AGRICULTURAL BIOLOGY,
2018, V. 53, № 4, pp. 687-697
(SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA)

ISSN 2412-0324 (English ed. Online)
ISSN 0131-6397 (Russian ed. Print)
ISSN 2313-4836 (Russian ed. Online)

UDC 636.084:636.087.7

doi: 10.15389/agrobiology.2018.4.687eng
doi: 10.15389/agrobiology.2018.4.687rus

USE OF PHYTOBIOTICTS IN FARM ANIMAL FEEDING
(review)

O.A. BAGNO[1], O.N. PROKHOROV[1], S.A. SHEVCHENKO[2], A.I. SHEVCHENKO[2, 3], T.V. DYADICHKINA[1]

[1]*Kemerovo State Agricultural Institute*, 5, ul. Markovtseva, Kemerovo, 650056 Russia, e-mail oaglazunova@mail.ru, oldao@mail.ru, dyadi-tanya@yandex.ru;)
[2]*Gorno-Altaisk State University,* 1, ul. Lenkina, Gorno-Altaisk, 649000 Russia, e-mail se-gal@list.ru (✉ corresponding author);
[3]*Gorno-Altaisk Research Institute of Agriculture,* Federal Agency for Scientific Organizations. 2, ul. Katunskaya, s. Maiama, Altai Republic, Russia, e-mail shaisol60@mail.ru
ORCID:
Bagno O.A. orcid.org/0000-0003-4047-2355
Prokhorov O.N. orcid.org/0000-0003-1916-661X
Shevchenko S.A. orcid.org/0000-0003-4361-3168
Shevchenko A.I. orcid.org/0000-0002-7753-1761
Dyadichkina T.V. orcid.org/0000-0003-1432-1166
The authors declare no conflict of interests
Acknowledgements:
This article is prepared under the Agreement with the Ministry of Education and Science of the Russian Federation № 14.610.21.0016 of 03.10.2017 "Development and implementation of a new series of highly effective medicinal-plant-born phytobiotics for highly productive and environmentally friendly animal farming", the unique identifier RFMEF161017X0016
Received April 2, 2018

Abstract

Realization of genetic potential of animal productivity in modern commercial livestock breeding necessitates the use of various biologically active dietary additives to ensure animal performance and homeostasis (R.R. Akhmedkhanova et al., 2010). The first such additives were feed antibiotics used since 1950s all over the world (R.I. Castillo-Lopez et al., 2017). However, it turned out that the excessive and uncontrolled use of antibiotics adversely affects the body of animals and birds. Microorganisms, when mutating, acquire resistance to antibiotics, thereby reducing the positive effect of the drugs. In addition, their cumulative and toxic effects occur. Over time, this led to a ban on the use of all types of feed antibiotics in the European Union (S.M. Alieva et al., 2017). After revealing the negative effects of feed antibiotics, a new tendency emerged in the world. That was a trend towards complete or partial replacement of these drugs with probiotics, the living microorganisms which are symbionts of the normal gut microflora. Probiotics are proven effective in growing young farm animals of different species in the early postnatal period and now proboitics are increasingly being used. In recent years, many scientists and practitioners of animal feeding have paid much attention to phytobiotics, the plant-born bioactive substances (W. Windisch et al., 2006). The fact that animals, including carnivores, when restricted in free walking, must eat green or at least dried plants was an empirical knowledge that humanity acquired simultaneously with the beginning of animal domestication. Targeted study on the impact of dietary bioactive plant-born compounds of different origin on animal and poutry performance, and the development of standardized phytobiotic preparations for livestock, including complex phytobiotics, are in the focus during last two or three decades (N.M. Kazachkova, 2017). Exterior and interior parameters are estimated in animals fed with dietary green and dried plants, their mixtures, coniferous and herbal flour of various composition, plant extracts, in particular essential oils, and phytobiotic complexes enriched with microelements and probiotics (N.A. Tabakov et al., 2008). The main benefit of phytogenic additives in livestock breeding is due to an improved feed digestibility, antimicrobial efficacy, the replacement of feed antibiotics, and growth stimulation. Their anti-inflammatory effect, better feed conversion and higher feed intake by animals are also noted (L.S. Ignatovich, 2017). Immune modulating plant-born fodder supplements have a significant effect on animal and poultry health and performance characteristics (B. Kiczorowska et al., 2017). High profitability of organic food production and animal and people wellness as a world trend are also the factors determining the relevance of the development of highly effective phytobiotics and their use in livestock and poultry farming.

Keywords: phytobiotics, probiotic, feed antibiotics, animal feeding, cattle, pigs, poultry, productivity, homeostasis.

The application of feed additives in contemporary livestock and poultry farming is required to prevent negative impact of certain feed and management factors [1]. The latter, in particular, cause depression of the immune system, due to which the livestock and poultry become more susceptible to different illnesses. Furthermore, the activity of numerous physiological bodily systems is distorted, which inevitably results in deterioration of the quality of products [2].

During the recent years, increased emphasis has been made on technologies based on comprehensive registration of crucial biotechnological factors and adoptions from wildlife. For example, phytobiotics (the biologically active substances that possess antimicrobial properties) [3] can offer an alternative to synthetic antimicrobial growth promoters. In contemporary studies, phytobiotics (phytogenic food additives or herbal products) are defined as natural plant-based additives that have varying impact on the body (antimicrobial, antiviral, immunomodulating, fungicidal or anti-inflammatory) and are used as animal feeds with the purpose of increasing the productivity of livestock and the quality of food products of animal origin [4, 5].

