

Prebiotics in the feeding of monogastric animals

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Generalities on the prebiotic concept are presented. The characteristics of fructans, including inulin as the most used additive worldwide, are highlighted. Its beneficial effect on the health and productive performance of animals is referred.

Key words: *prebiotic, fructans, additive, monogastric.*

INTRODUCTION

Antibiotics have been traditionally used on the feeding of monogastrics as growth promoter additives to improve the productive performance and the prevention of diseases (Murry *et al.* 2006). However, the continuous consumption of antimicrobials at sub-therapeutical level increases the possibility of finding antibiotics residues on the feeds and the development of bacteria resistant to these substances (Morales 2007). Besides, antibiotics damage the ecological balance of the gastrointestinal biota, hence they predispose animals to diseases. This situation has provoked regulator actions by different countries. In the European Union, for example, the use of these products as additives in animals' diets was forbidden (European Parliament and Council 2003).

Searching for alternatives on the use of antibiotics as growth promoter additives and due to the importance of the eubiotic stage of the intestinal microbiota for

animal nutrition, researches to assess different additives to improve the health and productive indicators of animals were conducted (Castro 2005 and Santomá *et al.* 2006). The strategies developed are based on managing organic acids (Ricke 2003), essential oils and other plant extracts (Ayala 2005), symbiotic (Rostagno *et al.* 2003) and probiotic (Doyle and Erickson 2006 and Souza *et al.* 2007). It is pretended to increase the interest on applying prebiotics as non-edible feed ingredients favoring the specific development of the beneficial intestinal biota (Lewis *et al.* 2005 and García *et al.* 2006).

The objective of this review was to present some generalities on prebiotics and their mechanisms of action, as well as to characterize the fructans, including the inulin. The beneficial effect of prebiotics on the health and productive performance of the animals is also intended to be explained.

PREBIOTICS. CONCEPT

In 1995, Gibson and Roberfroid defined the term prebiotic as a feed ingredient influencing positively on the hostage for the selective stimulation of growth and activity of one or a limited number of bacteria in the colon, implying health improve. This definition only considered the changes on the microbiota of the colon ecosystem. Gibson *et al.* (2004) redefined this concept and characterized prebiotics as feed ingredients fermented selectively by the beneficial intestinal biota. They also modify its composition and metabolic activity, contributing to improve the health of the hostage.

According to Schrezenmeir and de Vrese (2001), prebiotics should present the following attributes: not be hydrolyzed or absorbed in the upper part of the gastrointestinal tract, be a selective substrate, for one or limited number of beneficial intestinal bacteria such as *Lactobacillus spp.* and *Bifidobacterium spp.*, and be able to modify the microbiota on a population or activity more benefic.

The intestinal microbiota composition is modified by adding prebiotic products in the diets of monogastrics and health benefits are obtained.

PREBIOTICS MECHANISMS OF ACTION

The prebiotics have a marked incidence on the metabolic activity of the intestinal microbiota (Kaplan and Hutkin 2000), they are part of the stimulation of the immune system (Swanson *et al.* 2002), regulate the

glucose levels and the lipid metabolism (Van Loo *et al.* 1999) and increase the bioavailability of minerals (Aggett *et al.* 2003), among other benefits.

The main fermentation products of prebiotics are

the short-chain fatty acids, mainly acetic, propionic and butyric acids (Guarner and Malagelada 2003). These acids diminish the intestinal pH, affect the pathogen microorganisms and favor the intestinal eubiosis (Bosscher *et al.* 2006).

The acetic acid is absorbed and gets to the liver through the portal vein. This is the main passage through which the hostage obtains energy from the non-digested soluble carbohydrates (Roberfroid 1999). The propionic acid regulates the cholesterol metabolism (Hara *et al.* 1999). The butyric acid is the main energy source for the intestinal epithelium and regulates the growth and cell differentiation (Salminen *et al.* 1998).

