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Alternatives to Antibiotics in Livestock Farming: Phytotherapy, Probiotics and Organic Acids

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Abstract

The massive and sometimes inappropriate use of antibiotics in livestock farming has encouraged the emergence of antimicrobial resistance (AMR), posing a major threat to animal, human and environmental health. In the global fight against AMR, the search for effective, safe and sustainable alternatives to antibiotics is becoming a priority. This review looks at three promising alternatives: phytotherapy, probiotics and organic acids.

Firstly, phytotherapy is based on the use of medicinal plant extracts with antimicrobial, anti-inflammatory, immunostimulant and antioxidant properties. Certain species, such as *Azadirachta indica*, *Allium sativum* and *Thymus vulgaris*, have been shown to be effective against a range of bacterial pathogens, while also boosting the intestinal health of animals. These plants therefore offer significant potential in the prevention and treatment of infectious diseases.

Secondly, probiotics, defined as live micro-organisms administered in adequate quantities, help to restore the balance of the intestinal microbiota, boost immune defences and reduce the adhesion of pathogens to the digestive mucosa. Strains such as *Lactobacillus spp*., *Bacillus subtilis* and *Saccharomyces cerevisiae* are commonly used in poultry and pig production. As a result, probiotics are perfectly suited to strategies for preventing digestive disease.

Organic acids such as formic, propionic or butyric acid have an acidifying effect in the digestive tract, inhibiting the growth of pathogenic bacteria while improving digestibility and zootechnical performance. Their use in animal feed is recognised for improving feed conversion rates and reducing digestive tract infections. They are therefore a complementary solution to phytotherapeutic and probiotic approaches.

Ultimately, these alternatives, alone or in synergy, offer concrete ways of reducing the use of antibiotics while maintaining farm productivity. However, their effectiveness depends on a number of factors, including formulation, dose, target animal species, administration method and rearing conditions. The review therefore stresses the importance of rigorous evaluation, based on sound scientific data, as well as support for farmers as part of integrated biosecurity programmes and good husbandry practices.

Keywords: *Antibiotics; Livestock Farming; Phytotherapy; Probiotics; Organic Acids*

Introduction

The massive use of antibiotics in livestock farming, whether for curative treatment, prophylaxis or growth promoters, has led to the emergence and spread of antibiotic-resistant bacteria. This phenomenon, now recognised as a major threat to public health, has led the health authorities to make reducing the use of antibiotics in veterinary medicine a strategic priority. Antibiotic consumption in the livestock sector accounts for a considerable proportion of overall exposure to antimicrobials. In some countries, it is estimated that up to 80% of antibiotics of critical importance for human medicine are used in production animals, often to promote growth in healthy animals [1]. This situation encourages the emergence of resistant bacterial strains that can be transmitted from animals to humans, which justifies an integrated "One Health" approach to containing this threat. In the European Union, for example, the use of antibiotics as growth-promoting additives in animal feed has been totally banned since 2006, in order to limit the selection of bacterial resistance. While this ban has led to a reduction in the prevalence of certain resistant pathogens, notably vancomycin-resistant enterococci in pigs and poultry, it has been accompanied by a resurgence of certain diseases previously controlled by these antibiotics. There has been an increase in neonatal diarrhoea in piglets (colibacillosis caused by *Escherichia coli*, *Lawsonia intracellularis* infections) and a resurgence of necrotising enteritis in broilers following the withdrawal of growth-promoting antibiotics [2]. This observation has made it necessary to develop alternative approaches capable of ensuring the health and good zootechnical performance of animals without generating selection pressures leading to antibiotic resistance. These alternative strategies fall into three main categories: phytotherapy (use of plant extracts, essential oils, active plant ingredients, etc.), probiotics (administration of beneficial live micro-organisms) and organic acids (incorporation of weak acids into the feed). Although these alternative approaches cannot generally replace antibiotics in the treatment of acute bacterial infection, they do make a significant contribution to preventing the onset of disease and improving the health of livestock, thereby reducing the need for antibiotic treatment [3]. These solutions, along with other approaches (vaccination, use of prebiotics/probiotics and bacteriophages), are now recognised by international bodies as ways of improving animal health while reducing the need for antibiotics. Indeed, organisations such as the FAO and WHO emphasise that strengthening prevention (through vaccination, better nutrition or the use of microbial additives) helps to maintain herds in good health and reduces the need for antimicrobials. Similarly, WHO Europe notes that bacteriophages, bacteria-killing viruses, can be used in veterinary medicine to treat specific infections, reducing reliance on antibiotics in farm animals. These alternative strategies are part of the global action plan against antibiotic resistance, promoted by the WHO, FAO and OIE, aimed at preserving the efficacy of antibiotics in human and animal health [4-8]. In this review, we examine the efficacy and mechanisms of action of each of these alternative categories, highlighting the expected benefits but also the possible limitations, illustrating with examples of practical applications in livestock farming, and finally addressing the regulatory aspects governing their use.