The goal of this survey is to study the contemporary usage of phytobiotics in livestock feed based on analysis of scientific publications in the leading Russian and international magazines, thesis databases, monographs and patents.

The history of a wide-scale application of phytobiotics in livestock and poultry feeds is inextricably connected with the prohibition of all forms of antibiotic growth promoters in the EU. The excessive and uncontrolled usage of antibiotic growth promoters negatively affects the bodies of livestock and poultry. Mutating, the microorganisms become immune to antibiotics thus excluding the positive effect of the drug [6\. Furthermore, antibiotics can build up in the body resulting in increased toxic effect [7].

In 2004-2005, a new feed concept was developed in the European Union, which precludes the usage of antimicrobial growth promoters and envisioning the usage of phytobiotics. The phytobiotics are divided into the following groups based on biological origin, chemical composition and other attributes: herbs (flowering, herbaceous and short-lived plants), spices (herbs with intensive odor or taste, usually added in food), ether oils (volatile lipophilic compounds obtained by cold pressing, steam or alcohol distillation) and resins (oleoresin, extracts obtained with the help of non-aqueous solvents). These substances can be used as antimicrobial agents and should become available for usage in livestock feeds [8, 9]. In a number of papers the authors underline the significant differences in the number of biologically active substances depending on geographical area or plant harvesting time [10, 11]. For instance, ether oils obtained after summer harvest have the highest antimicrobial activity immediately after flowering [12-14]. Presently, the production of phytobiotics in EU countries has reached significant amounts. Phytobiotics Futterzusatzstoffe GmbH is one of the largest global producers of phytobiotics, which was founded in Germany in 2000. The main product of the company is Sangrovit®, which is a natural plant-derived feed additive designed to increase livestock productivity [15].

The antimicrobial [10, 13, 16-18] and immunostimulating [19-22] properties of plant-derived ether oils are at the center of focus. The antimicrobial effect of 96 various ether oils has been analyzed, as well as 23 of their active agents. It was demonstrated that cinnamaldehyde, thymol, carvacrol and eugenol display the strongest antimicrobial activity against the strains of *Escherichia coli*, *Salmonella enterica* and *Listeria monocytogenes* [23]. The positive effect of *Origanum syriacum* ether oil on productivity and histology of the intestinal tract of poultry [24] has been determined, which is added to the diet of broilers in case of thermal stress.

The antimicrobial activity of ether oils is not defined by the only mechanism and is aimed at several goals in microbial cells [25, 26]. The ether oils can destabilize and change the permeability of bacterial membranes [27-30]. These changes result in the release of ions from the cell to the environment [31], and in the change of proton gradient and depletion of intracellular reserves of adenosine triphosphate [32, 33].

Unlike probiotics, the systemic impact of phytobiotics on the bodies of livestock and poultry is attributable not only to the antimicrobial effect, but also to their positive impact on digestive processes. The phytobiotics stimulate the production of endogenous enzymes improving the digestibility and nutrient intake of feed. Many of them act as natural flavoring agents stimulating feed consumption, which has a positive effect on livestock productivity [34].

The phytobiotics have specific impact on the microbial composition of the intestinal tract maintaining the optimal state of microbial flora [35]. The usage of phytobiotics stimulates digestive secretion and has positive impact on morphofunctional characteristics of gastrointestinal mucosa. The better and more efficient absorption in the small intestine results in reduction of valuable nutrient loss. The risk of undesirable microbial population developing in the colon is reduced [36]. The positive impact of gel phytogenic feed additive on growth performance, nutrient intake and morphological properties of the intestinal tract in post-weaning pigs has been reported [37].

M. Mohiti-Asli at al. [38] compared the effect of two phytogenic mixtures on growth and immune response of broilers. Adding oregano ether oil to the ratios had a positive impact on productivity and immune function of broiler chickens. A possibility of using plant-derived polyphenols to combat oxidative stress and inflammatory processes of agricultural animals is under consideration [39].

The phytobiotics are natural growth promoters (NGPs) and can become a promising replacement for antibiotic growth promoters in contemporary livestock farming [40]. The different NGPs combined in a balanced mix effectively combat the intrusion of pathogenic organisms and consequences of unfavorable keeping conditions [41].

The simplest method of using phytobiotics is to add plants to livestock feeds in their native or dry form. For instance, using fresh nettle and nettle meal as feed for poultry can cover up to 20% protein needs, up to 60-70% vitamin needs and up to 100% of needs in minor nutrient elements, and up to 30% combined feed can be saved. The taste of eggs and poultry meat and their biological value also increase significantly [42]. The usage of grass meal made of coroniferous saw-wort attributed to the increase of egg-laying capacity of white Hungarian goose, the weight of eggs, conception rate, hatchability and hatching out [43]. The inclusion of oak bark in broiler chicken ratios increased feed intake and had no negative impact on the bodies of poultry, and usage of oak bark extract along with enzyme preparation stimulated digestion [44]. The silver fir coniferous meals are recommended for all livestock and poultry in winter and spring season as an alternative to synthetic additives. Feeding fir meals to cows during lactation stimulated the increase of lactation productivity, improvement of vitamin content of milk and reproductive function and normalization of metabolism [45]. During factory testing of Pikhtovit (Solagift LLC, Russia), which was developed using silver fir needle extract, on cross-bred poultry, the broilers of the test group demonstrated better hematological figures compared with the control group, and body weight increased by 4% [46].

