Chapter 17

The Use of Medicinal and Aromatic Plants in Livestock Production and Their Phytochemical Effects

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Abstract

The use of medicinal and aromatic plants in animal husbandry and veterinary practice is increasingly recognised for their phytochemical richness and as sustainable alternatives to synthetic antibiotics. This review examines their roles as functional feed additives; stimulating appetite, promoting growth, combating bacterial, viral, and parasitic infections, and enhancing meat quality and aroma. In addition to these applied benefits, the active compounds in these plants modulate gene expression and transcriptomic pathways, thereby influencing metabolism, immunity, and muscle development. Growing concerns about antibiotic residues in animal products further underscore their significance. By integrating medicinal and aromatic plants into livestock feeding strategies, both productivity and welfare may be improved. This review highlights key chemical constituents, their molecular mechanisms, and implications for livestock production systems, proposing that such integration offers a promising, health-conscious, and environmentally relevant approach to modern animal production.

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1. Introduction

The valuable bioactive compounds of secondary metabolites also find applications in the livestock sector. The rapid growth of the global population continuously increases the demand for animal products, which directs the livestock industry towards innovations focused on productivity and sustainability. However, ensuring sustainability in production and maintaining animal health have become challenging, particularly due to the prolonged and uncontrolled use of antibiotics, which causes various issues (Gadde et al. 2017). In particular, the European Union's ban on antibiotics as feed additives in 2006 necessitated the exploration of natural and safe alternatives in the sector (Castanon, 2007).

In this context, medicinal and aromatic plants have gained prominence; due to their antibacterial, antioxidant, antiviral, and digestive-regulatory properties, they have been increasingly used to support animal health and enhance production performance (Windisch et al. 2008). The effects of medicinal and aromatic plants on important parameters such as meat quality, growth, development, and gene expression are being increasingly investigated across different animal species.

In ruminants, particularly cattle, sheep, and goats, the use of medicinal and aromatic plants supports feed efficiency through enhanced digestive functions, optimizes growth rates, and strengthens immune responses (Hashemipour et al. 2013a). In large animals with sensitive digestive systems, such as horses, these plants are particularly important for supporting digestion and immunity. Variations in metabolic characteristics and nutritional requirements among different breeds create diversity in the dosage and composition of these herbal additives (Srinivasan, 2016). Additionally, biological responses can vary across breeds. In poultry, especially chickens, medicinal and aromatic plants have been reported to positively affect growth performance, feed conversion ratio, and limb and claw health. Their effects may vary among different production-oriented breeds, such as broilers and laying hens (Brenes and Roura, 2010). The effects of bioactive compounds are evident in the development of muscle and adipose tissue, which are directly related to growth performance and meat quality. Medicinal and aromatic plants improve microbial balance in the digestive system, enhance nutrient absorption, and support gut health (Hashemipour et al. 2013b; Liu et al. 2020). This not only increases feed efficiency but also strengthens immune system functions (Windisch et al., 2008). Furthermore, certain plant compounds exert regulatory effects on the endocrine system, influencing the expression of growth-related hormones

and genes (e.g., IGF-1, mTOR, MyoD), resulting in positive effects on muscle and adipose tissue development (Liu et al. 2020).

These biological effects allow medicinal and aromatic plants to be considered in animal production systems not only as performance enhancers but also as natural health-supporting agents (Maqsood et al. 2014; Hashemi and Davoodi, 2012).

This review examines their roles as functional feed additives—stimulating appetite, promoting growth, combating bacterial, viral, and parasitic infections, and enhancing meat quality and aroma. In addition to these applied benefits, the active compounds in these plants modulate gene expression and transcriptomic pathways, thereby influencing metabolism, immunity, and muscle development.

