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Review

Herbs as feed additives in small ruminant nutrition: A review

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Abstract. *The prohibited use of nutritional antibiotics due to the emerging resistance of microbial pathogens has initiated a quest for alternatives to replace them in the feed of animals from different species and categories. Increasing attention is paid to plants' natural antibiotic properties, the intake of which does not lead to resistance in any form. In recent years, the research interest into the use of various types of herbs as dietary additives for specific species and categories of animals is particularly increased. They are used to improve growth performance, feed conversion, health status, meat quality, as well as for prevention and treatment of various illnesses. Along with beneficial ingredients, plants contain several antinutritional factors (substances) of particular importance for young animals, for example weaned lambs. This article examines the effects of seven herbal species on growth traits, blood parameters and meat quality in small ruminants.*

Keywords: sheep, goat, essential oils, growth performance, blood parameters, meat quality

Introduction

The prohibited use of nutritional antibiotics due to the emerging resistance of microbial pathogens resulted in the quest for alternatives to replace them in the feed of animals from different species and categories. Increasing attention is paid to plants' natural antibiotic properties, the intake of which does not lead to resistance in any form. People have been using various plants for food and in traditional medicine since antiquity. These plants are known as phytomedicines, medicinal plants or herbs. Local plant species are used in the daily lives of different peoples according to the faunal diversity of the inhabited territory. In recent years, the research interest into the use of various types of herbs as dietary additives for specific species and categories of animals is increased (Wang et al., 2024). They are used to improve growth performance, feed conversion, health status, meat quality, as well as for prevention and treatment of various illnesses. Along with beneficial ingredients, plants contain several antinutritional factors (substances) of particular importance for young animals, for example weaned lambs. For this reason, any plant introduced as a feed additive for them must undergo a thorough preliminary investigation. The still underdeveloped forestomachs and organism of young lambs may not respond well to the antinutritional substances contained in the respective plant. This article aims

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to examine the effects of seven herbal species on growth traits, blood parameters and meat quality in small ruminants.

Thyme *(Thymus vulgaris)* is a relevant wild edible plant, studied for centuries because of its unique applications in the food, pharmaceutical and cosmetic industries. It is rich in phytonutrients, minerals, vitamins, proteins and crude fibre. Research studies have proved the therapeutic properties of thyme and its essential oils, thymol and carvacrol in particular, against various illnesses. In addition to its remarkable microbial biofilm destruction ability, thyme has been recognised for its antiviral, antibacterial, antifungal and antiseptic activities (Halat et al., 2022).

The bioactive compounds of oregano *(Origanum vulgare)* – carvacrol, thymol, antioxidants, possess antidiabetic, anti-inflammatory, antimicrobial, antiviral, antiparasitic, antineoplastic and immunomodulatory properties. Oregano is a natural, low toxicity feed supplement and has been successfully used in farm animals and fish as a growth promoter (Alagawany et al., 2020).

The common nettle *(Urtica dioica)* is an excellent dietary source of protein and fibre in farm animal nutrition (Jin et al., 2018); it is also used in the cosmetic industry. Various pharmacological properties of nettle - antibacterial, antioxidant, analgesic, anti-inflammatory, antiviral, immunomodulatory, hepatoprotective, anticolic and anticancer, have been reported (Joshi et al., 2014).

The dandelion *(Taraxacum officinale)* and dandelion extract are a good source of functional components, e.g. peptides, terpenes, poly- and oligosaccharides, antioxidant phenolic compounds, flavonoids, alkaloids, vitamins, minerals. The enumerated substances are responsible for its antioxidant, antibacterial, immunomodulatory and anti-inflammatory activities, hence its use in traditional medicine for stimulation of the appetite, improvement of intestinal, liver and splenic functions (Tan et al., 2017).

For centuries, the milk thistle *(Silybum marianum L.)* has been known for its main active compound silymarin: a powerful antioxidant composed of several flavonoids. Milk thistle contains apigenin, silybonol, myristic, oleic, palmitic and stearic acids, as well as the hepatoprotector betaine hydrochloride (Rezaeieh et al., 2015).

