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EDITORIAL

Direct-fed microbial: Animal nutrition and reproduction responses

Manipulating the gastrointestinal microbial ecosystem to enhance animal performance and reproductive responses has been one of the main goals of animal science researchers and veterinarians. Recent restrictions to the use of antimicrobials as growth promoters led researchers to seek alternative practices that can show promise both from the standpoint of efficacy as well as from the practical and economic aspects. One of the alternatives that surfaced as very promising in the last few decades is the use of direct-fed microbials (DFM) as a means to modulate the effects of the gastrointestinal microbiome on the host immune status, health and productivity.

Direct-fed microbials or probiotics is a term most commonly reserved for live, naturally occurring microorganisms that can be supplemented orally to animals to cause a beneficial effect in the host animal. The main objective of this special focus is to expand the knowledge on the mode of action of different microorganisms used as additives as well as to explore novel species of microorganisms and their potential contributions to enhance animal performance and health in ruminants and non-ruminants.

As a member of JIA Editorial Board and the guest editor, we are very pleased to see that 12 of the manuscripts were accepted by the Editor-in-Chief of the *Journal of Integrative Agriculture* for publication in this special focus. These manuscripts accepted reflect some of the newer frontiers in terms of DFM research, highlighting novel applications of well researched DFM, as well as novel microorganisms with potential to enhance animal productivity or decrease environmental impact of animal production.

Section 1: Direct-fed microbials as inoculants to improve fiber digestion

The field of silage inoculants has demonstrated great advances in recent years and it is one of the technologies in feed conservation that has been proved consistently cost-effective. The search for new bacterial inoculants continues to be an area of active research. In this special focus, Reyes-Gutiérrez *et al.* (2015) discussed an innovative and low-cost approach by testing the effects of an inoculum based on urea, molasses, yogurt, minerals (sulfate and phosphorous) and chicken manure. Under the same concept of providing inoculum to enhance fiber digestion during the ensiling process, Liu *et al.* (2015) discussed the effect of lactic acid bacteria culture broth on rice straw digestion and nutritive value, and they reported an improvement in the aerobic stability of rice straw when fermented using the lactic acid bacteria as an inoculant. Similarly, Marrero *et al.* (2015) used *in vitro* ruminal fermentation models to show that different species of the yeast *Candida* spp. may affect ruminal fermentation differently, however, in all cases, the fermentation variables were positively affected, relative to control treatments. Their work highlighted the potential impact of the correct choice of DFM on ruminal fermentation. The role of yeast DFM in rabbits health and performance was studied by Campos-Morales *et al*. (2015). The authors reported that feeding the yeast *Saccharomyces cerevisiae* negatively affected nutrient digestibility in volcano rabbits in captivity. Furthermore, their study, which was conducted at the Chapultepec Zoo (Mexico City, Mexico), showed that *S. cerevisiae* supplementation increased the mortality rate in volcano rabbits.

Section 2: Fungi, enzymes and new developments in direct-fed microbials

Elghandour *et al.* (2015) and Abdel-Aziz *et al.* (2015b) provided a review of the current literature available on the potential of DFM to enhance fiber digestion, especially in low quality feedstuffs, respectively. The authors in both manuscripts highlighted the potential of exogenous enzymes as feed additives to aid in the digestive process of fibrous feedstuffs such as sugarcane bagasse, which is researched more in depth by Abdel-Aziz *et al.* (2015a) using rabbits as a

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model animal. Complementing the overview by Elghandour *et al.* (2015), Puniya *et al.* (2015) conducted a review of available DFM, their proposed mode of action and effects on animal performance. The authors concentrated the review on the potential of anaerobic fungi in ruminant diets, providing a very relevant discussion on the potential of fungal DFM to mitigate enteric methane emissions. The potential contributions of DFM to decrease the environmental impact of ruminant production has not been explored extensively, and Puniya *et al.* (2015) provided some insight into potential benefits considering the state of current knowledge. Also related to the environmental impact of DFM, Kumar *et al.* (2015) explored the potential of a bacteriocinogenic strain of *Pediococcus pentosaceus* in decreasing methane emissions *in vitro*. They investigated the effects of *P. pentosaceus* on *in vitro* gas production and substrate digestibility, and noted as a curious result, that the addition of live cultures of this DFM decreased methane production, indicating a potential environmental effect.

Moreno-Camarena *et al.* (2015) and Hernández-García *et al.* (2015) investigated the effects of supplementing organic minerals such as selenium and chromium to lambs, with or without the addition of *Saccharomyces cerevisiae.* Moreno-Camarena *et al.* (2015) showed that the supplementation with up to 0.4 mg of organic chromium per kg of diet dry matter to Suffolk lambs did not enhance growth performance, while showing some positive effects on muscle conformation. Hernández-García *et al.* (2015) investigated the effects of supplementation lambs with either *S. cerevisiae* yeast, organic Se and Cr, or yeast plus organic Se and Cr. No effects on lamb growth performance (average daily gain, final body weight, back fat) were reported by either organic Cr and Se, or organic minerals plus yeast, while either organic minerals or minerals plus yeast increased dry matter intake when compared with control lambs (Hernández-García *et al.*, 2015).

Exploring the use of novel DFM with potential to enhance fish growth, a novel approach was taken by Bhatnagar and Lamba (2015), where microflora from the economically important fish *Cirrhinus mrigala* were isolated and identified. The authors identified several bacterial species with antimicrobial potential and incorporated one of them (*B. cereus*) into a pellet that was later fed to fish, showing an enhanced growth performance and protein digestibility. The research approach by Bhatnagar and Lamba (2015) represented an innovative step towards the search for alternatives to antimicrobial growth promoters.

Conclusion

In conclusion, many of the recent advances in the area of DFM research have been related to the discovery of new microorganisms with potential to enhance animal productivity, or additional properties of known DFM. Considering the increasing pressure to produce more animal proteins with a decreased environmental footprint, future DFM research would likely be directed at processes that target decreased greenhouse gases emissions from enteric fermentation, or other environmental pollutants. Increasing the efficiency of feedstuffs utilization will also continue to be an area of active DFM research, with the objective of decreasing the carbon footprint per unit of animal protein produced.

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