Phytotherapy (plant extracts and essential oils)

Phytotherapy applied to livestock farming refers to the use of substances of plant origin such as plant extracts, essential oils, powders or decoctions to prevent or treat certain animal ailments, or to boost production performance. This approach is part of the search for alternatives to conventional antibiotics, particularly since the ban on their use as growth promoters in several countries, notably in Europe [2]. Phytogenic products include a wide range of natural bioactive compounds such as polyphenols, flavonoids, alkaloids, saponins and terpenes, with antimicrobial, antioxidant, anti-inflammatory and immunomodulatory properties [9]. These substances act directly against pathogens, by inhibiting bacterial growth or disrupting the cell membrane, but also indirectly by stimulating the host's immune defences or modulating the intestinal microbiota, thereby improving digestive health and reducing the risk of enteric diseases [10]. Among the most widely studied plants are oregano (*Origanum vulgare*) and thyme (*Thymus vulgaris*), whose essential oils are rich in carvacrol and thymol, two monoterpenes with strong antimicrobial activity against pathogens such as *Escherichia coli*, *Clostridium perfringens* and *Salmonella* spp. [11]. Garlic (*Allium sativum*) is also well documented for its antibacterial effects attributed to allicin, a sulphur compound capable of inhibiting essential bacterial enzymes. Other commonly used ingredients include cinnamon (cinnamaldehyde), cloves (eugenol), rosemary (rosmarinic acid), black pepper (piperine), turmeric (curcumin) and various citrus

extracts rich in flavonoids [12]. These compounds are incorporated into animal feed in various forms (dried plant powders, fluid or dry extracts, microencapsulated essential oils, etc.) and are mainly intended for monogastric animals (pigs and poultry), although their use is tending to extend to ruminants and aquaculture [13]. Their main advantages are the absence of residues in animal products, low toxicity and reduced likelihood of inducing bacterial resistance [14]. However, their effectiveness can vary depending on the plant, its chemical composition, the dose administered, the extraction method and the rearing conditions. Some essential oils, for example, can be unstable at high temperatures or cause digestive problems in high concentrations. In addition, the regulations governing their use differ from one country to another and are not always harmonised, particularly as regards their status (zootechnical additives, natural substances, plant-based medicines). Experimental studies have shown that including oregano essential oil at 300 mg/kg in broiler feed significantly reduced the intestinal *Clostridium perfringens* load and improved average weight gain [15]. Similarly, the addition of thyme extract showed an improvement in the feed conversion index and better intestinal villi integrity in weanlings [16]. Despite these promising results, further research is needed to standardise formulations, gain a better understanding of the synergistic interactions between plant compounds, and establish reproducible, regulated protocols for use. In conclusion, phytotherapy represents a credible alternative to antibiotics in livestock farming, provided that the biological, technological and regulatory variables can be controlled.

Plant extracts used in animal feed exert their effects through multiple mechanisms of action, justifying their increasing use as non-antibiotic alternatives in livestock farming. These plant compounds, derived from spices, medicinal herbs or essential oils, contain a wide range of bioactive molecules including phenols, flavonoids, alkaloids, terpenoids and saponins, capable of positively influencing animal health and zootechnical performance [17]. Their efficacy is based on a multi-factorial action that is at once digestive, antimicrobial, antioxidant, anti-inflammatory and immunomodulatory, with synergistic and complementary effects that differ according to the animal species, the formulations used and the rearing conditions.

From a digestive point of view, plant extracts improve enzymatic activity, bile secretion and the digestibility of nutrients, particularly proteins and dietary fibre. In monogastric animals, this translates into better feed conversion, higher weight gain and a reduction in digestive disorders [9,18]. For example, the use of a mixture of oregano, cinnamon and black pepper extracts significantly increased live weight and feed consumption in broiler chickens, while reducing performance losses linked to environmental stresses [12]. These effects can be explained in particular by an improvement in the integrity of the intestinal mucosa, as shown by increases in the height of the villi and a reduction in epithelial permeability in several trials [15].

In terms of antimicrobial activity, several phytochemicals have direct activity against enteric pathogens such as *Escherichia coli*, *Salmonella enterica* and *Clostridium perfringens*. They act either by inhibiting the synthesis of bacterial enzymes, or by destabilising the cytoplasmic membrane, altering the cell viability of microorganisms [11]. For example, oregano essential oil, rich in carvacrol and thymol, has shown comparable efficacy to certain antibiotics in reducing the intestinal bacterial load in poultry, while promoting growth and batch homogeneity [20]. In addition, these compounds often have a selective action, reducing pathogenic germs without affecting the beneficial bacteria of the intestinal microbiota, thus contributing to a better balance in the digestive ecosystem.

The antioxidant activity of plant extracts is another important lever for improving animal performance. Many plant metabolites, such as flavonoids and rosmarinic acid, are capable of scavenging free radicals and protecting cells against oxidative damage induced by thermal or nutritional stress [14]. In livestock, this effect translates into an improvement in general health, a reduction in the incidence of inflammatory diseases and greater resilience in the event of disease or vaccination.

The anti-inflammatory and immunomodulatory properties of plant extracts have also been widely documented. Some plant substances are capable of attenuating the production of pro-inflammatory cytokines (such as TNF-α or IL-6), while stimulating non-specific immune defences (phagocytosis, lysozyme, IgA) [9,21]. For example, turmeric or ginger extracts incorporated into broiler feed have been shown to significantly reduce oxidative stress markers (MDA) and increase immunoglobulin levels in the blood, in addition to having a beneficial effect on growth [3].