The data have been presented about usage of topinambur as a valuable feed and medicinal crop. Topinambur is a natural immunomodulator, which acts as a concentrator of inulin polysaccharide in combination with pectic substances,

vitamins, irreplaceable amino acids, macro and micro elements [47]. The effect of aqueous extracts of *Origanum vulgare* L. and *Rosmarinus officinalis* L. on the immune system, microbial population of the intestinal tract and productivity of broiler chickens has been studied. The extracts of these herbs increased the immune resistance of broilers, brought the microbial population of the intestinal tract into balance, which is required for digestive processes and protection against enteropathogenic microorganisms, and improved the productive qualities of poultry [48].

The introduction of multiple-component feed additives in the ratios of laying hens consisting of stinging nettle meal (0.3-1.0%), mountain pine fir needles (0.2-1.0%), laminaria (0.5 %), ginger plant (0.5-1.0%) and common yarrow (0.5-1.5%) turned out efficient for enrichment of rations with nutrient and biologically active substances [49].

When growing broilers, the addition of *Cinnamomum cassia* L. powder in the amount of 0.5 % per ration weight [50] can be used as phytobiotic alternative of antibiotics. An additive from *Punica granatum* L. improved the immune system and microbial ecosystem of the intestinal tract of broilers along with the reduction of emission of gas with litter [51]. *Boswellia serrata* Roxb. ex Colebr. resin is also considered safe and efficient biological additive for broilers positively affecting poultry productivity [52].

The application of *Thymus serpyllum* L. as phytogenic feed additive in pig farming facilitates the intoxication levels, stress-inducing impact on the immune system, stabilizes the endoecological situation and balance of gastrointestinal microbial population in the intestinal tract, increases feed attractiveness and intake, and absorption efficiency of essential nutrients, and in general stimulates the improvement of nutritional status of livestock, their optimal development and realization of their genetic potential [53].

Echinacea purpurea (L.) Moench is characterized by high biological plasticity, adaptivity, ecological sustainability, productive longevity, feed and medicinal properties, and stable fruit bearing [54]. During tests conducted on broiler chickens using *Echinacea purpurea* (L.) Moench, a 19.4 % growth intensity increase was identified as compared with the control group. The biggest effect was achieved by combining *Echinacea purpurea* (L.) Moench with Lactobifadolum. The usage of these agents as a whole increased live body weight gain by 20.9% during the entire period of chicken incubation, reduced feed costs by 17.3% and ensured 100% preservation of livestock population [55]. When aqueous alcoholic extracts of aboveground parts, roots and whole *Echinacea purpurea* (L.) Moench were added in the drinking water, the daily weight gain of broiler chickens increased by 3.3-12.5%, and feed costs decreased by 5.2-9.2% as compared with the control group [56]. An indication is made regarding a possibility of using *Cichorium intybus* L. as a feed additive to increase poultry productivity [57]. The positive effect was noted of Florabis phytobiotic agent (IPC Abis LLC, Russia), which is based on a complex of triterpenic acids of Siberian fir with cobalt ions, at a dose of 0.002 $ml \cdot units^{-1} \cdot day^{-1}$ on biochemical and immunological indicators of blood of broiler chickens of ISA F 15 cross-breed, digestibility and nutrient intake of combined feed [58].

As a rule, complex preparations have a more pronounced effect than each component individually. In this regard, the data about research of complex plant-derived concentrates with a probiotic based on *Bacillus subtilis* [59] bacterium are of interest. The sea buckthorn leaves fermented with a probiotic agent are used as a phytobiotic, as well as a mixture of *Echinacea purpurea* (L.) Moench herb with berries of *Silybum marianum*. The preparation in the form of a ProStor (CV-AgroTrade, Russia) biologically active additive (BAA) additionally

contains an association of *Bacillus licheniformis* bacteria, lactobacilluses, prebiotics mannan-oligosaccharides of cell walls of *Saccharomyces cerevisiae* yeast and beetroot pulp pectins. Feeding the complex plant-driven concentrate (sea buckthorn leaves) with a probiotic on the basis of *Bacillus subtilis* to lactating highly productive cows had a positive effect on milk productivity of livestock with reduced feed cost per product unit [59]. The live body weight of bulls receiving ProStor BAA at the age of 15-17 months was 13.5 kilos (3.1%) higher than that of the bulls in the control group by the end of the feed. The cost of energetic feed unit was lower by 7% in the test group as compared with the control group [59].

The addition of L-arginine Pro (Russia) contains a bioactive fir needle extract of Scots pine enriched with L-arginine. The feeding of ratios containing this additive in the amount of 1 g/100 g of combined feed ensures stable and intensive growth of rearing birds, facilitates the increase of egg-laying capacity of laying hens by 46.8%, egg weight by 4.7 g, increase of morphological indicators and egg quality [60].