The chamomile *(Matricaria chamomilla)* is a renowned globally distributed medicinal plant, with applications in both veterinary and human medicine. It is used to treat all kinds of illnesses, including infections, neuropsychiatric, respiratory, gastrointestinal and liver pathologies. It is also applied as a sedative, spasmolytic, antiseptic and antiemetic agent. Chamomile essential oils contain terpenoids, such as bisabolol and its oxides A and B, bisabolone oxide A, chamazulene and farnesene among others. The major constituents of extracts are the phenolic compounds, including phenolic acids, flavonoids and coumarins (El Mihyaoui et al., 2022).

The sage *(Salvia officinalis)* is widely used both as a culinary herb and in medicinal preparations. It is used in the treatment of a number of diseases, including digestive and circulatory, as well as in case of bronchitis, cough, asthma, memory problems, angina, buccal and throat inflammations, depression and hyperhidrosis. Sage is known for its antioxidant properties and the ability to improve brain function and memory, invigorating the senses and retarding the cognitive decline occurring with ageing (Lopresti, 2017).

The inclusion of phytogenic dietary supplements in lamb rations is recommended by Silva et al. (2025). According to researchers, this does not change the nutrient intake, yet improves the crude protein digestibility and increases their average daily weight gain without affecting the survival rates. Phytosupplements also improve the quality of the lambs' carcass and meat (Silva et al., 2025). The authors conclude that phytogenic supplements have antibiotic-like properties, such as promoting growth and maintaining rumination parameters.

Effect of dietary supplementation with various herbs on the growth performance of small ruminants

Thyme (*Thymus vulgaris*)

The daily supplementation of Barki sheep with 20 g of thyme per animal for 90 days significantly increased final live weight, the total weight gain

for the period, average daily weight gain and milk yield vs. the control group that received no herbal supplement (Abd El Tawab et al., 2020). The same authors reported that the addition of thyme to the feed considerably increased intake and digestibility of nutrients, as well as the ruminal concentrations of total volatile fatty acids and acetic acid while reducing the ammonia nitrogen in the rumen compared to the controls (Abd El Tawab et al., 2020).

The addition of 15 g powdered thyme leaves per Barki lamb resulted in significantly greater corn intake, overall feed intake and digestibility of nutrients compared to the non-supplemented control group of lambs (Shaaban et al., 2021).

In a 150-day experiment with male Saidi lambs, the total weight gain for the period and the average daily weight gain were significantly greater for the group that received 1.5% mixture of rosemary, thyme and mint (1:1:1) in relation to the controls (Khattab et al., 2022); better feed conversion in the group supplemented with the herbal mixture was also reported.

The average daily feed intake (g) in the group supplemented with 3% thyme was statistically significantly greater than that in the control group in a 90-day experiment conducted with male Sanjabi lambs (Khamisabadi et al., 2016). The researchers concluded that the addition of thyme to lamb feed increased dry matter intake, which may be related to the high content of cymophenol in this herb, along with improved nutrient digestibility, increased feed intake and average daily weight gain (Khamisabadi et al., 2016).

The substitution of 50 g, 75 g and 100 g of concentrate in the diet of Arsi-Bale lambs with the same amounts of thyme leaves resulted in greater dry matter and organic matter intakes, but crude protein intake in the experimental groups was lower compared to the controls that received 300 g of concentrate per lamb (Baye et al., 2020). Effects on dry matter, organic matter and crude protein digestibility were demonstrated, as they were statistically significantly lower in the groups supplemented with thyme leaves vs those of the controls (Baye et al., 2020). Significantly increased average daily weight gain in the control group compared to the groups whose concentrate was partially replaced with thyme leaves was also reported. The highest feed conversion rate was found in controls, and the lowest - when 75 g/d of concentrate feed was replaced with thyme leaves, followed by that in the group receiving 100 g thyme leaves per day (Baye et al., 2020).

The addition of thyme essential oil to the feed at 2 ml/day/lamb had no significant effect on nutrient intake and lamb performance in terms of final live weight, average daily gain and feed conversion rate (El-Essawy et al., 2019).

Oregano *(Origanum vulgare)*

Saidi lambs supplemented with 2.5% dried oregano for 60 days had better digestibility of crude protein compared to the control group of lambs, however there were no significant differences in average weight gain, final body weight and feed conversion (Farghaly and Abdullah., 2021). Similar results without statistically significant differences in final weight, feed intake, average daily gain and feed conversion rate were also reported by Munoz-Cuautle et al. (2022) in Suffolk Hampshire lambs after dietary supplementation with 0.02% and 0.04% oregano. According to Scarpa et al. (2021), the addition of 3% extruded linseed and 3% linseed + 6% oregano affected neither the growth performance and feed intake of Italian Gentile di Puglia lambs, nor the carcass traits and meat quality. The authors concluded that the tested additives did not alter the physical characteristics and chemical composition of lamb meat.