In ruminants, although there is less evidence than in poultry or pigs, some phytogenic formulations seem promising for improving milk production, reducing methane production or limiting metabolic disorders linked to transition stress [13]. However, the efficacy of plant extracts is sometimes inconsistent, notably due to the variability of their chemical composition depending on geographical origin, growing conditions and extraction methods. In addition, encapsulation or galenic formulation (in the form of microgranules, lipid matrices or cyclodextrin complexes) plays an essential role in their stability, intestinal release and in vivo efficacy [15].

In summary, plant extracts offer a range of complementary mechanisms of action that can improve digestive health, boost immunity, reduce infections and optimise the performance of production animals. However, their use requires rigorous selection of plant species, standardisation of manufacturing processes and careful assessment of their safety, efficacy and compatibility with current regulations [22]. Their integration into farming practices will also need to be backed up by robust, reproducible scientific data to ensure their credibility as a sustainable alternative to antibiotics.

Plants	Active principles	Mechanisms of action	References
Oregano	Carvacrol, Thymol	Antimicrobial, anti-inflammatory	[11]
Thyme	Thymol, Carvacrol	Antimicrobial, immune stimulation	[9]
Garlic	Allicin	Antibacterial, enzyme inhibition	[10]
Cinnamon	Cinnamaldehyde	Antibacterial, antioxidant	[12]
Turmeric	Curcumin	Anti-inflammatory, antioxidant	[3]
Clove	Eugenol	Antimicrobial, antiseptic	[14]
Rosemary	Rosmarinic acid	Antioxidant, cell protection	[5]
Ginger	Gingerol, Shogaol	Anti-inflammatory, digestive stimulation	[18]
Black pepper	Piperine	Digestive enzyme stimulation, antimicrobial	[13]
Peppermint	Menthol	Antimicrobial, refreshing	[21]
Basil	Rosmarinic acid	Antioxidant	[20]
Sage	Thujone	Neuroprotective, antimicrobial	[23]
Eucalyptus	1,8-Cineole	Antiseptic, expectorant	[42]
Laurel	Laurein	Anti-inflammatory	[41]
Coriander	Linalool	Antioxidant	[11]
Dill	D-Limonene	Antispasmodic	[9]
Fenugreek	Galmacine	Immunomodulator	[10]
Licorice	Glycyrrhizin	Anti-inflammatory	[12]
Lavender	Linalool	Calming, antioxidant	[3]
Lemon balm	Rosmarinic acid	Anxiolytic	[14]
Marjoram	Terpenols	Digestive, antimicrobial	[15]
Tarragon	Estragole	Digestive, antispasmodic	[18]
Chamomile	Bisabolol	Sedative, anti-inflammatory	[13]
Basil, holy	Eugenol	Antiseptic	[21]
Savory	Carvacrol	Antimicrobial	[20]
Yarrow	Thujone	Analgesic, antimicrobial	[23]
Cardamom	Alpha-terpineol	Expectorant, antioxidant	[42]
Caraway	Carvone	Antioxidant	[41]

Cumin	Thymoquinone	Antioxidant, immunostimulant	[11]
Fennel	Anethol	Antispasmodic	[9]
Pepper	Capsaicin	Thermogenic	[10]
Onion	Quercetin	Antioxidant	[12]
Hibiscus	Anthocyanins	Antioxidant	[3]
Rosemary	Rosmarinic acid	Antioxidant, antimicrobial	[14]
Thyme	Thymol	Antimicrobial, immune stimulant	[15]
Oregano	Carvacrol	Antimicrobial, antioxidant	[18]
Citronella	Citronellal	Antimicrobial, repellent	[13]
Wild thyme	Thymol	Antimicrobial, immune stimulant	[21]
Turmeric	Curcumin	Anti-inflammatory	[20]
Ginger	Gingerol	Anti-inflammatory, antioxidant	[23]
Licorice	Glycyrrhizin	Antioxidant	[42]
Coriander	Linalool	Enzymatic stimulation	[41]
White pepper	Piperine	Immunomodulator	[11]
Fenugreek	Galmacine	Antiseptic, antimicrobial	[9]
Clove	Eugenol	Antioxidant	[10]
Cumin	Thymoquinone	Antimicrobial, antioxidant	[12]
Star anise	Anethol	Antioxidant	[3]
Mace	Macine	Immunostimulant	[14]
Rosehip	Vitamin C	Antimicrobial, anti-inflammatory	[15]
Basil	Linalool, eugenol	Antibacterial, digestive stimulant	[9]
Mint	Menthol	Antimicrobial, refreshing	[21]
Fennel	Anethol	Carminative, antimicrobial	[9]
Star anise	Anethol	Carminative, spasmolytic	[13]
Chamomile	Apigenin	Anti-inflammatory, soothing	[9]

Table 1: *Some mechanisms of action of plant extracts.*

Advantages and limitations of phytotherapy in animal production

As a promising alternative to antibiotics, phytotherapy offers many advantages in the field of animal health. It is based on the use of bioactive compounds of natural origin, such as essential oils, flavonoids, alkaloids, saponins, tannins and phenols, derived from medicinal and aromatic plants [10,11]. These compounds exert a wide range of biological effects, including antimicrobial, anti-inflammatory, antioxidant, immunomodulatory, digestive and antiparasitic [3,9,12,13].

