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Can insects be used in the nutrition of ruminants?

M. Renna[1*], L. Rastello[1] and L. Gasco[2]

[1]*Department of Veterinary Sciences, University of Turin, Largo Paolo Braccini 2, 10095 Grugliasco (TO), Italy;* [2]*Department of Agricultural, Forest and Food Sciences, University of Turin, Largo Paolo Braccini 2, 10095 Grugliasco (TO), Italy: manuela.renna@unito.it*

EDITORIAL

Abstract

Recent studies pointed out that live insects and their products (meals and oils) are suitable protein and fat sources and can be used in the nutrition of farmed monogastric animals. This is as an alternative to traditional plant-derived and animal-derived feedstuffs. To date very little information is available concerning the effects of the dietary inclusion of insects on feed digestibility and performance of ruminant animals. The aim of this editorial is to briefly review the published information on this topic.

1. Introduction

Currently, the global population is facing an important rise in food demand due to the continuous demographic increase and income growth in developing countries. This has led to a massive increase in demand for animal-derived food products (Gasco *et al.*, 2018) and severe competition between feed and food producers for natural resources (e.g. water and land), thus worsening the global situation of food insecurity (Fraanje and Garnett, 2020). Regarding the livestock industry, the feed cost accounts for approximately 60-80% of the total production costs, the most expensive feed ingredients being undoubtedly the protein sources (Uyeh *et al.*, 2018). Soybean meal (SBM) is by far the most used protein source for animal nutrition purposes worldwide, consequently being subjected to a high international price volatility (Pérez-Franco *et al.*, 2022). The increased cultivation of soybean and other oil crops has recently raised concerns due to the related negative impacts on the environment (e.g. greenhouse gas emissions and biodiversity losses) (Spiller *et al.*, 2020). The limited protein and energy feed sources available worldwide make this situation even more critical, and the need to find new sustainable alternatives in ruminant nutrition is compelling (Renna *et al.*, 2020).

In the last few decades, researchers have investigated various alternative protein sources that would best suit the demand of the feed industry and effectively meet the nutritional requirements of farmed animals. Insect-derived processed animal proteins (PAPs) are nowadays considered among the most promising and sustainable alternative protein sources for monogastrics as they can be obtained applying the circular economy model (Gasco *et al.*, 2020). Regarding ruminants, the use of insect-derived PAPs has been much less investigated so far. This is partly the consequence of the legislative framework currently applying in most developed countries (Lecrenier *et al.*, 2020). For instance, under the current European Union (EU) regulations, insect-derived PAPs are only authorised for use in the nutrition of monogastric (aquaculture, poultry, and swine) animals (European Commission, 2017; 2021). Conversely, for about 20 years, the EU has prohibited the use of PAPs in ruminant feed due to the outbreak of Bovine Spongiform Encephalopathy (BSE), also known as 'mad cow disease', an incurable neurodegenerative disease of cattle transmissible to humans, which occurred in the late '90s of the last century (European Commission, 2001). The same restriction also applies in other countries, e.g. USA, Canada, Argentina, and Japan (Ahmed *et al.*, 2021). However, the legislation that rules the use of insects in livestock production systems is not consistent among countries worldwide. In fact, many Asian and African countries do not impose limitations on the use of insects in ruminant nutrition (Jayanegara *et al.*, 2020).

Most published articles dealing with the use of insects in animal feed, and related effects on feed digestibility and quantitative-qualitative aspects of animal performance, have been released in the last decade by researchers from countries where the above-mentioned feed ban is applied. Therefore, literature on insects as feed has been mainly devoted to monogastric species, while research on the use of insects for ruminant rations is still at an infant stage. Considering that the expected population increase will be predominant in emerging countries (Mottet *et al.*, 2017), where the use of PAPs for ruminant feeds is allowed, research on this topic is highly relevant.

