Animal Nutrition xxx (2018) 1–8

Contents lists available at ScienceDirect

Animal Nutrition

journal homepage: http://www.keaipublishing.com/en/journals/aninu/

Review Article

Potential of essential oils for poultry and pigs

Hengxiao Zhai [a,*], Hong Liu [a], Shikui Wang [a], Jinlong Wu [a], Anna-Maria Kluenter [b]

[a] *DSM (China) Animal Nutrition Research Center, Bazhou 065799, China*
[b] *DSM Nutritional Products Ltd., Basel 4002, Switzerland*

A R T I C L E I N F O

Article history:
Received 10 August 2017
Received in revised form
16 December 2017
Accepted 10 January 2018
Available online xxx

Keywords:
Antibiotics
Chickens
Essential oils
Pathogens
Pigs

A B S T R A C T

The increasing pressure of abolishing and/or decreasing the use of antibiotics as antimicrobial growth promoters for livestock calls for alternative solutions to sustain the efficiency of current livestock production. Among the alternatives, essential oils have a great potential and are generally considered natural, less toxic, and free from residues. Essential oils have been proven in numerous *in vitro* studies to exert antimicrobial effects on various pathogens. The current review touched on the basics of essential oils, and the *in vivo* effects of essential oils on growth, intestinal microflora, anti-oxidation, immune functionality, meat qualities as well as the possible modes of action in poultry and pigs, and the future research areas were proposed.

1. Introduction

The recognition of microorganisms being responsible for a variety of diseases in the late half of the 19th century ushered in the discoveries of antibiotics, which saw its golden era between 1950s and 1970s. But since then, no new classes of antibiotics had been discovered (Aminov, 2010). Meanwhile, the improper use of antibiotics resulted in the selection of bacteria resistant to antibiotics. One of the solutions is to implement bans of using antibiotics as antimicrobial growth promoters (AGP) for farm animals, which makes it imperative to find effective alternatives to antibiotics to sustain the efficiency of current livestock production. Among the alternatives, essential oils have a great potential. The essential oils are generally considered natural, less toxic, and free from residues when compared with antibiotics (Gong et al., 2014).

Essential oils are complex mixtures of volatile compounds produced by living organisms and isolated by physical means only (pressing and distillation) from a whole plant or plant part of known taxonomic origin (Franz and Novak, 2009). The term “essential oils” emerged because “oils” were wishfully believed to be “essential” to life, and have a long history of being used by human for cosmetic and medicinal purposes. The development of essential oils, however, was delayed by the advent of antibiotics in the middle of the 19th century, and was renewed recently. It was estimated that, out of 3,000 known essential oils, 300 were recognized as commercially important and mainly used in the flavors and fragrances market (van de Braak and Leijten, 1994). The global essential oil market is expected to reach 11.67 billion USD by 2022.

The aim of the current review was to identify the well-recognized efficacy of essential oils for poultry and pigs as well as the conflicting research findings, whereupon more research efforts could be directed to the inconclusive area to facilitate a better understanding of essential oils.

2. Basics of essential oils

Essential oils are a sum of constituent volatiles, and thus the effects of essential oils should be a totality of effects of all components and their interactions. However, 2 or 3 components could account for up to 85% of the total mixture compared with the minors (Miguel, 2010), and thereby contribute to the primary property of the mixture. For example, the phenols (thymol and carvacrol) constitute about 80% of the essential oils of oregano, the

* Corresponding author.
E-mail address: heng-xiao.zhai@dsm.com (H. Zhai).

Peer review under responsibility of Chinese Association of Animal Science and Veterinary Medicine.

Production and Hosting by Elsevier on behalf of KeAi

https://doi.org/10.1016/j.aninu.2018.01.005
2405-6545/

most widespread species of *Lamiaceae* family, and are mainly responsible for its antibacterial and antioxidant activities. Besides thymol and carvacrol, ρ-cymene was found as another dominant component of oregano (Bouhaddouda et al., 2016). Although the ρ-cymene is not an effective antimicrobial agent by itself, it could facilitate the transport of carvacrol across the cytoplasmic membrane (Oke et al., 2009).

The composition of essential oils is primarily determined by the homogeneity of the starting materials, whose characteristics could be influenced by a plethora of factors. For example, the total content of monoterpene hydrocarbons (mostly γ-terpinene and ρ-cymene) and phenol terpenes (mostly thymol and carvacrol) ranges from 57.3% to 62.5% of the essential oils from a Thyme (*Thymus pulegioides* L.), relatively constant over different harvesting times, but the phenol content starts to increase at the beginning of the flowering and reaches its greatest value during the full flowering period of the plant (Senatore, 1996). The biological activities in *in vivo* trials largely depend on the chemical profile of essential oils.

Essential oils account for only a small proportion (usually less than 1%) of the wet weight of plant materials, which makes it imperative to improve the yield of essential oils by continuous developments in relevant fields such as genetic engineering and extraction methods. These developments presented challenges to the concept of essential oils as well as the knowledge of biological activities of essential oils. For example, the steam-distilled essential oils from *Origanum vulgare* showed a great antibacterial activity against reference strains with a moderate antioxidant activity, while the methanolic extract exhibits no antibacterial activity but a high antioxidant activity (Bouhaddouda et al., 2016), which suggests that the bioactivity of essential oils is indeed based on the method of extraction (Vigan, 2010). In addition, there is a growing part of chemically-synthesized essential oils used in feed industry.