One of the main advantages of phytotherapy is the absence of chemical residues in animal products, which meets the growing demands for food safety and quality [23]. In addition, plant extracts present a low risk of the emergence of specific bacterial resistance, making them a strategic lever in the fight against antibiotic resistance [20,32]. Certain aromatic plants, such as thyme, oregano, rosemary and holy basil, also improve the palatability of feed, thereby contributing to better ingestion and zootechnical performance [15,18,21].

However, there are still a number of limitations to the widespread application of phytotherapy in livestock farming. Firstly, the efficacy of plant extracts is often less consistent than that of conventional antibiotics, and their activity is highly dependent on the concentration of active ingredients [14,26,27]. This variability can be attributed to factors such as botanical variety, terroir, season, stage of harvest or extraction method [15,28]. In addition, scientific results are sometimes difficult to compare, due to a lack of harmonisation in experimental protocols [27,29].

Some essential oils, when administered in high doses, can also cause side effects: irritation of the mucous membranes, alteration of the sense of smell, or reduced appetite, particularly because of their organoleptic power [9,13,30]. Furthermore, the spectrum of action of each plant is generally limited: an extract that is active against enteric infections will not necessarily be effective against respiratory or parasitic infections [31]. It is therefore essential to adopt a targeted approach, based on the precise selection of phytobiotics according to the pathogens concerned, or even on the synergy between several extracts [15,32].

On the basis of current data, although phytotherapy represents a sustainable complementary approach, its optimal use requires rigorous standardisation, controlled clinical trials and a better understanding of the mechanics of its active ingredients. As part of an overall strategy to reduce the use of antibiotics, it could play a decisive role in improving animal health and food safety in the long term.

Examples of applications and regulatory status of phytogenic alternatives

Many commercial plant-based products are now available as feed additives, often referred to as phytobiotics, phytogenic or natural growth promoters. In poultry farming, for example, mixtures of essential oils of oregano (carvacrol) and cinnamon (cinnamaldehyde) have been shown to be effective in preventing necrotic enteritis caused by *Clostridium perfringens*, thereby reducing the use of antibiotic anticoccidials in several commercial farms [31,33].

In the European Union, plant substances used as feed additives are not classified as veterinary medicinal products, which makes it easier to market them. They are classified by EFSA as technological, sensory or zootechnical additives, depending on their function [34]. Compounds such as carvacrol, thymol and capsaicin already have specific authorisations as sensory additives or growth promoters, and are listed in the Community register of feed additives [35].

However, marketing authorisation still requires a rigorous scientific assessment of efficacy, safety (for animals, consumers and the environment) and product quality. This assessment is carried out at European level by EFSA's FEEDAP Panel, which examines applications from industry on a case-by-case basis [36]. The diversity of plant extracts, their chemical variability and their often complex mode of action make this assessment more difficult than for conventional additives.

France's ANSES has also stressed the importance of clarifying the legal status of these products, in order to provide a better framework for their use, guarantee their traceability and prevent misuse. It recommended that a clear distinction be made between herbal extracts used in phytotherapy, veterinary medicines, additives and complementary foods [23].

Some standardised products, such as microencapsulated preparations of essential oils, are already being marketed with claims to stimulate appetite, improve digestion or support immunity. On the other hand, other more complex formulations, such as mixtures of broad-spectrum botanical extracts, are still sold as complementary foods, with more flexible but also less clear-cut legislation [37].

To sum up, while phytotherapy in livestock farming offers interesting prospects for animal health, full regulatory recognition will depend on the harmonisation of standards, precise chemical characterisation of the products and rigorous scientific demonstration of their efficacy, particularly in livestock farming conditions.

Probiotics

Probiotics are defined by the FAO/WHO as "live micro-organisms which, when administered in adequate amounts, confer a health benefit on the host". In practice, they are most often beneficial bacteria (or yeasts) incorporated into animal feed or drinking water. These microbial additives, used mainly in pigs and poultry [38], aim to improve the balance of the intestinal microbiota and the digestive health of livestock. The probiotic strains commonly used are Gram-positive bacteria, in particular lactic acid bacteria (genera *Lactobacillus*, *Pediococcus*, *Enterococcus*, *Streptococcus*), *Bifidobacteria* and spore-forming *Bacillus*. Yeasts such as *Saccharomyces cerevisiae* are also used in animal feed. They are generally administered at high doses (typically ≥10^9 CFU per kg of feed) to ensure that a sufficient quantity of micro-organisms reaches the intestine [39].

Mechanisms of action and efficacy

Probiotics work by several complementary mechanisms to promote intestinal health. Firstly, they exert a direct antagonistic effect on pathogenic bacteria by producing inhibitory substances (e.g. bacteriocins, hydrogen peroxide or organic acids such as lactic acid) which limit the development of undesirable germs. They also compete with pathogens for mucosal adhesion and available nutrients, preventing them from colonising the digestive tract (competitive exclusion). The production of organic acids by probiotics helps to lower intestinal pH, creating an unfavourable environment for many pathogenic bacteria sensitive to acidity [39]. Probiotics also strengthen the intestinal barrier (integrity of the mucosa) and modulate the host's local immune system: they stimulate protective immune responses while reducing excessive inflammation [39,40]. Finally, some probiotic strains improve digestion by helping to break down food components (fibre, etc.) and increasing digestive enzyme activity, which can result in better use of nutrients and improved growth performance [39].