The diminishing of glucose concentration in blood is among the physiological effects generated by the prebiotics supply (Gibson and Roberfroid 2008). Delzenne and Kok (2001) state that the ingestion of fructan stimulates the development of the intestinal mucosa cells in the cecum-colon region, where the greatest amount of L endocrine cells is in the intestine synthesizing the peptide 1 type glucagon (GLP 1). This peptide is part of the control of glucose metabolism, when stimulating the insulin secretion in the β pancreatic cells and inhibiting the synthesis of glucagon in the cells α .

The increase of minerals bioavailability due to the prebiotics supply is attributed, mainly, to the high production of SCFA, which diminish the luminal pH

and increases the concentration of ionized minerals in the large intestine. As consequence, solubility increases, as well as the active and passive diffusion of minerals through the intestinal cells (Coudray *et al.* 2003 and Holloway *et al.* 2007).

The use of prebiotics increases the specific and non-specific immunity, which is related with the stimulation of benefic microorganisms (Dubert-Ferrandon *et al.* 2008). One of the main functions of prebiotics is the activation and regulation of immune mechanisms. In this sense, they prevent the colonization of pathogens through the adhering and blocking of the intestinal surface, stimulates the intestinal immune-competent cells, associated to the linfoid issue; tonify the immune system thorough the activation of macrophagous and favor the high levels of immunoglobuline (local and systemic). They also take place on the differentiation of suppressing cells or stimulators and of limphocytes (Seifert and Watzl 2008).

Some authors state that prebiotics may regulate the lipidic metabolism and be part of the diminishing of triglicerids and colesterol (Letexier *et al.* 2003 and Uyeda and Repa 2006). The propionic acid production through fermentation is part of the cholesterol diminishing as it inhibites the enzyme 3-hidroxi-3-metil-glutaril-CoA reductase (HMG-CoA reductase) that regulates this metabolic via of synthesis (Nagendra 2000).

TYPES OF PREBIOTICS

The molecular structures that could be considered as prebiotics are still under study. However, there is experimental evidence that could allow the inclusion of some non-digestible soluble carbohydrates in this group (Voragen 1998 and Tuohy *et al.* 2003). These products are recognize as secure substances and are classified according to their chemical structure (Hantermink 1999).

Both, oligo and non-digestible polysaccharides could have prebiotic activity. However, the structures with low polymerization are more used for this purpose as they are a substrate of easy fermentation for the beneficial intestinal microorganisms (Perrin *et al.* 2001).

The compounds with prebiotic criteria are: fructans,

oligosaccharides of glucan and mannan, lactulose, lactitol, xiloglucanes and oligogalacturonides. Some of them need more research to deepen in their effects (Delzenne 2003 and Hopkins and Macfarlane 2003).

Fructans, mainly inulins, are the most studied and commercialized prebiotics. One or more links fructosilfructose are most of the glycosidic links. They are hot-resistant carbohydrates and very soluble in water and ethanol (López *et al.* 2003). They are synthesized in some plants, fungi and bacteria, and their structure could be linear or root-like (Roberfroid and Delzenne 1998).

CHARACTERISTICS OF FRUCTANS

The presence of fructans in plants was first reported in 1804, when they were extracted from *Inula helenium* (Mancilla 2006). In plants, only 15 % of the angiosperm flora is capable of producing these carbohydrates. These species belong, mainly, to the orders Asterales (*Cichorium intybus* and *Helianthus tuberosus*), Liliales (*Allium cepa*) and Poales (*Triticum aestivum* and *Hordeum vulgare*) (Hendry and Wallace 1993 and Ritsema *et al.* 2004).

Generally, the fructans' structure comprises an initial saccharose, followed by a variable number of fructose residues, which in their form β -D-furanose, get together by glycoside links, although sometimes these compounds do not have the glucose molecule. The structure of glucose molecule belongs to the series GF_n, and those with only fructose molecules belong to that of Fn (Franck 2002). The absence of reducing power in fructans facilitates their conformational stability

(Waterhouse and Chatterton 1993).

Vijn and Smeekens (1999) classify fructans in five main groups, and consider the major structural units forming their molecules:

- Inulin: it is a linear polymer of units D-fructose with links β (2-1) and a molecule of saccharose in one of their extremes. It is in some plants of the Asterales order, such as achicoria (*Cichorium intybus*) and alcachofa of jerusalem (*Helianthus tuberosus*) and in some fungi.