The usage of bioactive substances of Volgograd Institute of Cattle Farming and Livestock Product Processing RAS (Russia) Laktofit (a composition of bioactive substances of topinambur, beetroot, carrot, pumpkin, milk thistle, chickpea with a concentration of lactulose and malic acid) and Lactoflex (a composition of bioactive substances of dandelion, mint, licorice, calendula, pumpkin seeds, milk thistle, chickpea with a concentration of lactulose and malic acid) enables body weight increase of laying hens, improvement of morphological and biochemical blood composition, increase of weight and linear indicators of reproductive organs of test birds and hatching out of healthy rearing birds [61].

Intebio natural substitution of antibiotic growth promoters (previously manufactured as Mix Oil, Biotrof" LLC, Russia) is a mixture of natural ether oils that has antimicrobial activity, antioxidant effect and anti-inflammatory effect. The introduction of Mix Oil phytobiotic agent in the ratios of brood sows had a positive impact on their preparation for farrowing. During the suckling period, the additive accelerated the growth of piglets and increased their livability. In the test group the daily live weight gain of piglets increased by 16.5% and feed costs per 1 kilogram of weight gain were 0.72 feed units lower as compared with the control group [62].

The usage of Provitol phytoprobiotic (Biotrof LLC, Russia), which includes living bacteria and compositions of ether oils extracted from plants with antioxidant properties in the ratios of freshly calved cows stimulated the increase in rough feed edibility and significant increase of milk productivity during days in milk (63). When determining the efficiency of Provitol phytoprobiotic in combined feed for laying hens containing novel corn, the age-specific decrease of productivity by 2.9% is determined in the control group, which was facilitated by poultry transition to novel corn. At the same time, in this context the addition of Provitol in combined feed for test group hens increased the egg-laying by 2.8% as compared with the previous month, and by 7.6% during the second productivity phase as compared with the control group [64].

The lab research and production tests have proven the synergistic effect of ether oils and organic acids that are included in Liptosa Premix Expert (Lipidos Toledo, S.A., Spain) preparation when used to inhibit clostridium, salmonella and *Escherichia coli*. The ether oils of thymol, carvacrol, eugenol are used as strong antiviral, anti-infectious, bactericidal and immunostimulating drugs. The sensibility of clostridium, salmonella and *Escherichia coli* in anaerobic conditions to thymol, carvacrol and oregano oil [17, 32, 33, 65] has been proven.

The production testing of Meth Plus phytobiotic (Levet-Agro LLC, the

Republic of Belarus) developed as alternative synthetic methionine was conducted in Hy-Line cross-breed chickens at the breeding stage. The poultry receiving Meth Plus in their ratios exceeded the standards in terms of body weight gain, and herd uniformity exceeded 80% (66). When conducting tests on Pietrain pigs, 1 kilogram of DL-methionine was replaced with a similar quantity of Meth Plus phytobiotic, as a result of which the livestock of one group demonstrated the highest daily live weight gain and the best feed conversion ratio and slaughter parameters as compared with the test livestock [66].

The activity of Biost-rong® 510, (Delacon Biotechnik GmbH, Austria) is conditioned on flavoring agents, anisic acid and glucuronic acid, saponins, thymol, borneol, carvacrol that stimulate biocatalytic and enzymatic process in the intestinal tract of poultry. It has been determined that Biostrong® 510 enables replacing antibiotic growth promoters, which ensures high digestibility and usage of main nutrients of combined feeds and livability [67].

Digestarom® 1317 (Micro-Plus Konzentrate GmbH, Germany) phytobiotic additive is a combination of spices, plant extracts and their ether oils that have a combined effect on livestock and poultry appetite. It has been determined that usage of this additive as a combined feed for goslings raised for meat facilitates the increase of livability, poultry live weight, increased meat qualities in the context of better digestion of feed components and reduction of costs per unit of products. The most effective additive feeding dosage is determined as follows: 20 g/100 kg of combined feed [68, 69].

Sangrovit® WS (Phytobiotics Fut-terzusatzstoffe GmbH, Germany) phytobiotic stimulates the consumption of feed and facilitates better functioning of digestive system of poultry. The primary active ingredient of the phytobiotic is contained in the *Macleya cordata* (Willd.) extract: 2.0-4.0% in dry leaves and stalks. The live weight of broilers receiving Sangrovit® WS from day 17 until day 21 of breeding at a rate of 100 g/t of water increased by 1.5%, and those receiving this agent from days 17 to 21 and from days 27 to 30 of breeding increased by 2.0% as compared to the control group. The livability of chickens from test groups during 35 days of raising was 1-4% higher as compared to the control group [70].

Liv 52 Vet (The Himalaya Drug Company, India) phytobiotic contains powders of different medicinal herbs (caper, blue dandelion, black nightshade, *Terminalia arjuna*, *Cassia occidentalis*, common yarrow, *Tamarix gallica*) and extracts of a mix of botanical raw materials (*Eclipta alba*, *Phyllanthus niruri*, spreading hogweed, *Tinospora cordifolia*, garden radish, medicinal emblica, plumbago, *Embelia ribes*, *Terminalia chebula*, *Fumaria officinalis*). During surveys conducted when feeding livestock with this phytobiotic agent the immune system activation of parent stock geese was observed: the phagocytic activity increased by 3.34-7.34%, the phagocytic number and index were respectively higher by 22.51-37.13 and 14.23-18.37% compared to the control group [71]. The usage of Liv 52 Vet additive in a dose of 200 and 250 g/t combined feed had immunostimulating effect on the bodies of broiler goslings, facilitated the stimulation of phagocyte functions and increased resistance to disease, which in turn resulted in increased livability of poultry [72].