Simitzis et al. (2008) investigated the effect of concentrate feed, uniformly sprayed with oregano essential oil (1 ml/kg) on growth performance of Chios lambs and found no consistent differences after the addition of oregano essential oil in terms of final live weight (kg), average daily weight gain (g) and slaughter yield (%).

The addition of oregano essential oil added to Kivircik lambs diet at amounts of 250 mg/kg and 500 mg/kg resulted in no statistically significant between-group differences in terms of average live weight and average daily weight gain (Unal et al., 2014). According to Aydin et al. (2020), the 52-day daily oral administration of 1 ml and 2 ml oregano

oil to weaned Tuj lambs had no effect on final weight gain, average daily weight gain and feed conversion rate.

Common nettle *(Urtica dioica)*

Ndegwa et al. (2023) reported that the addition of pelleted nettle to the ration of pasture-raised yearling goats for 12 weeks had no effect on live weight gain during the experiment. Although the values in the nettle-supplemented group were slightly higher, they were not significantly different from the control group.

Rahchamani et al. (2019) affirmed that the dry matter intake and weight gain in Dallagh rams were not influenced by the addition of 10% liquorice *(Glycyrrhiza glabra)* and nettle *(Urtica dioica)* powder, but reported a better feed conversion rate (FCR) in comparison to the control group.

No statistically significant differences in relation to dry matter intake, daily weight gain, feed conversion rate and slaughter weight were demonstrated in 120-day-old male Ujumuqin x Han lambs fed concentrate and *Leymus chinensis* hay (1:1), concentrate and hemp nettle *Urtica cannabina* (1:1) or concentrate, hay and nettle (1:0.5:0.5) compared to control animals fed concentrate and roughage (1:1) (Jin et al., 2018). According to the authors, the share of the rumen and small intestine was significantly smaller in lambs fed hemp nettle (1:1) than both controls and lambs fed concentrate, hay and nettle (1:0.5:0.5). The small animal proportion was smaller in animals that received concentrate + hay (1:1) and concentrate + hemp nettle (1:1) in comparison to controls (Jin et al., 2018). The abomasum size was statistically significantly larger in lambs fed concentrate + hemp nettle (1:1) and concentrate + hay + nettle (1:0.5:0.5) than in the other 2 groups (Jin et al., 2018). The different diets had no influence on the proportions of the reticulum (second chamber of the four-chamber ruminant stomach), the third chamber of the ruminant stomach and large intestine (Jin et al., 2018).

Dandelion *(Taraxacum officinale)*

Dietary supplementation of lambs with 50 ml aqueous dandelion extract, fermented cow's milk with lactic acid bacteria or 1:1 mixture of both resulted in significantly greater final live weight compared to the control group (El-Mehanna et al., 2017). The authors found no significant differences in biometric measurements between treated and control groups in relation of pelvic length, tibia length, chest depth, width and circumference, wither height, rump height and body length.

Milk thistle *(Silybum marianum L.)*

The daily addition of 10 g, 20 g and 30 g milk thistle extract to the ration of growing Shami goats for 120 days had a beneficial effect on daily weight gain and final live weight compared to the controls (El Sabaawy et al., 2022).

According to Rayni et al. (2023), the addition of 2% powdered milk thistle seed to the feed of Romanov x Shawl lambs resulted in statistically significant effects in feed conversion, daily weight gain, final weight, meat/bones ratio, hot and cold carcass weight as compared to the control group. Comparable statistically significant positive effects on feed conversion, daily weight gain and final live weight of Shawl x Romanov crosses fed 2% milk thistle seeds were reported by Nasiripour et al. (2024). Dawood (2024) demonstrated improved feed conversion rate in lambs from a local Iraqi sheep breed when its feed was supplemented with 210 mg/kg and 420 mg/kg silymarin, a flavonoid extracted from milk thistle.

Chamomile *(Matricaria chamomilla)*

The addition of 0.5 g and 10 g of chamomile to 100 kg feed of Farafra lambs significantly increased the average daily weight gain in both supplemented groups compared to the controls (Khattab et al., 2021). The authors concluded that the use of chamomile flower as a feed additive had a positive effect on feed conversion rate and average daily weight gain in growing lambs.