- Levan or flein: is a linear polymer of units D-fructose with links β (2-6). It is in pastures like *Dactylis glomerata* and in bacteria.

- Graminan: contains both thypes of links β (2-1) and β (2-6). This molecule is in most of the plants of the Poaceae family, like wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*).

- Inulin neo-series: the structural unit of this fructan is based on the neo-kestose. It is present in the asparagus (*Asparagus officinalis*) and onion (*Allium cepa*).

- Levan neo-series: compound polymer of residues of fructose with unions β (2-1) and β (2-6) on both extremes of an internal glucose. It is the less common fructan and it is in few species of Poales, like

oats (*Avena sativa*).

These carbohydrates may be found in form of oligo or polysaccharides. The International Union of Pure and Applied Chemistry and the International Union of Biochemistry defined the oligosaccharides as compounds with certain degree of polymerization in their structure, between two and ten units. In the case of fructans, they are named fructooligosaccharides or oligofructans. Those of highest polymerization degree are polysaccharides (van Loo *et al.* 1999).

In plants, fructans are part of different functions: they are reserve of carbohydrates, are part of osmoprotection (Wang and Nobel 1998), and tolerance to cold (Tabaei *et al.* 2003), drought and salinity (Pilon *et al.* 1995 and Kerepesi y Galiba 2000). The studies of the last decades highlight that these carbohydrates have several applications on medicine, feeding and industry (Yun 1996 and De Leenher and Smeekens 1998). Therefore, obtaining fructans for their application in animals (Awati *et al.* 2006 and van Loo and Vancraeynest 2008) and humans (van den Heuvel *et al.* 2009 and Lavanda *et al.* 2011) is important, as they are ingredients that offer nutritional value to the feedings and improve the health of the consumer.

FRUCTANS AS PREBIOTICS IN THE FEEDING OF MONOGASTRIC ANIMALS

At present, the use of fructans as prebiotic additives in animal production increases (de Lange *et al.* 2010 and Huyghebaert *et al.* 2011). Different experiments show that the inclusion of these products have positive effects on the physiology and productive performance of animals. Table 1 shows examples of the action of these compounds.

It is necessary to consider that the prebiotic effect depends on different factors, including the type of compound, the dosage, the animal species, the exploitation conditions, among other. All this influences on their activity and on the different physiological and productive responses found in the literature.

Table 1. Action of fructans as prebiotics on monogastrics

Animal category	Effects	Reference
Pigs (fattening stage)	Disminishing of escatol in the digesta and fat issue. Reduction of enterobacteria in the colon	Kjos <i>et al.</i> 2010
Pigs (weaning stage)	Reduction of ammonia excretion. Changes on the bacterial metabolic activity	Halas <i>et al.</i> 2010
Broilers	Increase of <i>Bifidobacterium spp.</i> and diminishing of mortality when supplying fructooligosaccharides	Cao <i>et al.</i> 2005
Laying hens	Increase of mineral absorption of calcium and phosphorous in the shinbone. Increase of hardness of the egg shell and cholesterol diminishing of the yolk	Janssens y van Loo 2006
Ducks	Diminishing of the cecal pH and increase of the short-chain fatty acids concentration , mainly of butyric acid	Zduncz <i>et al.</i> (2005)
Rabbits	Diminishing of mortality and increase of the short-chain fatty acids with diminishing of the cecal pH	Volek <i>et al.</i> (2004)

FINAL CONSIDERATIONS

Prebiotic additives are a viable alternative for substituting antibiotics as growth promoter additives in monogastric production due to their beneficial effects on the hostage. Fructans are among the most studied compounds for these purposes, with great structural diversity influencing on their prebiotic response. Their main effects are related with the stimulation of the beneficial intestinal microbiota, the activation of the

immune system, the improvement of the digestive physiology and its repercussion of the productive performance. It is necessary to increase the diffusion of knowledge related with prebiotics their use and achieve positive effects on monogastrics' feeding. Likewise, new sources of raw material should be found for obtaining these products.

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