Numerous studies confirm the positive effects of probiotics in livestock farming. For example, in broiler chickens, the administration of probiotics (alone or in mixtures) has been shown to stimulate the immune system, reduce intestinal inflammation, prevent colonisation of the intestine by pathogens such as *E. coli*, reduce nitrogenous waste (ammonia, urea) and improve animal growth. One study cited even reported that a group of chickens receiving a probiotic cocktail showed greater daily weight gain not only than the control group, but also than a group receiving a growth-promoting antibiotic [40]. In weaned piglets, a period of high digestive risk, the addition of certain strains (e.g. *Bacillus*, *Lactobacillus*) helps to reduce the incidence and severity of post-weaning diarrhoea, thereby reducing the use of therapeutic antibiotics in this indication. Convincing results have also been obtained in aquaculture: the use of probiotics in the feed of farmed fish has reduced mortality linked to bacterial diseases, attesting to the potential of these beneficial micro-organisms to prevent infections [23].

Advantages and limitations

The value of probiotics lies in their ability to improve animal health without resorting to chemical antimicrobial substances. They restore or maintain a balanced microbiota, a key factor in good digestion and immunity. They do not leave residues in animal products and can even have a *'post-weaning'* effect by stabilising the intestinal flora after antibiotics have been stopped. However, their practical use does have its constraints: they are living additives that have to survive the storage conditions of the feed, the granulation processes (temperature, pressure) and the passage through the first segments of the digestive tract (acidity of the stomach) to reach the intestine in sufficient quantity [40]. This limits the number of suitable strains and sometimes requires specific formulations (microencapsulation, protective carriers) to guarantee their viability. What's more, not all probiotics are equal: efficacy is strain-dependent and closely linked to rearing conditions (animal species, hygiene, feed, etc.). A probiotic that is effective in chickens will not necessarily be effective in pigs, and vice-versa, which means that the strains used must be carefully chosen to suit the target animal. There are also variations in efficacy between studies: while the majority of studies conclude that the effects are favourable, some results remain modest or variable, making it necessary to use appropriate experimental protocols to detect these subtle benefits [23]. Finally, one aspect to be monitored is the safety profile of the strains used: they must be free of transmissible antibiotic resistance genes or pathogenicity. For example, certain *Enterococcus* strains can carry resistance, and toxigenic *Bacillus cereus* strains must be excluded [39]. This is why the authorities require a rigorous assessment of the safety of each probiotic strain before authorisation.

Examples of applications and regulatory recognition

There are many probiotic products on the market for farm animals - for example, live yeasts for ruminants (to improve ruminal fermentation), *Bacillus* for poultry (to reduce *Clostridium* necrotic enteritis), or mixtures of *lactobacilli* to make piglet weaning safer. In the European Union, probiotics are classified as zootechnical additives (category "intestinal flora improvers" under EC regulation 1831/2003) and are authorised after assessment by EFSA. Many strains (e.g. *Bacillus subtilis*, *Saccharomyces cerevisiae*, *Pediococcus acidilactici*, etc.) have been approved for one or more animal species, attesting to their safety and recognised beneficial effect on performance or health. The development of the probiotics market is dynamic: estimated at more than $110 million in 2023 for the livestock sector, it is growing at the same pace as the restrictions on antibiotics [24]. At the same time, so-called symbiotic products (combining probiotics and prebiotics) are emerging that aim to optimise the implantation of beneficial bacteria in the intestine, with results that are often superior to the use of probiotics alone [24]. Other non-living alternatives, such as postbiotics (metabolites or inert components of microbes), are also being explored as a way of circumventing viability constraints while still conferring similar health benefits [40]. Whatever the case, probiotics are now considered to be a key strategy for reducing the use of antibiotics in livestock farming, provided that they are used in accordance with good practice (choice of appropriate strain, regular preventive administration, concomitant hygiene of the farm, etc.) in order to get the most out of them.

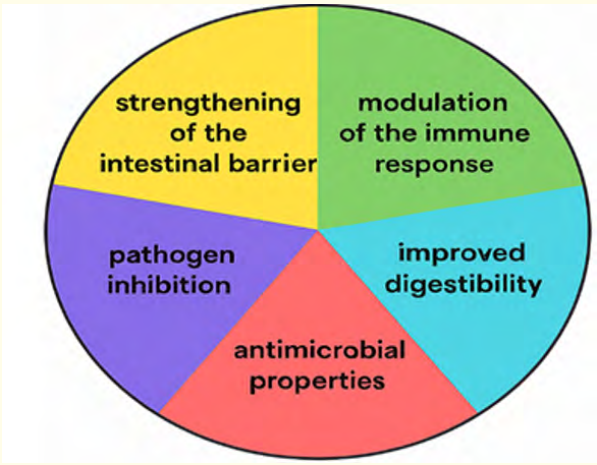

Figure 1: *Benefits of probiotics.*

Organic acids

Organic acids include various small acidic molecules (containing a carboxyl group -COOH) commonly used in animal nutrition, including formic acid, acetic acid (vinegar), propionic acid, butyric acid, lactic acid, citric acid, malic acid, benzoic acid, etc. Historically, these weak acids were first used as food preservatives (for example to acidify silage or prevent the development of mould in stored foodstuffs [40]. However, since the ban on antibiotic growth promoters, their zootechnical benefits have been highlighted: adding organic acids to feed has a beneficial effect on animal growth, feed conversion ratio and digestive health, particularly in young monogastric animals [38].