The inclusion of 10 g of chamomile flower per 100 kg of feed in the daily diet of Farafra ewes during late pregnancy and throughout the suckling period of the lambs was beneficial for live body weight at birth and weaning, as well as on the overall weight gain of the lambs (Khattab et al., 2018).

The daily addition of 2% dried chamomile flower

per animal to the feed of Awassi lambs improved feed conversion (Al-Hanna et al., 2018).

Sage *(Salvia officinalis)*

The supplementation of Awassi lambs' diet with 5 g and 10 g sage leaves per kg feed improved feed conversion, average daily weight gain, nutrient digestibility and rumen fermentation (Al-Bakhati and Al-Wazeer, 2023). The authors suggested that the positive effect of sage leaves on rumen fermentation was probably due to the content of phenolic compounds and flavonoids.

The addition of 0.12 ml sage extract /kg feed to Chinese Merino lambs for 85 days improved growth performance by increasing feed intake and nutrient utilisation, with statistically significantly grater average daily weight gain in the supplemented vs. the control group of lambs (Ma et al., 2024).

According to Al-Hanna (2022), the inclusion of 1% and 3% sage to the feed per animal for 8 weeks had a positive effect on Awassi lambs by stimulating feed intake and its utilisation.

Effect of dietary supplementation with various herbs on blood parameters of small ruminants

Thyme *(Thymus vulgaris)*

The supplementation of feed of lactating Barki sheep with 20 g thyme increased statistically significantly serum glucose, thyroxine and glutamate-pyruvate transaminase levels (Abd El Tawab et al., 2020).

The addition of 15 g powdered thyme leaves per animal and 15 g mixture of thyme and celery (1:1) to the feed of Barki lambs increased blood thyroxine concentration vs those in control group of lambs (Shaaban et al., 2021). The authors affirmed that these supplements did not influence blood total protein, albumin, globulins and glucose of lambs. The thyme and celery mixture reduced blood total cholesterol and glutamate-oxalacetate transaminase activity in comparison to the untreated control group (Shaaban et al., 2021).

Serum blood metabolites were not affected by the inclusion of 3% thyme to the feed of Sanjabi male lambs at the end of the 90-day fattening period. Blood concentrations of nitrogen, cholesterol, non-esterified fatty acids, beta-hydroxybutyric acid, creatine and creatinine were not affected by the 3% thyme dietary supplement, similarly to aspartate transaminase (AST) and alanine transaminase (ALT), indicating lack of change in fat mobilisation (Khamisabadi et al., 2016).

Cholesterol, non-esterified fatty acids, beta-hydroxybutyric acid and creatinine blood levels were not affected by the addition of 3% thyme to the feed of male Sanjabi lambs while triglycerides, glucose and urea concentrations were significantly lower in lambs whose feed was supplemented with the plant (Khamisabadi et al., 2016).

The addition of 2 ml thyme essential oil /day/ lamb had an obvious effect on blood plasma composition in Barki lambs, with significantly increased concentrations of creatinine, total lipids, low-density lipoproteins (LDL) and total cholesterol compared to controls (El-Essawy et al., 2019). Plasma total protein (TP), albumin, globulins, urea, triglycerides (TG), high-density lipoproteins (HDL), total antioxidant capacity, alanine aminotransferase (ALT), and aspartate aminotransferase (AST) were not affected by thyme essential oil supplementation (El-Essawy et al., 2019).

Oregano *(Origanum vulgare)*

The inclusion of 2.5% dried oregano for 60 days in the diet of Saidi lambs reduced serum glucose, cholesterol, triglycerides and urea concentrations vs those in the control group. The mean serum total protein, globulins, total antioxidant capacity and AST were significantly higher in the group of lambs fed 2.5% dried oregano than in controls (Farghaly and Abdullah., 2021).

No statistically significant differences were demonstrated between Kivircik lambs supplemented with oregano essential oil at a dose of either 250 mg/kg or 500 mg/kg in terms of serum total cholesterol, triglycerides, LDL and HDL cholesterol (Unal et al., 2014).

Total protein, triglycerides and AST levels in blood differed statistically significantly in Merino lambs supplemented with 250 mg/day and 500 mg/day oregano essential oil compared to the controls. The highest total protein level was observed in the

group that received 250 mg/day oregano essential oil on day 45 (5.91 g/dl). Triglycerides and AST levels in the group supplemented with 500 mg/day oregano essential oil exceeded those in the control group (Karakci et al., 2023).