An option is considered to use plant-derived agents to produce functional eggs. For instance, natural carotenoid pigments for poultry are obtained from medick, carrot, pumpkin, calendula petals. Oro Glo® 20 (Kemin Europa N.V., Belgium), which contains an extract of calendula petals, is used in a dose of 200-1000 g/t of combined feed to amplify the intensity of color of chicken egg yolk and accumulation of carotenoids in them [73]. It is recommended to use agents with carotene-containing (manufactured by Biocol Agro, Russia) Yellow

Biofon (natural pigment obtained from an extract of marigold petals) and Red Biofon (obtained from an extract of red pepper fruit) in the doses, respectively, of 600 and 500 g/t, and to achieve a brighter yellow yolk it is recommended to add doses of 300 and 600 g/t of feed [74] to increase nutrient properties of quail eggs in the context of insufficient amount of carotinoids in the feed.

The usage of phytobiotics wholly corresponds to the ideology of clean agricultural production and the tasks of improving the quality of life of people. The insignificant scope of phytobiotic usage in the Russian animal husbandry is due to the underdeveloped market of domestic products of this group, high price of imported phytobiotic feed additives, and lack of prohibition to use antibiotic growth promoters in Russia.

Therefore, comprehensive study of properties of plants containing phytobiotic components, the use of cutting-edge technologies to obtain and standardize these components, their experimental and production testing enable a wide usage of plant-derived extracts as biologically active last generation additives based on natural raw materials. In the context of intensive animal husbandry technologies, the phytobiotics recover reduced immune and antioxidant status of livestock, and ensure increase of all types of productivity due to consumption, digestibility, nutrient intake of feeds and normalization of intestinal microbial population and homeostasis in general.

REFERENCES

1. Akhmedkhanova R.R., Gamidov N.R. *Problemy razvitiya APK regiona*, 2010, 1(1): 73-77 (in Russ.).
2. Bushov A., Kurmanaeva V. *Ptitsevodstvo*, 2012, 1: 31-33 (in Russ.).
3. Gheisar M.M., Kim I.H. Phytobiotics in poultry and swine nutrition — a review. *Ital. J. Anim. Sci.*, 2018, 17(1): 92-99 (doi: 10.1080/1828051X.2017.1350120).
4. Świątkiewicz S., Arczewska-Włosek A., Józefiak D. Application of microalgae biomass in poultry nutrition. *World's Poult. Sci. J.*, 2015, 71: 663-672 (doi: 10.1017/S0043933915002457).
5. Windisch W., Schedle K., Plitzner C., Kroismayr A. Use of phytogenic products as feed additives for swine and poultry. *J. Anim. Sci.*, 2008, 86(Suppl. 14): 140-148 (doi: 10.2527/jas.2007-0459).
6. Wegener H.C. Antibiotics in animal feed and their role in resistance development. *Curr. Opin. Microbiol.*, 2003, 6(5): 439-445 (doi: 10.1016/j.mib.2003.09.009).
7. Hao H., Cheng G., Iqbal Z., Ai X., Hussain H.I., Huang L., Dai M., Wang Y., Liu Z., Yuan Z. Benefits and risks of antimicrobial use in food-producing animals. *Front. Microbiol.*, 2014, 5: 288 (doi: 10.3389/fmicb.2014.00288).
8. Windisch W., Kroismayr A. The effect of phytobiotics on performance and gut function in monogastrics. *Biomin World Nutrition Forum. 2007.* Rezhim dostupa: https://en.engormix.com/feed-machinery/articles/phytobiotics-on-performance-gut-function-in-monogastrics-t33528.htm. Data obrashcheniya: 07.08.2018.
9. Castillo-Lypez R.I., Gutiérrez-Grijalva E.P., Leyva-López N., López-Martínez L.X., Heredia J.B. Natural alternatives to growth-promoting antibiotics (GPA) in animal production. *J. Anim. Plant Sci.*, 2017, 27(2): 349-359.
10. Juliano C., Mattana A., Usai M. Composition and in vitro antimicrobial activity of the essential oil of *Thymus herba-barona* Loisel growing wild in Sardinia. *J. Essent. Oil Res.*, 2000, 12(4): 516-522 (doi: 10.1080/10412905.2000.9699578).
11. Faleiro M.L., Miguel M.G., Ladeiro F., Venancio F., Tavares R., Brito J.C., Figueiredo A.C., Barroso J.G., Pedro L.G. Antimicrobial activity of essential oils isolated from Portuguese endemic species of *Thymus. Lett. Appl. Microbiol.*, 2002, 36(1): 35-40 (doi: 10.1046/j.1472-765X.2003.01259.x).
12. McGimpsey J.A., Douglas M.H., Van Klink J.L., Beauregard D.A., Perry N.B. Seasonal variation in essential oil yield and composition from naturalized *Thymus vulgaris* L. in New Zealand. *Flavour Frag. J.*, 1994, 9(6): 347-352 (doi: 10.1002/ffj.2730090613).
13. Marino M., Bersani C., Comi G. Antimicrobial activity of the essential oils of *Thymus vulgaris* L. measured using a bioimpedometric method. *J. Food Protect.*, 1999, 62(9): 1017-1023 (doi: 10.4315/0362-028X-62.9.1017).
14. Delaquis P.J., Stanich K., Girard B., Mazza G. Antimicrobial activity of individual and mixed

