., Zalewska A., Lutostański K., Batorska M., Michalczuk M. (2023) Phytobiotics – natural additives that improve health. Poultry Farmer 4:20–23
[59] Urban J, Jaworski S, Lange A, Bień D, Matuszewski A, Michalczuk M (2023) Effects of the Addition of Crude Fibre Concentrate on Performance, Welfare and Selected Caecal Bacteria of Broilers. Animals 13:3883. doi: 10.3390/ani13243883
[60] Urban J, Kareem KY, Matuszewski A, Bień D, Ciborowska P, Lutostański K, Michalczuk M (2024) Enhancing broiler chicken health and performance: the impact of phytobiotics on growth, gut microbiota, antioxidants, and immunity. Phytochemistry Reviews. doi: 10.1007/s11101-024-09994-0
[61] Urban J, Michalczuk M, Batorska M, Marzec A, Jaroszek A, Bień D (2024) Effect of crude fibre additives ARBOCEL and VITACEL on the physicochemical properties of granulated feed mixtures for broiler chickens. Anim Biosci 37:274–283. doi: 10.5713/ab.23.0218
[62] Vinus RD, Sheoran N, Maan NS, Tewatia BS (2018) Potential benefits of herbal supplements in poultry feed: A review. The Pharma Innovation Journal 7:651–656
[63] Wenk C (2003) Herbs and Botanicals as Feed Additives in Monogastric Animals. Asian-Australas J Anim Sci 16:282–289. doi: 10.5713/ajas.2003.282
[64] Windisch W, Schedle K, Plitzner C, Kroismayr A (2008) Use of phytogenic products as feed additives for swine and poultry1. J Anim Sci 86: E140–E148. doi: 10.2527/jas.2007-0459
[65] World Health Organization (2019) Ten threats to global health in 2019. In: https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019
[66] Yarru LP, Settivari RS, Gowda NKS, Antoniou E, Ledoux DR, Rottinghaus GE (2009) Effects of turmeric (Curcuma longa) on the expression of hepatic genes associated with biotransformation, antioxidant, and immune systems in broiler chicks fed aflatoxin. Poult Sci 88:2620–2627. doi: 10.3382/ps.2009-00204
[67] Yeung AWK, Orhan IE, Aggarwal BB, Battino M, Belwal T, Bishayee A, Devkota HP, El-Demerdash A., Balacheva AA, et al. (2020) Berberine, a popular dietary supplement for human and animal health: Quantitative research literature analysis—A review. Anim Sci Pap Rep 28:5–15·