2. Use of Medicinal and Aromatıc Plants in Anımal Feeding: Impacts on Physiology, Health and Performance

The use of medicinal and aromatic plants (MAPs) in animal feeding is not limited to enhancing nutritional value but also exerts multifaceted effects on overall physiology and health. Particularly, these plant-based components, when included in diets, influence numerous biological processes in animals, ranging from feed utilization efficiency via digestive system regulation to modulation of hormonal balance and gene expression (Hashemi and Davoodi, 2012; Windisch et al., 2008; Greathead, 2003). The following sections provide a detailed evaluation of these effects in a holistic approach.

2.1. Effects on the Regulation of the Digestive System and Feed Utilization

The healthy and efficient functioning of the digestive system in animals is among the key factors directly influencing growth. Volatile compounds such as carvacrol, thymol, and cinnamaldehyde, present in medicinal and aromatic plants (MAPs), enhance the activity of digestive enzymes, thereby improving the digestion of proteins and carbohydrates (Windisch et al., 2008). The ability of plant compounds to modulate microbial balance is critical for maximizing feed utilization (Ribeiro-Santos et al., 2015). The efficacy of these natural feed additives varies depending on animal species, breed, and diet composition, highlighting the importance of optimizing application doses (Wang et al., 2020). A meta-analysis in cattle by Benchaar et al. (2008) review evaluates the potential of plant-derived essential oils (EOs) as natural alternatives to antibiotics in response to growing concerns over antibiotic use in livestock production. Essential oils contain secondary

metabolites such as thymol, carvacrol, eugenol, and cinnamaldehyde, which possess antimicrobial properties and can modulate rumen microbial activity, thereby improving protein and energy utilization. In vitro studies have shown that EOs can reduce amino acid deamination and ammonia formation in the rumen, and certain components may also inhibit methane production. However, long-term in vivo studies indicate that rumen microbes may adapt to EOs, leading to diminished effects over time. The ability of EOs to alter rumen fermentation patterns in a manner similar to ionophore antibiotics (e.g., decreasing the acetate-to-propionate ratio) is considered beneficial for feed efficiency. Moreover, EOs have demonstrated strong bactericidal activity against foodborne pathogens such as E. coli O157:H7 and Salmonella spp. Nonetheless, identifying optimal doses that enhance rumen function without inhibiting overall fermentation and ensuring sustained efficacy remain major challenges. In conclusion, essential oils are promising natural feed additives that may enhance feed efficiency, reduce nitrogen and methane emissions, and help control pathogenic bacteria in ruminant production. Further in vivo research is required to clarify dose-response relationships, microbial adaptation mechanisms, and the long-term impacts of EO supplementation. Some in vitro studies suggest that aromatic plant essential oils (including fennel) may enhance rumen microbial protein synthesis or improve digestibility, though quantitative effects and consistent in vivo validation remain limited (Zhao et al. 2020). These plants are also significant for environmental sustainability due to their methane-reducing potential. Tannin-containing extracts can reduce ruminal protein degradation and thereby increase the flow of undegraded (bypass) protein to the small intestine; several meta-analyses and trials report improved nitrogen utilization with low-to-moderate tannin levels, although the magnitude of effects varies by tannin type, dose, and animal/breed (Jayanegara et al. 2019). Dietary supplementation with ginger (Zingiber officinale) has been shown to improve growth performance and feed efficiency in livestock and poultry. In broiler chickens, Hashemipour et al. (2013c) reported improved body weight gain and feed conversion ratio, whereas studies in small ruminants such as Awassi sheep have shown variable or modest effects depending on dose, duration, and diet composition. The study investigated the effects of a 10% aqueous garlic solution on parasitic infestation, live weight, and hematological parameters in Black Bengal goats. Garlic supplementation significantly reduced fecal egg counts while improving live weight gain and blood parameters (TEC, Hb, PCV). The findings suggest that garlic can serve as a natural antiparasitic and health-promoting feed additive for goats (Hasan et al., 2015). Similarly, cumin (*Cuminum cyminum*) and fennel

essential oils in Suffolk sheep increased body weight gain by 10% and total protein synthesis by 7%, while also improving liver function (Khan et al., 2021a). Thyme and clove (*Syzygium aromaticum*) essential oils in sheep diets increased growth rate by 9% on average and enhanced digestive enzyme activities by 15% (Al-Mamun and Islam, 2021).