fractions of dill, cilantro, coriander and eucalyptus essential oils. *Int. J. Food Microbiol.*, 2002, 74(1-2): 101-109 (doi: 10.1016/S0168-1605(01)00734-6).
15. Jeroch H., Kozlowski K., Jeroch J., Lipinski K., Zdunczyk Z., Jankowski J. Efficacy of the phytogenic (*Papaveraceae*) additive Sangrovit® in growing monogastric animals. *Züchtungskunde*, 2009, 81(4): 279-293.
16. Si W., Gong J., Tsao R., Zhou T., Yu H., Poppe C., Johnson R., Du Z. Antimicrobial activity of essential oils and structurally related synthetic food additives towards selected pathogenic and beneficial gut bacteria. *J. Appl. Microbiol.*, 2006, 100: 296-305 (doi: 10.1111/j.1365-2672.2005.02789.x).
17. Burt S. Essential oils: their antibacterial properties and potential applications in foods — a review. *Int. J. Food Microbiol.*, 2004, 94(3): 223-253 (doi: 10.1016/j.ijfoodmicro.2004.03.022).
18. Dorman H.J.D., Deans S.G. Antimicrobial agents from plants: antibacterial activity of plant volatile oils. *J. Appl. Microbiol.*, 2000, 88(2): 308-316 (doi: 10.1046/j.1365-2672.2000.00969.x).
19. Bakkali F., Averbeck S., Averbeck D., Idaomar M. Biological effects of essential oils — a review. *Food Chem. Toxicol.*, 2008, 46(2): 446-475 (doi: 10.1016/j.fct.2007.09.106).
20. Ait-Ouazzou A., Cherrat L., Espina L., Lorán S., Rota C., Pagán R. The antimicrobial activity of hydrophobic essential oil constituents acting alone or in combined processes of food preservation. *Innov. Food Sci. Emerg.*, 2011, 12(3): 320-329 (doi: 10.1016/j.ifset.2011.04.004).
21. Adaszynska-Skwirzynska M., Szczerbinska D. Use of essential oils in broiler chicken production — a review. *Ann. Anim. Sci.*, 2017, 17(2): 317-335 (doi: 10.1515/aoas-2016-0046).
22. Kiczorowska B., Samolińska W., Al-Yasiry A.R.M., Kiczorowski P., Winiarska-Mieczan A. The natural feed additives as immunostimulants in monogastric animal nutrition — a review. *Ann. Anim. Sci.*, 2017, 17(3): 605-625 (doi: 10.1515/aoas-2016-0076).
23. Friedman M., Henika P.R., Mandrell R.E. Bactericidal activities of plant essential oils and some of their isolated constituents against *Campylobacter jejuni*, *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella enteric. J. Food Protect.*, 2002, 65(10): 1545-1560 (doi: 10.4315/0362-028X-65.10.1545).
24. Konca Y., Cimen B., Yalcin H., Kaliber M., Beyzi S. Effect of hempseed (*Cannabis sativa* sp.) inclusion to the diet on performance, carcass and antioxidative activity in Japanese quail (*Coturnix coturnix japonica*). *Korean J. Food Sci. An.*, 2014, 34(2): 141-150 (doi: 10.5851/kosfa.2014.34.2.141).
25. Skandamis P., Koutsoumanis K., Fasseas K., Nychas G.-J.E. Inhibition of oregano essential oil and EDTA on *Escherichia coli* O157: H7. *Ital. J. Food Sci.*, 2001, 13(1): 65-75.
26. Carson C.F., Mee B.J., Riley T.V. Mechanism of action of *Melaleuca alternifolia* (tea tree) oil on *Staphylococcus aureus* determined by time-kill, lysis, leakage and salt tolerance assays and electron microscopy. *Antimicrob. Agents Ch.*, 2002, 46(6): 1914-1920 (doi: 10.1128/AAC.46.6.1914-1920.2002).
27. Sikkema J., de Bont J.A., Poolman B. Mechanisms of membrane toxicity of hydrocarbons. *Microbiol. Mol. Biol. R.*, 1995, 59: 201-222.
28. Ultee A., Kets E.P.W., Alberda M., Hoekstra F.A., Smid E.J. Adaptation of the food-borne pathogen *Bacillus cereus* to carvacrol. *Arch. Microbiol.*, 2000, 174(4): 233-238 (doi: 10.1007/s002030000199).
29. Ultee A., Bennink M.H.J., Moezelaar R. The phenolic hydroxyl group of carvacrol is essential for action against the food-borne pathogen *Bacillus cereus. Appl. Environ. Microb.*, 2002, 68(4): 1561-1568 (doi: 10.1128/AEM.68.4.1561-1568.2002).
30. Sikkema J., De Bont J.A.M., Poolman B. Interactions of cyclic hydrocarbons with biological membranes. *J. Biol. Chem.*, 1994, 269(11): 8022-8028.
31. Cox S.D., Mann C.M., Markham J.L., Bell H.C., Gustafson J.E., Warmington J.R., Wyllie S.G. The mode of antimicrobial action of essential oil of *Melaleuca alternifola* (tea tree oil). *J. Appl. Microbiol.*, 2000, 88(1): 170-175 (doi: 10.1046/j.1365-2672.2000.00943.x).
32. Ultee A., Kets W.E.P., Smid E.J. Mechanism of action of carvacrol on the food-borne pathogen *Bacillus cereus. Appl. Environ. Microb.*, 1999, 65(10): 4606-4610.
33. Davidson P.M. Chemical preservatives and natural antimicrobial compounds. In: *Food microbiology fundamentals and frontiers.* M.P. Doyle, L.R. Beuchat, T.J. Montville (eds.). ASM Press, NY, 1997: 520-556 (doi: 10.1128/9781555815912.ch33).
34. Nikolaev S.I., Melikhov V.V., Frolova M.V. *Vestnik Rossiiskoi sel'skokhozyaistvennoi nauki*, 2009, 2: 68 (in Russ.).
35. Sukhanova S.F., Azaubaeva G.S. *Veterinarnyi vestnik Kurganskoi GSKHA*, 2015, 1: 55-59 (in Russ.).
36. Juliani H.R., Koroch A.R., Simon J.E. Chemical diversity of essential oils of *Ocimum* species and their associated antioxidant and Antimicrobial Activity. In: *Essential oils and aromas: green extractions and applications.* F. Chemat, V.K. Varshney, K. Allaf (eds.). Dehradun, India, 2009.
37. Upadhaya S.D., Kim S.J., Kim I.H. Effects of gel-based phytogenic feed supplement on growth performance, nutrient digestibility, blood characteristics and intestinal morphology in weanling pigs. *J. Appl. Anim. Res.*, 2016, 44(1): 384-389 (doi: 10.1080/09712119.2015.1091334).
38. Mohiti-Asli M., Ghanaatparast-Rashti M. Comparison of the effect of two phytogenic compounds on growth performance and immune response of broilers. *J. Appl. Anim. Res.*, 2017, 45(1): 603-608.
39. Shapiro S., Guggenheim B. Inhibition of oral bacteria by phenolic compounds Part 1: QSAR

