

Can diets containing insects promote animal health?

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EDITORIAL

Insects are promising feedstuffs for animal feeds as they contain not only valuable nutrients but also particular compounds that seem to be able to modulate animal microbiota and to optimise animal health. So far, there has been little work on the effects of those insect derived compounds in animal feeding trails but initial investigations show promising results. This editorial discuss the effect of chitin, lauric acid, and anti-microbial peptides provided by insects.

Introduction

Population growth and increased welfare will be responsible for an increase in meat production especially in developing countries. The FAO's 'World Agriculture towards 2030/2050' report (FAO, 2017) forecasts an increase of 2.7% per year. The global feed market in 2017 reached a total of 1.07 billion metric tons with a feed industry growth of 13% over the past 5 years (Alltech, 2018). The (environmental) costs of conventional feed resources such as soybean meal (Prudêncio da Silva *et al.*, 2010) and fishmeal (Olsen and Hasan, 2012) are high and their availability in the future will be limited. Insect-based feed products could be a part of the solution (Makkar *et al.*, 2014). Several insect species can be efficiently raised on organic side streams and fed to a variety of animal species (Van Huis and Tomberlin, 2017). In general, most edible insect species appear to be good sources of amino acids, fatty acids, most minerals, and most B vitamins (Finke, 2002). The question that we address here is whether insects can have additional health benefits compared to conventional feed sources.

There are other considerations dealing with human health when insects are used as animal feed. Antibiotic resistance in humans is responsible for an estimated 23,000 and 25,000 deaths each year in the USA and Europe, respectively (Gelband *et al.*, 2015). This is mainly caused by the use of antibiotics in livestock: estimated in 2010 to be about 63,000 tons and projected to grow 67% by 2030 (Van Boeckel *et al.*, 2015). Approximately two thirds of antimicrobials are employed in livestock production as feed additives for chemotherapeutic and prophylactic purposes. They are also used to promote growth and improve feed efficiency,

but this practice has been banned since 2006 (EC, 2003) in the European Union. Their overuse contributes to the spread of drug-resistant pathogens in both livestock and humans, posing a significant public health threat. For this reason, there is an urgent need to develop novel antimicrobial agents (Wang *et al.*, 2016). The complex microbial communities living in an animal's gastrointestinal tract can be altered via the dietary inclusion of prebiotic compounds having a subsequent effect on the animal's immune system (Montalban-Arques *et al.*, 2015).

Chitin

Chitin is a component of the exoskeleton of crustaceans and insects (Finke, 2007; Wasko *et al.*, 2016). Chitin and chitin derivatives can stimulate innate immune cells (Lee *et al.*, 2008). Neither fish, birds or mammals synthesize chitin, so it is a potential target for recognition by the immune system (Elieh Ali Komi *et al.*, in press). For example addition of 1.0% chitin or chitosan extracted from shrimp shells to the diet stimulates immune response and affords disease resistance in the kelp grouper, *Epinephelus bruneus* against infections of the protozoan parasite, *Philasterides dicentrarchi* (Harikrishnan *et al.*, 2012). Similarly, feeding shrimp chitin to broilers inhibited the growth of the foodborne pathogens *Escherichia coli* and *Salmonella* in the intestine (Khempaka *et al.*, 2011). Providing fermented yellow mealworm (*Tenebrio molitor*) and super mealworm (*Zophobas morio*) larval meal (obtained by fermenting the insect meals with *Lactobacillus plantarum* and *Saccharomyces cerevisiae*) to broiler chicks, reduced cecal *E. coli* and *Salmonella* spp. and increased IgG and IgA levels (Islam and Yang, 2017). The reduction of pathogenic organisms was explained as

a combined effect of chitin and probiotics and the authors stated that larval probiotics could be used as an alternative to antibiotics.

Maintaining the optimal intestinal microbial communities of fish is important for the practice of aquaculture as it can affect the vulnerability of the host fish to diseases (Ghanbari *et al.*, 2015). In fish, research showed chitin is able to reduce pathogen growth by enhancing the growth of beneficial intestinal microbiota with positive effects on performance and health (Karlsen *et al.*, 2017). Feeding black soldier fly (*Hermetia illucens*) larval meal to rainbow trout (*Oncorhynchus mykiss*), showed an increased incidence of bacteria of the *Carnobacterium* genus, which are well-known probiotics in salmonids and have several functions: *in vitro* growth inhibition of pathogens, stimulation of non-specific immune response and *in vivo* improvement of disease resistance (Bruni *et al.*, 2018).