Most constituents of essential oils are terpenoids and phenylpropanoids. Phenylpropanoids occur less frequently and less abundantly than terpenoids (Hammer and Carson, 2011). The well-known plant families for producing essential oils with medicinal and industrial values include *Alliaceae, Apiaceae, Asteraceae, Lamiaceae, Myrtaceae, Poaceae,* and *Rutaceae* (Raut and Karuppayil, 2014). Some representative essential oils include, but not limited to, anise (*Apiaceae*), oregano (*Lamiaceae*), cinnamon (*Lauraceae*), garlic (*Liliaceae*), thyme (*Myrtaceae*), black pepper (*Piperaceae*), and Turmeric (*Zingiberaceae*).

3. Essential oils for poultry

3.1. Growth performance

Essential oils are perceived as growth promoters in poultry diets (Zhang et al., 2014). Animal trial results, however, are considerably variable. Table 1 gives a summary of the factors which could influence the efficacy of essential oils for both poultry and pigs. These factors relate to the experimental essential oils, animals, diets, and environment.

3.1.1. Feed intake

Recently-published reviews (Brenes and Roura, 2010; Bozkurt et al., 2014; Franz et al., 2010; Hashemi and Davoodi, 2010; Hippenstiel et al., 2011) reported that feed intake in chicks was unchanged or slightly reduced by dietary inclusion of essential oils. For the decreased feed consumption, one possible explanation is that essential oils possess an irritating smell, which renders the palatability of diet disagreeable to birds. Amad et al. (2011) and Halle et al. (2004) reported that daily feed intake of broilers was numerically decreased by increasing the dietary level of a blend of thyme, star anise, and origanum leaves, and its associated essential oils compared with control. Similarly, Cabuk et al. (2006) noted a significantly reduced feed intake of broilers from young breeders by graded inclusion of a cocktail of essential oils (oregano oil, laurel leaf oil, sage leaf oil, myrtle leaf oil, fennel seed oil, and citrus peel oil). In contrast to pigs, information of poultry concerning feed preference was scarce. Moran (1982) reported that poultry might not be sensitive to flavor as pigs, and Roura et al. (2008) reported that birds are more tolerant to exposure of moderate levels of essential oils than pigs.

3.1.2. Feed utilization

Unlike feed intake, improvements in weight gain and feed conversion ratio dominate the observations. Two well-accepted mechanisms are the stimulation of digestive enzyme secretion and the stabilization of ecosystem of gut microflora, leading to improved feed utilization and less exposure to growth-depressing disorders associated with digestion and metabolism (Bento et al., 2013; Franz et al., 2010; Kurekci et al., 2014; Lee et al., 2003; O'Bryan et al., 2015; Williams and Losa, 2001). The positive effects of essential oils on digestive enzyme secretion from pancreas and intestinal mucosal have been reported in many broiler studies (Basmacioğlu Malayoğlu et al., 2010; Jamroz et al., 2006; Jang et al., 2007). These effects were confirmed by the increased digestibility of nutrients, but did not translate into improvement in growth performance (Amad et al., 2011; Botsoglou et al., 2004; Garcia et al., 2007; Hernández et al., 2004; Lee et al., 2003). It is noteworthy that there is an inadequate description of the environmental conditions under which these trials were conducted, and poor hygienic conditions might be instrumental for essential oils to favorably affect the growth performance of broilers.

3.2. Antimicrobial and anticoccidial activity

The antimicrobial activity of essential oils has been explored in many *in vitro* assays which showed that thymol, eugenol and carvacrol have high antimicrobial activity against pathogenic bacteria such as *Escherichia coli* and *Salmonella typhimurium*, both of which are potential risk factors of enteric infections (Bassolé and Juliani, 2012; Franz et al., 2010; Hippenstiel et al., 2011). Thymol, eugenol and carvacrol are structurally similar, and have been proved to exert synergistic or additive antimicrobial effects when combined at lower concentrations (Bassolé and Juliani, 2012). Therefore, it is necessary to unravel the synergistic mechanism to optimize their formulation. Different *in vitro* methods as well as different pathogens exist for ranking the antimicrobial capacity of essential oil components, which could vary dramatically as shown in Table 2. In *in vivo* studies, essential oils used either individually or in combination have shown clear growth inhibition of *Clostridium perfringens* and *E. coli* in the hindgut and ameliorated intestinal lesions and weight loss than the challenged control birds (Jamroz et al., 2006; Jerzsele et al., 2012; Mitsch et al., 2004). One well-known mechanism of antibacterial activity is linked to their hydrophobicity, which disrupts the permeability of cell membranes and cell homeostasis with the consequence of loss of cellular components, influx of other substances, or even cell death (Brenes and Roura, 2010; Solórzano-Santos and Miranda-Novales, 2012; Windisch et al., 2008; O'Bryan et al., 2015). It is of note that Gram-negative bacteria are more tolerant to the actions of essential oil than Gram-positive bacteria due to their hydrophilic constituents in the outer membrane (Brenes and Roura, 2010; Giannenas et al., 2013; Seow et al., 2014).

Coccidiosis, a common parasitosis disease caused by protozoa of the genus *Eimeria*, leads to malnutrition and performance depression in poultry. There is an increasing interest in using essential oils against coccidiosis infection. The supplementation of essential oils

Please cite this article in press as: Zhai H, et al., Potential of essential oils for poultry and pigs, Animal Nutrition (2018), https://doi.org/10.1016/j.aninu.2018.01.005