In a study evaluated the effects of fennel and ginger supplementation on nutrient digestibility and milk production in 15 early-lactation Egyptian buffaloes. Both supplements did not influence feed intake but significantly improved the digestibility of dry matter, organic matter, crude protein, and fiber. Fennel and ginger increased milk yield and energy-corrected milk, as well as milk fat concentration and overall milk energy output. The supplements did not adversely affect blood biochemical parameters and reduced somatic cell count, indicating improved udder health. Overall, daily supplementation with 75 g of fennel or ginger enhanced milk productivity and quality, with fennel demonstrating a greater improvement in the nutritive value of milk (Fahim et al., 2022). In Niger, supplementation of laurel and fennel oils in Sahel goats increased growth rate by 11% and feed utilization by 8% (Oke et al., 2021). Studies in Alpine and Saanen goats demonstrated that ginger and cumin essential oils optimized rumen fermentation, increasing feed utilization by 6–9% (Hasan et al., 2024). According to Zakeri et al. (2014), supplementation of fresh garlic at levels of 30–70 g/kg on a dry-matter basis for 14 days may reduce milk fat content in goats by influencing acetate production in the rumen. Indeed, several researchers (Kongmun et al., 2011, Kholif et al., 2012) have shown that garlic derivatives exert an inhibitory effect on acetate formation. Similarly, administering 2 mL/day of garlic oil to lactating goats for three months has been reported to provide comparable beneficial effects (Kholif et al., 2012). In addition, supplementation of garlic at 20 g/kg (DM) for approximately five months in sheep (El-Shereef, 2019) led to an increase in conjugated linoleic acid (CLA) and omega-3 fatty acids—nutrients of particular importance for human health—in milk (Cavaliere et al., 2018; Trinchese et al., 2019). Likewise, Yang and He (2016) reported that adding 5 g/day of garlic oil to dairy cow diets for three weeks elevated the cis-9, trans-11 CLA content of milk; this fatty acid possesses anti-inflammatory, anti-diabetic, and anti-tumor properties (Tudisco et al., 2019; Thanh et al., 2021). Overall, the use of different forms of garlic across studies has contributed to considerable variation in outcomes. Standardization of garlic products would therefore be beneficial for determining the most appropriate dose and formulation aimed at improving ruminant milk quality. In poultry, research on the Ross 308 broiler strain, widely used in commercial meat production, has shown

that oregano and thyme essential oils improve feed conversion by 7–10% and enhance gut microbiota (Hashemipour et al. 2013a). In Bovans White chickens, rosemary (*Rosmarinus officinalis*) essential oil reduced feed intake while improving feed efficiency, altered yolk fatty acid composition, and modulated gut microflora (Kılıç, 2022).

2.2. Effects on the Immune System

The immune system is critical for sustaining growth. The antimicrobial and anti-inflammatory properties of medicinal and aromatic plants (MAPs) help reduce the risk of infections, thereby supporting animal health. Numerous studies have demonstrated that these plants, through their antioxidant and immunomodulatory effects, enhance immune function and mitigate oxidative stress. Research across various animal species—including cattle, sheep, goats, poultry, and horses—indicates that MAPs contribute both to health maintenance and productivity improvement.

In cattle, particularly beef breeds, essential oils derived from plants such as thyme (*Origanum vulgare*) and clove (*Syzygium aromaticum*) have been reported to enhance immune function, increase total antioxidant capacity, and balance liver enzyme activities (Michiels et al. 2010; Hashemipour et al. 2013a). Tassou et al. (2007) reported that dietary sage supplementation in sheep increased serum immunoglobulin G (IgG) levels by 15%.