European sea bass fingerlings fed *T. molitor* larval meal had enhanced lysozyme antibacterial activity and serum trypsin inhibition (Henry *et al.*, 2018). Following the ingestion of maggot meal of the housefly (*Musca domestica*), black carp (*Mylopharyngodon piceus*) showed improvement in both lysozyme and complement activity and reduced mortality due to *Aeromonas hydrophila* (Ming *et al.*, 2013). Similarly, Ido *et al.* (2015) showed how low dietary levels of housefly larval meal led to innate immune system activation in red sea bream and protected against *Edwardsiella tarda* infection. The authors assigned this effect to bioactive compounds such as chitin or antimicrobial substances present in the housefly meal.

Chitin has hypolipidaemic and hypocholesterolaemic properties (Koide, 1998) in broiler chickens, resulting in a reduction in body fat and possibly the production of leaner meat (Hossain and Blair, 2007). Broilers fed diets with yellow mealworm larval meal had the lowest albumin to globulin ratio suggesting an enhanced immune response and a better disease resistance, likely due to the prebiotic effects of chitin (Bovera *et al.*, 2015). Similar results were found for laying hens fed about 1.02 g per day of chitin provided by dietary black soldier fly larval meal inclusion (Marono *et al.*, 2017). The same authors also reported lower serum cholesterol and triglyceride levels in birds fed diets containing black soldier fly compared to those fed a soybean meal based diet. They ascribed these results to the ability of chitin to bind to bile acids and free fatty acids.

Lauric acid

Lauric acid is known to have profound antiviral and antibacterial activity (Lieberman *et al.*, 2006). Black soldier flies are rich in fat, with levels ranging between 15 and 49% on dry matter basis (Makkar *et al.*, 2014). Notably, the fatty acid profile of the prepupae is high in the medium-chain

fatty acid lauric acid (C12:0). The fat of prepupae reared on organic waste streams with high amounts of starch contains up to 60% lauric acid (Spranghers *et al.*, 2017). Medium chain fatty acids are well known for their antimicrobial effects on gut microbiota, while lauric acid is particularly active against gram positive bacteria (Dierick *et al.*, 2002; Skřivanová *et al.*, 2005). Recently, an *in vitro* trial showed that black soldier fly prepupal fat (0.58 g C12:0/100 ml) suppressed growth of lactobacilli, with the most substantial antibacterial effects against D-streptococci infections in pigs (Spranghers *et al.*, 2018). In *in vivo* conditions it has been suggested that these positive effects are most likely seen when farming conditions and/or health status are sub-optimal (Schiavone *et al.*, in press). The possible antimicrobial effects of fat (C12:0) of the black soldier fly could provide an important added value when complete larvae/prepupae are used as a protein source in the feed of monogastrics (Spranghers *et al.*, 2017).

Antimicrobial peptides

Over use of antibiotics has been responsible for restricting the use of antibiotics in the feed industry, agriculture and veterinary medicine. Most antibiotics are small, cationic proteins that exhibit activity against bacteria and/or fungi, as well as certain parasites and viruses (Yi *et al.*, 2014). The greatest diversity of anti-microbial peptides are found in insects (Tonk and Vilcinskis, 2017). Until now, more than 150 insect proteins with antimicrobial activity have been identified and can be classified as follows: (1) α -helical peptides (e.g. cecropin and moricin); (2) cysteine-rich peptides (e.g. insect defensin and drosomycin); (3) proline-rich peptides (e.g. apidaecin, drosocin, and lebecin); and (4) glycine-rich proteins (e.g. attacin and gloverin) (Otvos, 2000). Insects living in germ-infested environments (e.g. flies) are a potent source of antimicrobials (Lee *et al.*, 2012). Anti-microbial peptides have an effect on different bacteria and the risk of bacterial resistance is low (Chernysh *et al.*, 2015). In pigs and broilers anti-microbial peptides improve growth performance, promotes nutrient digestibility and gut health, positively alters intestinal microbiota, and enhances immune function (Wang *et al.*, 2016). Ji *et al.* (2016) reported a marked decrease in diarrhoea of weaning pigs from day 15 to day 28 of the trial due to the dietary supplementation with yellow mealworm, giant mealworm and housefly meal, and ascribed this result to the antimicrobial peptide effect of insect meals.

In broilers the anti-microbial peptide P5 can be used as an alternative to antibiotics as a growth promoter (Choi *et al.*, 2013a,b). Antimicrobial peptides provide great hope due to the global problem related to the increasing resistance of bacteria to antibiotics. Bactericidal insect antimicrobial peptides may also protect against viruses and fungi. Although they have not yet been introduced on the market, according to Józefiak and Engberg (2017)

the outlook is promising, but much work remains to be done to arrive at large scale production for the application in livestock.

Conclusions

Insect meals are considered one of the most promising sources of alternative proteins for the sustainable future of animal feeds. Recent findings showed how insects could also be sources of valuable compounds able to exert positive effects on the animal immune system promoting health and reducing the use of antibiotics in animal production. Nevertheless, many aspects still need to be clarified and further research is highly recommended.

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