Common nettle *(Urtica dioica)*

Ndegwa et al. (2023) reported that pelleted nettle supplementation of the diet of pasture-raised yearling goats for 12 weeks had the following potential benefits - improvement of haematological parameters, including the haematocrit and serum total protein.

According to Rahchamani et al. (2019), there were no statistically significant differences in plasma total protein, albumin, glucose, triglycerides and cholesterol in male Dallagh sheep fed a dietary supplement of 10% licorice (*Glycyrrhiza glabra*) and 10% nettle (*Urtica dioica)* powder.

Ujumuqin x Han crossbred male lambs fed concentrate and *Leymus chinensis* hay (1:1) concentrate and hemp nettle *Urtica cannabina* (1:1), concentrate, hay and nettle (1:0.5:0.5) and control lambs fed concentrate and roughage (1:1) demonstrated different biochemical parameters in the four groups (Zhang et al., 2021). Blood activities of ALT, AST and LDH were not affected by diet components. Blood albumin was greater in groups fed concentrate and hay (1:1) and concentrate and hemp nettle (1:1) than levels in controls. The groups that received concentrate and hemp nettle (1:1) and concentrate, hay and nettle (1:0.5:0.5) had statistically significantly higher glucose and reduced total cholesterol than the other two groups (fed concentrate and hay 1:1 and controls) (Zhang et al., 2021). The highest triglyceride concentration was detected in the control group, with statistically significant differences in relation to the other three groups. LDL cholesterol was lower in groups fed the experimental feeds compared to controls, but differences were insignificant. No consistent differences were found for the other assayed blood indices (total protein, globulins, urea, HDL cholesterol) (Zhang et al., 2021).

Dandelion *(Taraxacum officinale)*

No effect has occurred on red blood cell counts, haemoglobin content, cholesterol and haematocrit values in Noemi lambs supplemented with 50 ml aqueous dandelion extract, fermented cow's milk with lactic acid bacteria or their 1:1 mixture (prebiotic, probiotic or synbiotic). The white blood cell count was increased in the groups receiving these supplements compared to the control. Blood serum glucose in the probiotic and synbiotic groups was also increased compared to the control group, and the concentration in the prebiotic group was intermediate. There was a tendency towards increased blood serum insulin in the prebiotic and probiotic groups compared to the control one. However, lambs that received the synbiotic had significantly greater blood insulin and IGF-I levels compared to the other groups (El-Mehanna et al., 2017).

Milk thistle *(Silybum marianum L.)*

The daily administration of 10 g, 20 g and 30 g milk thistle extract for 120 days per animal in growing Shami goats increased the concentrations of glucose, total protein, urea and creatinine and at the same time the activities ALT and AST were significantly reduced (ElSabaawy et al., 2022). According to the authors, the supplementation with high levels of milk thistle extract may alter the chemical composition of blood, which could improve growth performance and digestibility of nutrients.

The addition of 2% milk thistle seeds to the ration did not affect the blood concentrations of glucose, urea nitrogen, creatinine or total protein in Shawl x Romanov lambs, but resulted in a statistically significant reduction in total and LDL cholesterol (Nasiripour et al., 2024). The addition of 210 mg/kg and 420 mg/kg silymarin to the feed improved the haematological and blood biochemical parameters by reducing triglycerides and cholesterol in lambs from a local Iraqi sheep breed (Dawood, 2024).

Chamomile *(Matricaria chamomilla)*

The addition of 0.5 g and 10 g of chamomile to 100 kg of feed had a positive effect on most blood parameters of Farafra lambs (haemoglobin, total protein, globulin, glucose and triglycerides) whereas serum creatinine, cholesterol and enzyme

activities were higher in lambs fed the control ration compared to the two chamomile-supplemented groups (Khattab et al., 2021).

Sage *(Salvia officinalis)*

The addition of 0.12 ml/kg sage extract to the feed of Chinese Merino lambs for 85 days enhanced the immune response by increasing immunoglobulin and cytokinin concentrations and improved the antioxidant status by increasing the antioxidant enzymes' activities (Ma et al., 2024).

The inclusion of 1% and 3% sage per animal for 8 weeks in Awassi lambs' ration had a positive effect expressed by stimulation of the immune system through its antibacterial, antiviral, anti-inflammatory and antioxidant properties (Al-Hanna, 2022).