In poultry, diets containing essential oil blends have been shown to reduce inflammatory cytokines by 20%, resulting in an 8–10% improvement in growth performance. Numerous studies in broiler chickens indicate that supplementation with thyme oil, garlic (*Allium sativum*) extract, ginger (*Zingiber officinale*), and cinnamon (*Cinnamomum zeylanicum*) enhances immune cell activity, lowers disease incidence, and limits oxidative damage (Brenes and Roura, 2010; Gadde et al. 2017). In species with more sensitive digestive systems, such as horses, the use of plants like Echinacea purpurea, fennel (*Foeniculum vulgare*), and thyme is recommended to support immune function. Their use has been associated with lower infection rates and more balanced blood parameters, particularly in performance horses (Srinivasan, 2016).

2.3. Effects on the Hormonal Regulation and Gene Expression

In recent years, medicinal and aromatic plants (MAPs) have been shown to exert effects in animal organisms not only at the macroscopic or biochemical levels but also at the molecular level. These molecular effects are particularly elucidated through gene expression and transcriptomic analyses.

By modulating metabolic pathways, components of the immune system, and muscle development at the genetic level, MAPs have the potential to enhance both product yield and animal welfare. Focusing on the epigenetic and transcriptomic effects of specific MAP compounds on the animal genome is of great importance for sustainable animal production and functional feed strategies (Luo et al. 2020; Wang et al. 2020).

Plants such as thyme (*Thymus vulgaris*), sage (*Salvia officinalis*), rosemary (Rosmarinus officinalis), peppermint (*Mentha piperita*), summer savory (*Satureja hortensis*), and ginger (*Zingiber officinale*) can positively influence gene expression in animals due to their antioxidant, anti-inflammatory, and immunomodulatory properties.

Similarly, the use of summer savory led to positive changes in anti-inflammatory gene expression and modulated immune responses (Jahanian and Ashnagar, 2015). Broiler chickens supplemented with thyme exhibited significant upregulation of antioxidant defense genes, including superoxide dismutase (SOD1), catalase (CAT), and glutathione peroxidase (GPX), demonstrating the efficacy of thyme compounds in combating oxidative stress (Khan et al. 2021b). In broilers supplemented with ginger, the expression of pro-inflammatory genes TNF-α and IL-1β decreased, while antioxidant gene expression increased (Ali et al. 2020). In pigs, Wang et al. (2020) demonstrated that plant extracts, including capsicum oleoresin, garlic, and turmeric, modulated the expression of immune-related genes in alveolar macrophages under PRRSV infection, thereby influencing the infection response. This suggests that MAPs can trigger protective mechanisms against infectious diseases at the genetic level. In sheep supplemented with sage, regulatory effects on inflammation-related cytokines (IL-6, TNF-α, IFN-γ) were reported, providing positive modulation of the immune system (Morales-Martínez et al. 2020). In cattle, rosemary extract increased the expression of PPARγ and FABP4, genes related to energy and lipid metabolism, contributing to improved meat quality (Wang et al. 2020). Similarly, gene expression analyses in Wagyu and Holstein cattle have shown significant differences in PPARγ and FABP4 expression levels, genes involved in lipid metabolism, suggesting that these genetic variations are associated with breed-specific differences in meat quality (Wang et al. 2020).

MAPs have also been reported to regulate the release of growth-related hormones and gene expression. Compounds such as capsaicin were found to increase growth hormone (GH) and insulin-like growth factor-1 (IGF-1) levels by 12–15%, supporting protein synthesis (Jin et al. 2016). Additionally, their anti-inflammatory effects promote the activation of genes associated

with muscle tissue repair and development. Experiments in broilers showed that essential oil blends increased the expression of genes related to muscle development by 10–12% (Cross et al. 2007). In a study examining the effects of dietary fennel essential oil (FO) on growth performance, antioxidant status, inflammatory responses, and liver histopathology in heat-stressed broiler chickens. FO supplementation, particularly at 3 g/kg, improved body weight gain and feed conversion ratio compared with the positive control and paracetamol groups. It also enhanced antioxidant enzyme activities, reduced MDA and pro-inflammatory cytokines, and downregulated hepatic IL1-β and TGF-β expression. Overall, 3 g/kg FO effectively mitigated the negative impacts of heat stress and improved growth and physiological responses in broilers (Amer et al., 2025).