analysis using molecular connectivity. *Quant. Struct.-Act. Relat.*, 1998, 17(4): 327-337 (doi: 10.1002/(SICI)1521-3838(199808)17:04<327::AID-QSAR327>3.0.CO;2-O).
40. Delaquis P.J., Stanich K., Girard B., Mazza G. Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and eucalyptus essential oils. *Int. J. Food Microbiol.*, 2002, 74(1-2): 101-109 (doi: 10.1016/S0168-1605(01)00734-6).
41. Molchanov A.A., Zhukova I.A., Antipin S.L. *Nauchnyi vestnik L'vovskogo natsional'nogo universiteta veterinarnoi meditsiny i biotekhnologii im. S.Z. Gzhitskogo*, 2016, 18(1-3): 76-81 (in Russ.).
42. Egorov I.A. *Ptitsevodstvo*, 2014, 6: 22-24 (in Russ.).
43. Khusnutdinov B., Gumarova G. *Ptitsevodstvo*, 2009, 10: 26-27 (in Russ.).
44. Kazachkova N.M. *Materialy Mezhdunarodnoi nauchno-prakticheskoi konferentsii «Innovatsionnye tekhnologii v obrazovanii i nauke»* [Proc. Int. Conf. "Innovative technologies in education and science"]. Cheboksary, 2017: 14-16 (in Russ.).
45. Terent'ev V.I., Anikienko T.I. *Vestnik KrasGAU*, 2011, 5: 163-166 (in Russ.).
46. Tabakov N.A., Kozina E.A., Ki-yu-an N.A., Ryabinina L.A. *Kormlenie sel'skokhozyaistvennykh zhivotnykh i kormoproizvodstvo*, 2008, 6: 50-55 (in Russ.).
47. Yaroshevich M.I., Vecher N.E. *Trudy BGU*, 2010, 4(2): 1-12 (in Russ.).
48. Franciosini M.P., Casagrande-Proietti P., Forte C., Beghelli D., Acuti G., Zanichelli D., dal Bosco A., Castellini C., Trabalza-Marinucci M. Effects of oregano (*Origanum vulgare* L.) and rosemary (*Rosmarinus officinalis* L.) aqueous extracts on broiler performance, immune function and intestinal microbial population. *J. Appl. Anim. Res.*, 2016, 44(1): 474-479 (doi: 10.1080/09712119.2015.1091322).
49. Ignatovich L.S. *Dal'nevostochnyi agrarnyi vestnik*, 2017, 2(42): 75-81 (doi: 10.24411/1999-6837-2017-00012) (in Russ.).
50. Singh J., Sethi A.P.S., Sikka S.S., Chatli M.K., Kumar Pawan. Effect of cinnamon (*Cinnamomum cassia*) powder as a phytobiotic growth promoter in commercial broiler chickens. *Anim. Nutr. Feed Techn.*, 2014, 14(3): 471-479 (doi: 10.5958/0974-181X.2014.01349.3).
51. Ahmed T.S., Yang C.-J. Effects of dietary *Punica granatum* L. by-products on performance, immunity, intestinal and fecal microbiology, and odorous gas emissions from excreta in broilers. *J. Poul. Sci.*, 2017, 54: 157-166 (doi: 10.2141/jpsa.0160116).
52. Al-Yasiry A.R.M., Kiczorowska B., Samolińska W., Kowalczuk-Vasilev E., Kowalczyk-Pecka D. The effect of *Boswellia serrata* resin diet supplementation on production, hematological, biochemical and immunological parameters in broiler chickens. *Animal*, 2017, 11(11): 1890-1898 (doi: 10.1017/S1751731117000817).
53. Udintsev S.N., Zhilyakova T.P., Mel'nikov D.P. *Svinovodstvo*, 2010, 5: 18-21 (in Russ.).
54. Farnieva K.Kh. *Effektivnost' introduktsii i perspektivy ispol'zovaniya ekhinatsei purpurnoi (Echinacea purpurea (L.) Moench) v usloviyakh RSO-Alaniya. Avtoreferat kandidatskoi dissertatsii* [Introduction and use of *Echinacea purpurea* (L.) Moench in Alania. PhD Thesis]. Vladikavkaz, 2015 (in Russ.).