Effect of dietary supplementation with various herbs on the quality of small ruminants' meat

Thyme *(Thymus vulgaris)*

The supplementation of Barki lambs' feed with 15 g thyme increased significantly the area of *m. longissimus,* whereas the mixture of equal parts of thyme and celery in addition to greater *m. longissimus* area, increased also the fat thickness in the chest area compared to the control group (Shaaban et al., 2021). According to the authors, thyme increased the lean meat proportion and reduced the proportion of fat. The inclusion of thyme and a celery and thyme combination reduced meat protein content and meat brightness score, while the supplementation with thyme alone and with the thyme + celery combination increased the water holding capacity of the carcass (Shaaban et al., 2021).

In Barki lambs, no statistically significant differences were demonstrated between the experimental group receiving 2 ml/day/lamb of thyme essential oil and the control group regarding main carcass traits, e.g. slaughter weight, carcass weight and rib area, as well as the chemical composition of *m. longissimus lumborum.* This proved that the addition of 2 ml/day/lamb of thyme essential oil had no effect on carcass traits (El-Essawy et al., 2019).

To investigate the effect on lamb meat characteristics, Segurena sheep were supplemented with thyme leaves during pregnancy and lactation (Nieto et al., 2012). One of the groups was offered a basal feed, while the other two groups were fed a diet where 3.75% and 7.5% of the basal feed were replaced with thyme leaves. The addition of thyme leaves had no significant effect on meat moisture content and pH values (Nieto et al., 2012). Significant differences between the thyme-supplemented and control groups were observed in terms of meat protein and fat contents (Nieto et al., 2012). The control meat samples showed a significantly lower protein content than the experimental ones. In contrast, the fat percentage was higher in the thyme-supplemented meat samples (Nieto et al., 2012). The inclusion of thyme leaves in sheep ration reduced the percentage of saturated fatty acids (SFA) and the saturation index (S/P), the atherogenic (AI) and thrombogenic (IT) indices. In addition, the levels of polyunsaturated fatty acids (PUFA) and unsaturated fatty acids (UFA) in fresh lamb meat were significantly greater (Nieto et al., 2012). For these reasons, the authors recommended the inclusion of thyme leaves in the feed of ewes during pregnancy and lactation to improve the health value of lamb meat through fat profile modification and protection from lipid oxidation.

Most intramuscular saturated fatty acids (SFA) of Barki lambs were not affected by the dietary addition of 2 ml/day/lamb of thyme essential oil, with the exception of stearic acid, which was significantly reduced in the experimental group (El-Essawy et al., 2019). Vaccenic acid and total MUFA concentrations were increased in lambs supplemented with 2 ml/day/lamb of thyme essential oil. The percentage of total omega-3 fatty acids (PUFA n-3) was increased, while total omega-6 fatty acids (PUFA n-6) decreased significantly in the group fed 2 ml/day/lamb of thyme essential oil (El-Essawy et al., 2019).

Oregano *(Origanum vulgare)*

The effect of a concentrated feed uniformly sprayed with 1 ml/kg oregano essential oil on meat

quality of Chios lambs was investigated by Simitzis et al. (2008). The tenderness of the *m. longissimus thoracis* expressed through the sarcomere length and value of shear force was not affected by the addition of 1 ml/kg of oregano essential oil, while the meat pH and colour characteristics in the yellow-red quadrant appeared to increase. The results also evidenced that the inclusion of 1 ml/kg oregano essential oil in the feed had a strong antioxidant effect, by delaying meat lipid oxidation during cool and long-term frozen storage (Simitzis et al., 2008).

The oregano essential oil dietary supplement (300 mg/day) did not affect carcass traits and meat quality in fattening Menemen lambs (Ile de France x Kıvırcık). However, compared to female lambs, males had greater slaughter weight, warm carcass weight, cold carcass weight and yield, while having thinner backfat (Unlu et al., 2023). Moreover, the addition of 300 mg/day of oregano essential oil to the feed increased significantly intramuscular fat. The dry matter, protein, pH24, meat colour (L*, a* and b*), drip loss and cooking loss were not influenced by either the addition of oregano essential oil to the feed or lambs' sex. In a consumer test, the meat of female lambs was more preferred in terms of taste and overall acceptance (Unlu et al., 2023). The inclusion of 0.3 g/kg oregano essential oil in the diet of Dorper x Pelibuey lambs increased lamb meat tenderness and preserved the meat colour after 7-day storage (Garcia-Galicia et al., 2020). According to the authors, the added oregano essential oil has significantly affected the fatty acid profile, increasing the meat content of C16:1n7, C18:1n9c, C20:1n9 and C18:2n6.