2.4. Effects on Muscle and Adipose Tissue

Carcass quality, one of the key indicators of growth performance, is directly associated with the development of muscle and adipose tissues. Phenolic compounds present in medicinal and aromatic plants (MAPs) can modulate lipid metabolism, leading to favorable changes in fatty acid profiles. Specifically, studies have shown that MAPs can increase the proportions of omega-3 and polyunsaturated fatty acids; thereby enhancing both the nutritional value and palatability of meat. In addition, these compounds help preserve muscle protein structure, reducing tissue hardness and consequently improving meat quality and consumer satisfaction (Patra and Yu, 2014).

Studies in cattle breeds such as Holstein and Angus have demonstrated that the use of MAPs positively affects fatty acid profiles and antioxidant capacity (Michiels et al. 2008). In sheep, rosemary extract supplementation was reported to improve meat tenderness and flavor characteristics (Tassou et al. 2007). Rosemary (*Rosmarinus officinalis*) is well known for its antioxidant and antimicrobial properties. In cattle, rosemary extract supplementation was found to enhance the expression of genes related to energy and lipid metabolism, contributing to improved meat quality (Wang et al. 2020).

The study investigated the effects of thyme oil, acetic acid, and their combination (each at 2%) on the quality and shelf life of raw beef stored at 4 °C. Treatments with either thyme oil or acetic acid individually reduced pH, TVBN, TBARS, and aerobic plate counts compared with the untreated control, thereby slowing chemical and microbial spoilage. The combined treatment exhibited the strongest preservative effect, maintaining acceptable sensory attributes and microbial quality up to 15 days of storage. Across all treated groups, lipid oxidation and nitrogenous compound formation were

substantially lower than in the control samples. Overall, the findings indicate that thyme oil and acetic acid—especially when applied together—can serve as effective natural preservatives to extend the shelf life and improve the quality of raw beef meat (El Asuoty et al., 2023).

In poultry, especially broilers, essential oils from thyme (*Thymus vulgaris*) and summer savory (*Origanum vulgare*) have been shown to enhance meat quality. These essential oils positively influenced pH, color, and water-holding capacity, reduced lipid peroxidation, and improved microbial stability. Sensory panelists described meat from essential oil-supplemented groups as "fresh," "clean," and "pleasantly herbal," whereas control group meat exhibited slight rancidity. While the fatty acid composition, particularly unsaturated fatty acids, increased, no significant change in total fat content was observed. Zaazaa et al., (2022) reported that the effects of thyme and oregano essential oils, individually or in combination, on broiler growth performance, health parameters, and the prevalence of growth-related breast muscle abnormalities. Oregano oil supplementation resulted in the greatest improvements in body weight gain and feed conversion efficiency, while thyme oil also produced moderate performance benefits. However, the inclusion of either essential oil, alone or combined, markedly increased the incidence of white striping and wooden breast myopathies. No significant effects were observed on immune responses, as Newcastle disease antibody titers and interferon-γ levels remained comparable to the control group. Overall, although essential oils enhanced growth performance, their association with increased muscle abnormalities warrants careful consideration in broiler production systems.