Mechanisms of action and efficacy of organic acids

Organic acids act via several complementary mechanisms in the animal's digestive tract. Firstly, they induce acidification of the gastrointestinal contents by lowering the pH in the stomach and foregut [38]. A more acidic pH promotes the activity of digestive enzymes (for example, the conversion of pepsinogen to pepsin is optimised in an acidic environment), which improves protein digestion [39]. This

acidification also limits the survival of many acid-sensitive pathogenic bacteria (such as *E. coli*, *Salmonella* or *Clostridium perfringens*), thus playing a preventive antitibacterial role. In addition to this indirect action, certain acids can penetrate bacteria in undissociated form and disrupt their internal metabolism, leading to the destruction of the germ - this is the direct antimicrobial action of organic acids. Furthermore, by inhibiting undesirable flora, organic acids encourage the growth of beneficial acid-tolerant bacteria (such as lactobacilli), contributing to a more balanced microbiota [38].

Organic acids also improve the digestibility of nutrients: they increase the assimilation of proteins and energy from the ration, as well as the absorption of certain minerals such as calcium and phosphorus. Studies have shown, for example, that adding acidifiers to the ration increases nitrogen retention and phosphorus utilisation, leading to better growth and a more robust skeleton in pigs. By reducing intestinal pH, organic acids also modify the structure of the mucosa (e.g. increasing the height of the villi), improving the absorption surface and the health of the intestinal epithelium. Lastly, a non-negligible ancillary benefit is the sanitation of the food itself: acids protect compound foods against microbial or fungal contamination during storage, improving their overall hygienic quality [38].

Thanks to these mechanisms, the effectiveness of organic acids as alternatives is well documented. For example, incorporating butyric acid or its salts into the feed of weaned piglets significantly reduces the incidence of post- weaning diarrhoea and improves the animals' daily weight gain and digestive transit, an effect comparable to that obtained with certain protective antibiotics [43]. Similarly, in poultry, mixtures of acids (formic, acetic, propionic, etc.) have been shown to increase growth rates and improve feed conversion by reducing digestive disorders linked to *Salmonella* or *Clostridium*. A meta-analysis reported that, on average, acidifiers improve feed intake and final weight in chickens, while reducing mortality and intestinal bacterial load. It should be noted that the effects vary according to the type of acid: short-chain acids (C1-C4, e.g. formic, propionic, butyric) have a marked antimicrobial action and are often used against enteric pathogenic bacteria, whereas medium-chain organic acids (sorbic, caprylic acid, etc.) can act higher up in the digestive tract and have specific effects (e.g. modulation of local immunity) [39].

Advantages and limitations of organic acids

Organic acids have the advantage of being simple, relatively inexpensive molecules whose general mode of action (acidification) makes the development of specific bacterial resistance unlikely. They are often synergistic with each other or with other additives: for example, acidifying the environment boosts the effectiveness of exogenous enzymes added to the food and acid-tolerant probiotics. In addition, they are flexible to use, as they can be incorporated directly into compound feed or administered via water. From a food safety point of view, several organic acids (acetic, lactic, etc.) are naturally present in human food and do not pose any residue problems in the meat, milk or eggs of treated animals. They even help to reduce certain types of contamination.

Their limitations lie in their effectiveness, which is often inferior to that of a broad-spectrum antibiotic in treating an overt infection: organic acids act more as a preventive measure or to support performance, but will not be sufficient to treat a serious systemic bacterial disease. From a practical perspective, incorporating strong acids into feed can lead to corrosion issues (for livestock equipment) or reduced palatability if the dosage is excessive (too acidic taste). Therefore, protected or buffered forms (e.g. salts of organic acids rather than the free form) are often used to mitigate these issues. Furthermore, the optimum effectiveness of acids depends on the dosage and the context: too low a dosage will have no noticeable effect, while too high a dosage can irritate the digestive mucosa. It is therefore necessary to find a balance and adapt the formulas to the species concerned. Finally, as with any alternative strategy, organic acids alone cannot compensate for poor rearing conditions: they need to be part of an overall programme that includes hygiene, a balanced diet and possibly other additives to achieve the best results.

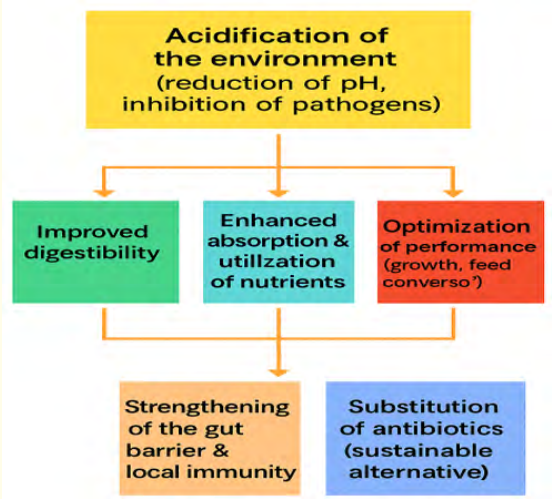

Figure 2: *Advantages of organic acids.*

Examples of applications and regulatory framework

Acidifiers are an integral part of antibiotic-free programmes on many farms. In the pig industry, protected benzoic acid was widely adopted following the ban on zinc oxide (another anti-diarrhoeal agent); it significantly reduces weaning diarrhoea and improves piglet growth, providing an effective alternative for making this critical phase safer [43]. Mixtures of formic acid, propionic acid and sorbic acid are frequently used in poultry feed to control *Salmonella* and improve weight gain. From a regulatory point of view, most organic acids used in livestock farming are approved as technological or zootechnical additives. For example, formic acid and propionic acid are authorised as feed preservatives (with maximum levels set to avoid any undesirable effects), and benzoic acid is specifically authorised as a zootechnical additive for weaned pigs in the EU. EFSA assessments have generally concluded that these acids are safe at the doses used, and that there is a modest but significant improvement in zootechnical performance (weight gain, feed conversion ratio) [39]. The use of organic acids is therefore well established and officially recognised as a measure that contributes to reducing the use of antibiotics in livestock farming [41].