Common nettle *(Urtica dioica)*

No significant differences in carcass traits were demonstrated between experimental groups of male Ujumuqin x Han crossbred lambs fed concentrate and *Leymus chinensis* hay (1:1), concentrate and hemp nettle *Urtica cannabina* (1:1) or concentrate, hay and nettle (1:0.5:0.5), compared to control lambs that received feed concentrate and roughage (1:1). Pre-slaughter live weight, hot and cold carcass weights were similar for all four different diets, and lambs had similar longissimus thoracis muscle area (Zhang et al., 2021).

The proportion of total saturated fatty acids (SFA) was lower in the concentrate, hay and nettle (1:0.5:0.5) and concentrate and hemp nettle (1:1) groups compared to the controls, while the concentrate and hay (1:1) group did not differ from the other three groups (Zhang et al., 2021). The amount of C15:0 was greater in the concentrate and hemp nettle (1:1) group compared to controls, and in the other two groups the values of this indicator were intermediate (Zhang et al., 2021). The concentrate and hemp nettle (1:1) and concentrate, hay and nettle (1:0.5:0.5) groups had significantly lower meat C16:0 content than the controls. The concentrate and hay (1:1) group showed insignificant differences in comparison to the other three experimental groups (Zhang et al., 2021). The authors found no significant differences in the other saturated fatty acids. The MUFA level was lower for the groups fed 1:1 concentrate and hemp nettle and 1:0.5:0.5 concentrate, hay and nettle than in control lambs. The animals receiving 1:1 concentrate and hemp nettle and 1:0.5:0.5 concentrate, hay and nettle had a higher content of C9-14:1, respectively a lower amount of C9-18:1, than controls (Zhang et al., 2021). The meat PUFA content was the highest for the concentrate and hemp nettle (1:1) and concentrate, hay and nettle (1:0.5:0.5) groups, the lowest for the control group and intermediate for the concentrate and hay (1:1) group with statistically significant between-group differences (Zhang et al., 2021). According to the same authors, the proportion of meat C 18:2n-6 was greater in lambs fed diets with concentrate and hemp nettle (1:1), concentrate and hay (1:1) and concentrate, hay and nettle (1:0.5:0.5), compared to animals fed the control feed. Lambs fed the 1:1 concentrate and nettle diet had a higher proportion of C9, t11-CLA compared both to those fed 1:1 concentrate and hay and the control diet (Zhang et al., 2021). Animals that received the 1:1 concentrate and nettle and 1:0.5:0.5 concentrate, hay and nettle diets had the highest percentage of C18:3n-3, lambs fed the 1:1 concentrate and hay diet - an intermediate value, and control lambs - the lowest value (Zhang et al., 2021). Lambs fed 1:1 concentrate and nettle, 1:1 concentrate and hay, and 1:0.5:0.5 concentrate, hay, and nettle rations

had higher meat content of eicosapentaenoic (C20:5n-3, EPA) and docosahexaenoic acids (C22:6n-3, DHA) than controls with insignificant differences between the three experimental dietary groups (Zhang et al., 2021). The highest PUFA:SFA ratio was observed in the concentrate and nettle (1:1) and concentrate, hay, and nettle (1:0.5:0.5) groups. In the concentrate and hay group (1:1) PUFA:SFA ratio was intermediate and the lowest – in the control group. Lambs fed concentrate and hemp nettle (1:1), concentrate and hay (1:1) and concentrate, hay and nettle (1:0.5:0.5) diets had a significantly lower n-6:n-3 ratio than controls without consistent differences between the first three groups.

Chamomile *(Matricaria chamomilla)*

Awassi lamb feed's supplementation of 2% chamomile flower meal per lamb improved meat lightness L*, while the daily addition of 6% per lamb reduced the meat drip losses (Al-Hanna et al., 2018).

Sage *(Salvia officinalis)*

The addition of 1% and 3% sage to the ration of Awassi lambs for 8 weeks showed no statistically significant differences in meat quality regarding meat pH, drip losses, cooking losses and meat tenderness (Al-Hanna, 2022).