Consumer acceptance of animal products is largely influenced by sensory attributes, especially meat aroma and flavor quality. The inclusion of MAPs in animal diets affects not only the physical and chemical properties of meat but also its aromatic profile and overall sensory quality. Meat sensory quality, determined by color, texture, water-holding capacity, aroma, and taste, is closely linked to animal nutrition. In this context, phenolic compounds, flavonoids, terpenoids, and essential oils in MAPs can directly influence the aromatic and sensory characteristics of meat (Mandal et al., 2021; Maqsood et al., 2014). Sheep and goat meat can face limitations in consumer acceptance due to their characteristic "gamey" aroma. To mitigate these undesirable aromatic traits, dietary supplementation with MAPs has been investigated. In goats, supplementation with thyme and fennel essential oils altered the aromatic compounds in meat, increasing the levels of more pleasant odor-active compounds such as linalool and α-terpineol. These changes were reported to suppress undesirable animal odors (Mandal et al. 2021). In a

sensory evaluation of sheep meat, the addition of garlic and thyme extracts to diets resulted in meat that was reported to be more tender, juicy, and aromatic. Taste panelists particularly noted that meat from this group had a "fresh and mildly herbal" flavor (Özkan et al. 2020). Hashemipour et al. (2013b) reported that the use of thyme oil in broiler diets reduced malondialdehyde (MDA) levels by 25%, leading to a 5–7% improvement in meat quality and growth rate.

2.5. Effects on Animal Health

Animal health and welfare are among the primary priorities in modern livestock production, with the rise of antibiotic resistance being one of the most significant challenges in these fields. The prolonged and uncontrolled use of antibiotics as growth promoters has facilitated the development of antimicrobial-resistant pathogens, posing a substantial threat to both animal and public health (Mathew et al. 2007). Consequently, many countries, particularly within the European Union, have banned such practices, leading to increased interest in and demand for alternative, natural feed additives (Hashemi and Davoodi, 2011). In this context, medicinal and aromatic plants (MAPs) have emerged as natural products with diverse pharmacological effects due to their bioactive constituents, including phenolic compounds, flavonoids, alkaloids, tannins, and essential oils. These compounds support the immune system of animals through their antiviral, antifungal, antibacterial, and antioxidant activities, thereby contributing to the control of infectious diseases and providing protection against pathogenic microorganisms (Burt, 2004; Windisch et al. 2008).

The effects of garlic extract on animal health were investigated by Hashemipour et al. (2013), focusing particularly on beef cattle. In this study, a total of 30 Holstein and Angus cattle were used, and garlic extract supplementation was found to enhance the activity of immune cells and strengthen resistance against infections. These results indicate that garlic extract acts as an immune modulator in cattle, helping to reduce the risk of infections.

Sage (*Salvia officinalis*), known for its antiviral and antibacterial properties, was shown by Tassou et al. (2007) to increase serum immunoglobulin G (IgG) levels in sheep, thereby enhancing immune function.

3. Conclusion

The use and research of medicinal and aromatic plants (MAPs) in animal husbandry and health are increasing day by day. With the advancement of modern feeding techniques, alternative feeding programs have emerged. Consequently, in recent years, MAPs have gained attention in animal nutrition, contributing significantly to enhancing the taste and flavor of animal products and addressing various nutritional challenges. By exhibiting prebiotic effects, MAPs promote the proliferation of beneficial bacteria and regulate microbial balance, thereby enhancing the activity of digestive enzymes. This contributes to improved gut health, increased feed utilization efficiency, and enhanced growth performance. Due to their bioactive constituents, these plants influence physiological systems in animals and exert multiple effects on these systems. When used as feed additives or incorporated into rations, they demonstrate antioxidant, antifungal, antimicrobial, immunomodulatory, and digestive-regulatory properties, serving both supportive and therapeutic purposes in livestock production. Such effects are particularly valuable in animal production systems aiming to reduce antibiotic use. Certain plant-derived compounds possess the potential to modulate the activity of specific genes at the molecular level, producing significant impacts on muscle development, metabolic processes, and stress responses. Additionally, they can play a regulatory role in the endocrine system, helping to balance hormone levels. To maximize the economic and health-related benefits of MAPs in animal production, careful consideration must be given to the plant species, dosage, duration of administration, and the animal species involved. It is also important to note that high doses of some of these plants may exert toxic effects on animals.

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