Phytotherapy, probiotics and organic acids all offer ways of reducing the use of antibiotics in livestock farming by improving animal health through natural or microbiological means. Numerous studies and practical applications show that these alternatives can strengthen animal defences, stabilise digestive flora, improve growth and reduce the incidence of farm diseases, thereby reducing the need for curative antibiotic therapy [40,42]. However, it is clear that none of these solutions is a *panacea* equivalent to antibiotics. Their efficacy, although real, is often more targeted or less extensive than that of a conventional antibiotic [24]. Consequently, in order to obtain an optimum level of protection and performance, an integrated approach combining several families of alternatives is preferred (e.g. probiotics *and* organic acids, or even symbiotics combining pre- and probiotics) in order to benefit from synergistic effects [38,39]. At the same time, improvements in farming practices (vaccination, biosecurity, welfare, balanced nutrition) remain essential to reduce infectious pressure and give these alternatives a chance to express their full potential [41].

On the scientific and regulatory front, efforts are continuing to rigorously assess the safety and efficacy of these products and to regulate their use. Agencies such as EFSA and Anses are encouraging research in this area, while stressing the need for appropriate protocols to detect benefits that may be modest but significant over time. They also recommend clarifying the regulatory status of these alternatives in order to facilitate their marketing, without treating them as veterinary medicinal products where this is not necessary [24].

In short, phytotherapy, probiotics and organic acids are today promising tools for more sustainable and responsible animal production. While they cannot completely eliminate the use of antibiotics - which will still sometimes be essential for treating infections - they do help to significantly reduce their preventive or abusive use, and therefore to limit the development of antibiotic resistance in livestock farming. Their role will undoubtedly increase in the years to come, supported by innovation (new strains, new extracts) and by widespread awareness of the importance of preserving the efficacy of antibiotics for humans and animals [42]. Judicious use, combined with well-managed livestock farming, will enable us to make the most of these alternatives and enter an era of rational livestock farming, reconciling animal health, economic efficiency and public health imperatives.

Bibliography

1. World Health Organization (WHO). "Critically important antimicrobials for human medicine: 5th Animal revision 2016". Geneva: WHO Press (2017).

2. Casewell M., *et al*. "The European ban on growth-promoting antibiotics and emerging consequences for human and animal health". *Journal of Antimicrobial Chemotherapy* 52.2 (2003): 159-161.

3. Gadde U., *et al*. "Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: A review". *Animal Health Research Reviews* 18.1 (2017): 26-45.

4. European Food Safety Authority (EFSA). "Alternatives to antimicrobials for animal production: Recommendations and conclusions from the RONAFA opinion". *EFSA Journal* 15.1 (2017): e04661.

5. Sumption K. "Antimicrobials must be used sparingly to preserve their utility for agrifood systems and human health" (2021).

6. Pew Charitable Trusts. "Alternatives to antibiotics in animal agriculture". The Pew Charitable Trusts (2017).

7. Organisation mondiale de la Santé (OMS: Bureau régional de l'Europe). "Bactériophages et leur utilisation dans la lutte contre la résistance aux antimicrobiens". OMS (2025).

8. Seal BS., *et al*. "Microbialderived products as potential new antimicrobials". *Veterinary Research* 49.1 (2018): 66.

9. Hashemi SR and Davoodi H. "Herbal plants and their derivatives as growth and health promoters in animal nutrition". *Veterinary Research Communications* 35.3 (2011): 169-180.

10. Windisch W., *et al*. "Use of phytogenic products as feed additives for swine and poultry". *Journal of Animal Science* 86.14 (2008): E140-E148.

11. Brenes A and Roura E. "Essential oils in poultry nutrition: Main effects and modes of action". *Animal Feed Science and Technology* 158.1-2 (2010): 1-14.

12. Zeng Z., *et al*. "Essential oils and aromatic plants as feed additives in non-ruminant nutrition: A review". *Journal of Animal Science and Biotechnology* 6.1 (2015): 7.

13. Greathead H. "Plants and plant extracts for improving animal productivity". *Proceedings of the Nutrition Society* 62.2 (2003): 279-290.

14. Nazzaro F., *et al*. "Effect of essential oils on pathogenic bacteria". *Pharmaceuticals* 6.12 (2013): 1451-1474.

15. Tiihonen K., *et al*. "The effect of selected plant-derived products and probiotics on gastrointestinal microbiota and performance of broiler chickens". *Livestock Science* 133.1-3 (2010): 100-102.

16. Manzanilla EG., *et al*. "Effect of plant extracts and formic acid on the intestinal equilibrium of early-weaned pigs". *Journal of Animal Science* 82.11 (2004): 3210-3218.