Recapitulation of findings

The addition of thyme or thyme essential oil to the diet of lambs and sheep increases feed intake and digestibility of nutrients, improves some blood parameters and has a beneficial effect on the meat quality in animals of this species and categories.

Despite the improved feed digestibility reported by some authors, the addition of oregano or oregano essential oil to the ration of lambs does not affect significantly their growth performance. However, in experiments with fattening lambs most authors report significant differences in some blood parameters. The antioxidant effect of meat is improved, which leads to slower oxidation of lipids and a longer shelf-life; the content of several fatty acids in the meat, e.g. C16:1n7, C18:1n9c, C20:1n9 and C18:2n6, is also increased.

The administration of nettle as a dietary additive for small ruminants does not have a significant effect on their growth performance. No significant differences were found in the carcass traits and the *longissimus thoracis* muscle area in lambs receiving or not a nettle supplement. The effect of nettle as a feed additive on blood parameters in small ruminants is controversial, as some authors do not find significant differences, while others do. For example, higher blood albumin and glucose, and lower total cholesterol, triglycerides and LDL cholesterol concentrations are reported. The SFA and MUFA amounts are lower in the groups receiving nettle as a dietary supplement, and the content of PUFA is the highest in these groups, respectively. Lambs fed nettle-supplemented feeds have a lower n-6:n-3 ratio.

The addition of dandelion to fattening lambs' feed affects positively the growth performance by increasing live body weight and modifying the intestinal microbiota, therefore some authors recommend the use of dandelion in feed as an alternative to nutritional antibiotics used in the past. An increase in white blood cell count, blood serum glucose and insulin levels is reported after dandelion supplementation of lambs' feed.

In the available literature, there are no data on the effect of dandelion feed additive on meat quality in small ruminants.

Milk thistle has a positive effect on feed conversion, average daily weight gain, final live weight, meat/bone ratio, hot and cold carcass weight in small ruminants, attributed by the authors to the flavonoid silymarin. The addition of milk thistle to goats' diet increases blood glucose, total protein, urea and creatinine concentrations and reduces the ALT and AST activities. Other authors affirm that when included in lamb feed, milk thistle does not affect the levels of glucose, urea nitrogen, creatinine or total protein in blood, yet leads to a statistically significant reduction in total cholesterol and LDL cholesterol concentrations. Despite the conflicting results for some of the blood parameters, most authors agree that the addition of milk thistle (silymarin) to feed improves haematological and

blood biochemical parameters. The literature does not provide any data regarding the effect of milk thistle on the quality of small ruminant meat.

The supplementation of lambs' feed with chamomile increases significantly live weight at birth and weaning, total weight gain, average daily weight gain and feed conversion. Chamomile added to lamb feed has a positive effect on most blood parameters (hemoglobin, total protein, globulin, glucose and triglycerides). It also improves the meat lightness L* and reduces drip loss.

The addition of sage as a lamb feed supplement improves growth performance, feed intake and feed conversion, average daily weight gain, nutrient digestibility and rumen fermentation. Dietary sage stimulates the immune system of lambs through its antibacterial, antiviral, anti-inflammatory and antioxidant properties, enhances the immune response by increasing immunoglobulin and cytokinin concentrations and improves antioxidant status by increasing antioxidant enzymatic activities. The inclusion of sage in lamb feed has no statistically significant impact on meat quality in terms of pH, colour, drip loss, cooking loss and meat tenderness.

Conclusion

The purpose of animal husbandry, sheep and goat farming in particular, is the cost-effective rearing of healthy animals that produce high-quality and safe animal products for human consumption. In this connection, herbs and spices should be considered not only as appetisers and digestives, but also as regulators of physiological processes, health status, welfare and productivity of animals. Last but not least, they often influence the quality of meat produced from animals. So far, research studies present promising results on the use of various herbs and spices as growth promoters, for improvement of health status and the quality of sheep and goat meat. The literature overview has shown that these studies are still incomplete (for example there are no data on the influence of dandelion and milk thistle on the quality of meat in sheep and goats). Of course, there are still many types of herbs that have not been explored, nor are their effects on animals elucidated when mixed in different ratios. Although the phytochemical composition of many herbs is already established, the mechanisms of their action in different animal species and categories, as well as the appropriate amount for their administration are not yet entirely clarified.

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