2. Digestibility and methanogenesis

Original research on the use of insects in ruminant nutrition dates back five years. The first trials were performed in Indonesia and focused on the assessment of *in vitro* digestibility aspects. Jayanegara *et al.* (2017a) found significantly lower *in vitro* dry matter (DM) digestibility, *in vitro* organic matter (OM) digestibility and total gas production for Jamaican field cricket (*Gryllus assimilis* Fabricius), yellow mealworm (*Tenebrio molitor* L.) and black soldier fly (*Hermetia illucens* L.) meals when compared to SBM. Using *H. illucens* larvae to substitute the 100% or 50% of SBM in a 60:40 forage:concentrate (F:C) diet, Jayanegara *et al.* (2017b) strengthened the previously obtained results, showing decreased ruminal ammonia concentration, *in vitro* DM digestibility, and *in vitro* OM digestibility as compared to the control diet containing SBM. The authors' hypothesis for such a depressed nutrient digestibility was the high fat and high chitin contents of the insect meals. However, the lowering of the chitin content in *G. assimilis* by means of exoskeleton removal and chitin chemical extraction was not successful in improving the digestibility characteristics of the crickets, suggesting that chitin may exert only a small role in lowering the overall digestibility performances when insects are fed to ruminants, and that other factors are involved (Jayanegara *et al.*, 2017c). It is well known that high-fat feedstuffs negatively affect ruminal microorganisms, specifically those involved in carbohydrate digestion (e.g. cellulolytic bacteria and protozoa), limiting the cellulolysis of structural carbohydrates (Palmquist and Jenkins, 2017). Moreover, variations in the fatty acid (FA) profile and protein content of insects may play a role in determining the ruminal degradation process (Hristov *et al.*, 2011; Vargas *et al.*, 2020), and interactions among these factors cannot be excluded. When using four edible insects, namely the house cricket (*Acheta domesticus* L.), the Taiwan giant cricket (*Brachytrupes portentosus* Serville), the two-spotted cricket (*Gryllus bimaculatus* De Geer) and the silkworm (*Bombyx mori* L.), as substitutes for the 25% of SBM in a 60:40 F:C diet, Ahmed *et al.* (2021) found no adverse effects on rumen fermentation characteristics or nutrient digestibility. This clearly suggests, as expected and recently confirmed by Phesatcha *et al.* (2022), that the insect dietary inclusion level also significantly affects fermentation and digestibility, as already reported to occur for monogastric animals (Elahi *et al.*, 2022; Hong and Kim, 2022; Tran *et al.*, 2022). Furthermore, Phesatcha *et al.* (2022) demonstrated that, when using *G. bimaculatus* meal as a protein replacement for SBM, regardless of the insect dietary inclusion or substitution level, fermentation and digestibility parameters were also affected by the F:C ratio of the diet, thus highlighting the great complexity of factors and interactions involved.

When evaluating insects as potential feed ingredients for ruminants, fundamental aspects to consider are related to protein, specifically the extent of ruminal protein degradation and the extent of intestinal digestibility of the protein not degraded inside the rumen. This was the goal of the work recently conducted by Toral *et al.* (2022) who, using three different methodologies, investigated the potential of four insect species (*T. molitor*, *Zophobas morio*, *Alphitobius diaperinus* and *A. domesticus*) as alternative protein sources for ruminants. These authors showed that the ruminal degradation of insect nitrogen (N) ranged, on average, from 46% for *T. molitor* to 74% for *Z. morio*, such values being lower than that of SBM (>85%) used by the authors as reference feedstuff. Low N degradation in the rumen may represent a positive aspect for ruminant nutrition purposes, if associated with a high intestinal digestibility. Toral *et al.* (2022) found that the *in vitro* intestinal digestibility of the N non-degraded inside the rumen ranged from 64% in *A. diaperinus* to 78% in *T. molitor*, thus demonstrating the potential of the four tested insects as alternative feedstuffs for ruminants.

Another field of interest for researchers working in the nutrition of ruminants is the mitigation of enteric methane emissions, as the latter contribute to global greenhouse gas emissions and represent a loss of feed energy, consequently determining a reduction of feed efficiency (Haque, 2018). In the study by Ahmed *et al.* (2021), the inclusion of *G. bimaculatus* and *B. mori* determined a 16% to 18% reduction of rumen methane production, confirming the results obtained for the same (*G. bimaculatus*; Phesatcha *et al.*, 2022) and other insect species (Jayanegara *et al.*, 2017a), and highlighting the potential environmental benefits of using insects as feed ingredients for ruminants. The oils chemically extracted from five insect species, namely *H. illucens*, *Z. morio*, *T. molitor*, *G. bimaculatus* and the weaver ant (*Oecophylla smaragdina* Fabricius), despite variations in their FA profile, were shown to be able to mitigate enteric methane emissions when added to both high forage (70:30 F:C) and high concentrate (30:70 F:C) diets (Jayanegara *et al.*, 2020). According to Haryati *et al.* (2019), chitin and chitosan extracted from *H. illucens* can decrease the acetate proportion in the rumen, thus reducing the production of H_2 and CO_2 as well. As most methanogenic archaea use H_2 and formate as energy sources (Beauchemin *et al.*, 2020), dietary insects overall result in a decline of ruminal methanogenesis.