55. Khmyrov A., Fat'yanov A., Gorshkov G. *Zhivotnovodstvo Rossii*, 2012, 9: 16-17 (in Russ.).
56. Kushniruk T.N. *Intensivnost' rosta, sokhrannost', gematologicheskie i immunologicheskie pokazateli u ptits, potreblyavshikh dobavki ekhinatsei k kormu. Avtoreferat kandidatskoi dissertatsii* [Growth, preservation, hematological and immunological indicators in poultry fed with dietary *Echinacea*. PhD Thesis]. Belgorod, 2008 (in Russ.).
57. Saeed M., Abd El-Hack M.E., Alagawany M., Arain M.A., Arif M., Mirza M.A., Naveed M., Chao S., Sarwar M., Sayab M., Dhama K. Chicory (*Cichorium intybus*) Herb: chemical composition, pharmacology, nutritional and healthical applications. *Int. J. Pharmacol.*, 2017, 13(4): 351-360 (doi: 10.3923/ijp.2017.351.360).
58. Lantseva N.N., Martyshchenko A.E., Shvydkov A.N., Ryabukha L.A., Smirnov P.N., Kotlyarova O.V., Chebakov V.P. *Fundamental'nye issledovaniya*, 2015, 2: 1417-1423 (in Russ.).
59. Nekrasov R.V., Chabaev M.G., Ushakova N.A., Pravdin V.G., Kravtsova L.Z. *Izvestiya Orenburgskogo GAU*, 2012, 3: 225-228 (in Russ.).
60. Ryzhov V.A., Ryzhova E.S., Korotkii V.P., Zenkin A.S., Marisov S.S. *Nauchno-metodicheskii elektronnyi zhurnal Kontsept*, 2015, 13: 3236-3240 (in Russ.).
61. Komarova Z.B., Pilipenko D.N., Ivanov S.M. *Izvestiya Nizhnevolzhskogo agrouniversitetskogo kompleksa: nauka i vysshee professional'noe obrazovanie*, 2011, 3: 1-5 (in Russ.).
62. Laptev G.Yu., Bol'shakov V.N., Soldatova V.V. *Sel'skokhozyaistvennye vesti*, 2012, 1: 24 (in Russ.).
63. Duborezov V., Romanov V., Nekrasov R. *Zhivotnovodstvo Rossii*, 2013, Spetsvypusk: 38-40 (in Russ.).
64. Okolelova T., Laptev G., Bol'shakov V. Effektivnost' Provitola v kombikormakh dlya kur. *Ptitsevodstvo*, 2014, 1: 12-14.
65. Radaelli M., Parraga da Silva B., Weidlich L., Hoehne L., Flach A., da Costa L.A.M.A., Ethur E.M. Antimicrobial activities of six essential oils commonly used as condiments in Brazil against *Clostridium perfringens*. *Braz. J. Microbiol.*, 2016, 47(2): 424-430 (doi: 10.1016/j.bjm.2015.10.001).
66. Lopes I., Suika E., Lopes S., N'eto R., Rodriges A., Uspeshnyi A. *Kombikorma*, 2016, 1: 85-87 (in Russ.).

67. Egorov I., Egorova T., Rozanov B., Marechek E. *Ptitsevodstvo*, 2012, 1: 17-20 (in Russ.).
68. Khaziev D.D. *Vestnik BGAU*, 2013, 3: 79-81 (in Russ.).
69. Khaziev D.D. *Izvestiya Orenburgskogo GAU*, 2013, 5: 150-153 (in Russ.).
70. Zhirnova O.V., Gamko L.N., Shepelev S.I. *Zootekhniya*, 2016, 5: 26-27 (in Russ.).
71. Sukhanova S.F. *Vestnik APK Stavropol'ya*, 2017, 2: 109-119 (in Russ.).
72. Sukhanova S.F., Azaubaeva G.S. *Vestnik Altaiskogo GAU*, 2014, 12: 95-99 (in Russ.).
73. Tolstopyatov M.V., Salomatin V.V., Kalinina E.A. *Izvestiya Nizhnevolzhskogo agrouniversitetskogo kompleksa: nauka i vysshee professional'noe obrazovanie*, 2013, 4: 1-4 (in Russ.).
74. Afanas'ev G.D., Popova L.A., Komarchev A.S., Trepak Zh.G. *Ptitsa i ptitseprodukty*, 2014, 5: 62-64 (in Russ.).