17. Windisch W., *et al*. "Use of phytogenic products as feed additives for swine and poultry". *Journal of Animal Science* 86.14 (2008): E140-E148.

18. Giannenas I., *et al*. "Effect of dietary supplementation with oregano essential oil on performance of broilers after experimental infection with *Eimeria tenella*". *Archiv für Geflügelkunde* 57.2 (2003): 99-106.

19. Brenes A and Roura E. "Essential oils in poultry nutrition: Main effects and modes of action". *Animal Feed Science and Technology* 158.1-2 (2010): 1-14.

20. Yang C., *et al*. "Phytogenic compounds as alternatives to in-feed antibiotics: Potentials and challenges in application". *Pathogens* 4.1 (2015): 137-156.

21. Gopi M., *et al*. "Essential oils as a feed additive in poultry nutrition". *Advances in Animal and Veterinary Sciences* 2.1 (2014): 1-7.

22. Chaachouay N and Zidane L. "Plantderived natural products: a source for drug discovery and development". *Drugs and Drug Candidates* 3.1 (2024): 184-207.

23. Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES). "Effets pharmacologiques des composés naturels dans les plantes médicinales". Avis n° 2019SA0155. MaisonsAlfort: ANSES (2022).

24. ANSES - Agence nationale de sécurité sanitaire ANSES. "État des lieux des alternatives aux antibiotiques en vue de diminuer leur usage en élevage: rapport d'expertise collective". (Avis n° 2013-SA-0122) [PDF]. Maisons-Alfort: ANSES. Academia+15Anses+15Anses+15 (2018).

25. Steiner T and Syed B. "Phytogenic Feed Additives in Animal Nutrition (Chapter 20)". In Á. Máthé (Ed.: Medicinal and Aromatic Plants of the World (Volume 1) Springer (2015).

26. Ducrot C., *et al*. "Perspectives d'alternatives thérapeutiques antimicrobiennes aux antibiotiques en élevage". *INRAE Productions Animales* 30.1 (2017): 77-88.

27. Franz C., *et al*. "Essential oils and aromatic plants in animal feeding-a European perspective. A review". *Flavour and Fragrance Journal* 25.5 (2010): 327-340.

28. Lehmann H. "Le médicament à base de plantes en Europe: statut, enregistrement, contrôles". Droit. Université de Strasbourg. Français. ffNNT: 2013STRAJ024ff (2013).

29. Burt S. "Essential oils: Their antibacterial properties and potential applications in foods". *International Journal of Food Microbiology* 94.3 (2004): 223-253.

30. Michiels J., *et al*. "*In vitro* characterisation of the antimicrobial activity of selected essential oil components and their mixture against swine gut pathogens". *Animal Feed Science and Technology* 151.1-2 (2008): 111-127.

31. Zhai H., *et al*. "Potential of essential oils for poultry and pigs". *Animal Nutrition* 4.2 (2018): 179-186.

32. Lillehoj HS., *et al*. "Phytochemicals as antibiotic alternatives to promote growth and enhance host health". *Veterinary Research* 49.1 (2018): 76.

33. Rafiq K., *et al*. "Role of different growth enhancers as alternative to infeed antibiotics in poultry industry". *Frontiers in Veterinary Science* 8 (2022): 794588.

34. EFSA FEEDAP Panel. "Guidance on the assessment of the efficacy of feed additives". *EFSA Journal* 19.6 (2021): e06558.

35. Commission européenne. "Registre communautaire des additifs pour l'alimentation animale" (2023).

36. European Medicines Agency and European Food Safety Authority Panel on Biological Hazards. "EMA and EFSA Joint Scientific Opinion on measures to reduce the need to use antimicrobial agents in animal husbandry in the European Union, and the resulting impacts on food safety (RONAFA)". *EFSA Journal* 15.1 (2017): 4666.

37. Rossi B., *et al*. "Single components of botanicals and natureidentical compounds as a nonantibiotic strategy to ameliorate health status and improve performance in poultry and pigs". *Nutrition Research Reviews* 33.2 (2020): 218-234.

38. Laval A. "Les alternatives aux antibiotiques en élevage [Rapport PDF]". Académie d'Agriculture de France. Manucrit révisé le 19 juin 2020 AnsesFrontiers+12Agri Mutuel+12academie-agriculture.fr+12 (2020).

39. Ayalew H., *et al*. "Potential feed additives as antibiotic alternatives in broiler production". *Frontiers in Veterinary Science* 9 (2022): 916473.

40. Ministère de l'Agriculture et de la Souveraineté alimentaire. "L'alimentation animale, facteur d'amélioration des performances zootechniques en élevage (Note d'analyse n° 209)" (2025).

41. Food and Agriculture Organization of the United Nations (FAO). "Reducing antimicrobial use in animal production: Practices, challenges and opportunities". Rome (2021).

42. European Food Safety Authority and European Medicines Agency. "It's time to reduce, replace and rethink the use of antimicrobials in animal production - alternatives such as vaccines, probiotics, prebiotics, bacteriophages and organic acids can help cut antimicrobial use [Communiqué de presse]". EFSA (2017).

43. RMT Élevage et Environnement. Guide des bonnes pratiques environnementales d'élevage. Fiche Utilisation d'acide benzoïque (2019): 3.

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