3. Quantitative and qualitative aspects of animal performance

To date, very limited information is available on the effects of the dietary inclusion of insects on the quantitative and qualitative aspects of ruminants' production performance. In a recent review, the Indonesian researchers Astuti and Wiryawan (2022) summarised the potential uses of the black soldier fly, the most widely used insect species in animal feed research, and its by-products (e.g. frass) as ingredients for milk replacers, creep feeds, fattening rations, and as a source of lauric acid (for its anti-bacterial effect) and lactic acid bacteria (to replace the use of antibiotic growth promoters) in ruminants. The few results obtained so far seem promising, except for the use of insect frass that, being characterised by a high concentration of undigestible fibre and chitin, led to a significant decrease in the digestibility of dry matter, organic matter, nitrogen-free extract and total digestible nutrients when compared to a commercial concentrate in the ration of growing goats.

Astuti *et al.* (2019) also analysed the effects of including cricket (*G. bimaculatus*) meal in milk replacers destined for pre-weaning goat kids and, as a substitution of soybean meal, in diets destined for post-weaning goats. This study showed interesting results, since the pre-weaning goat kids fed with the milk replacer containing the cricket meal showed no significant differences in their physiological status parameters and had the same average daily gain and final body weight when compared to the goat kids fed with goat milk. Similarly, the post-weaning goats fed with the cricket meal (up to 30% of the concentrate) did not show any significant variation in the rumen fermentation profiles or in their growth performance when compared to the post-weaning goats fed the control concentrate containing soybean meal. Overall, such results showed no adverse effects on palatability and health status of the goats when the cricket meal was included in their diet.

No information is currently available regarding the inclusion of insects in diets destined for dairy ruminants and the related effects on milk yield and composition. According to Hervás *et al.* (2022), some oils derived from insect defatting processes (e.g. from *A. domesticus* and *B. mori*) may potentially be used in the substitution of soybean oil to improve the energy density of ruminant diets and to modulate ruminal biohydrogenation, increasing the concentration of the health-promoting vaccenic (C18:1 *trans*-11) and rumenic (C18:2 *cis*-9, *trans*-11) acids, without altering the concentrations of C18:1 *trans*-10 (which may exert potentially negative effects on animal performance and human health). However, the contribution that insects may provide to the overall quality and the nutraceutical value of milk, meat and derived products is expected to be quite variable, since the fatty acid profile of insects strongly depends on the insect species, the developmental stage, the applied technological processes, and the substrate used for insect rearing (Gasco *et al.*, 2022; Riekkinen *et al.*, 2022). Most insect meals tested so far for monogastric feeding purposes are characterised by a high content of unsaturated fatty acids (mainly of the n-6 series) and could therefore be interesting for the improvement of the quality of ruminant-derived food products.

4. Conclusions

Although the available data on the potential uses of insects as alternative protein and fat sources to traditional plant-derived feedstuffs in ruminant nutrition are encouraging, research on the topic is still very limited, thus preventing any conclusive remarks so far. Some *in vitro* studies highlighted a relatively low digestibility of insects in ruminants, which may restrict their use, unless processing technologies are developed to improve this aspect. Further *in vitro* trials, but especially i*n vivo* feeding trials, are advocated to assess the effects of live insects, insect meals, insect oils and insect by-products on the quantitative and qualitative aspects of ruminant production systems, as well as on the health of these farmed animals. Last, but not least, safety aspects must be addressed. Insects are currently banned for their use as feeds to ruminants in many countries worldwide due to the perceived risk of BSE. Even if to date there has been no evidence to suggest that insects carry and transmit prions (DiGiacomo and Leury, 2019), further specific research is clearly required on this topic.

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