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Organic Acids in Today's Livestock Production

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Abstract

Organic acids have been used for decades as forage and grain preservatives and in livestock nutrition. They make an important contribution to feed hygiene, as they suppress the growth of mold and bacterial pathogens. Due to their antimicrobial activity are also effective in maintaining the nutritional value of the feed to ensure animal performance, as well as improving nutrient digestibility, which in turn leads to stable animal health and increased performance. The most commonly used organic acids in feed are propionic, fumaric, formic and lactic acid, with an overall Compound Annual Growth Rate of 4.5%. Europe represents the biggest market due removal of sub-therapeutic antibiotics in 2006 (Regulation (EC) Nº 1831/2003). This situation has increased the interest in improving intestinal health and nutrient utilization. Different feed additives and nutritional strategies have shown promise in changing and mediating the response and recovery of the animals to various stressors and challenges after the AGP's prohibition. The primary effect of antibiotics is antimicrobial and organic acids have several additional effects that go beyond that antimicrobial activity. Organic acids have a clear and significant benefit in weanling piglets and in poultry performances. This review presents recent studies on the effect of organic acids on enteric diseases, nutrient digestibility, immune response and performance in broilers and piglets.

Introduction

The European Union allowed the use of organic acids and their salts in animal production because these are generally considered safe (Adil et al., 2010). Formic, propionic, lactic, citric, fumaric and sorbic are used under the classification "feed preservative" (Lückstaädt and Mellor, 2011) and have been included for decades in feeds. Other short-chain fatty acids (C4-C7) or medium-chain fatty acids (MCFA, C8-C12) are feed materials. Some of these acids are synthetics and others like MCFA's are naturally present in foods such as coconut oil and palm kernels.

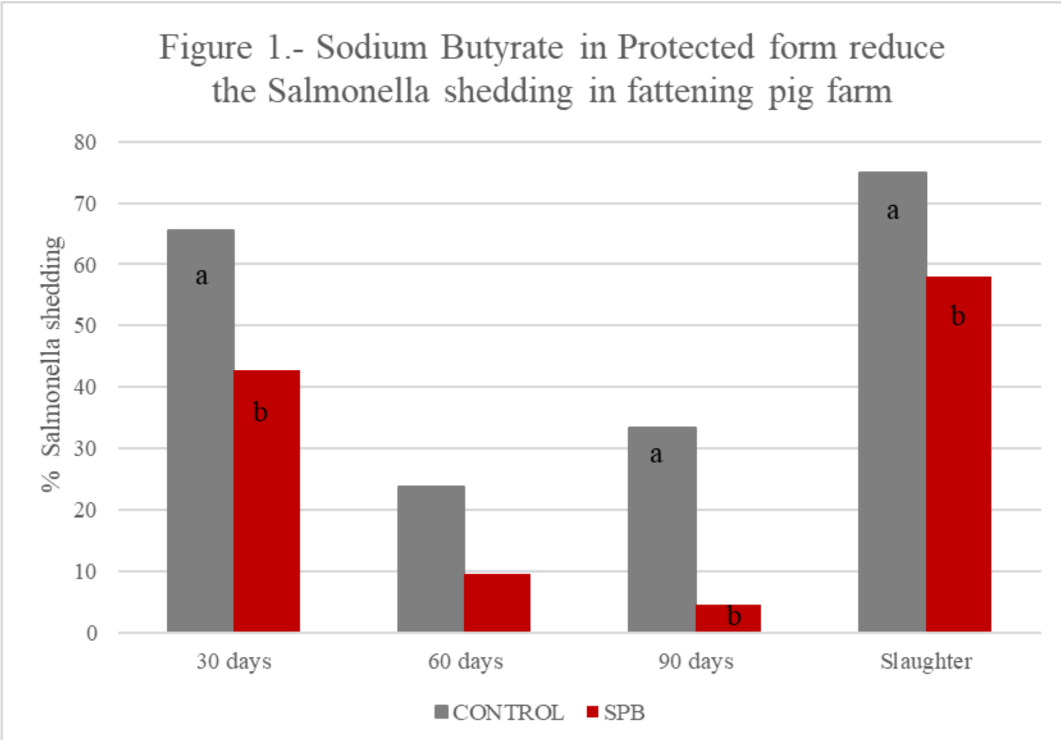
They are characterized by the possession of one or more carboxylic group with general structure of R-COOH. Their capacity to give up protons defines how strong or weak is an acid. A quantitative measure of acid strength is pK (a negative logarithmic scale of dissociation constant). It is characteristic of each acid and depends on whether it is lineal (formic, acetic, propionic), hydroxyl group contents (lactic, malic and citric acid) or it has the presence of double bonds like fumaric and sorbic acids (Shahidi et al., 2014).

Organic acids are available on the market in a variety of forms:
Adsorbates: liquid acids or mixtures of acids adsorbed onto a solid, inert substrate, usually silica or sepiolite.

Salts: produced by reaction acid-base to obtain solid product (except, for example, ammonium formate and ammonium propionate which are liquids) to minimize functional properties such as corrosion, volatility and odor.
Coated: produced by mixing with vegetable fat and spry-system with the objective to release the organic acid in the lower gastrointestinal tract.
Protected: produced by double reaction of organic acid and medium or long chain fatty acids delaying the release of carboxylic acid along the gastrointestinal tract.
This review presents recent studies on the effect of organic acids on enteric diseases, nutrient digestibility, immune response and performance in broilers and piglets.

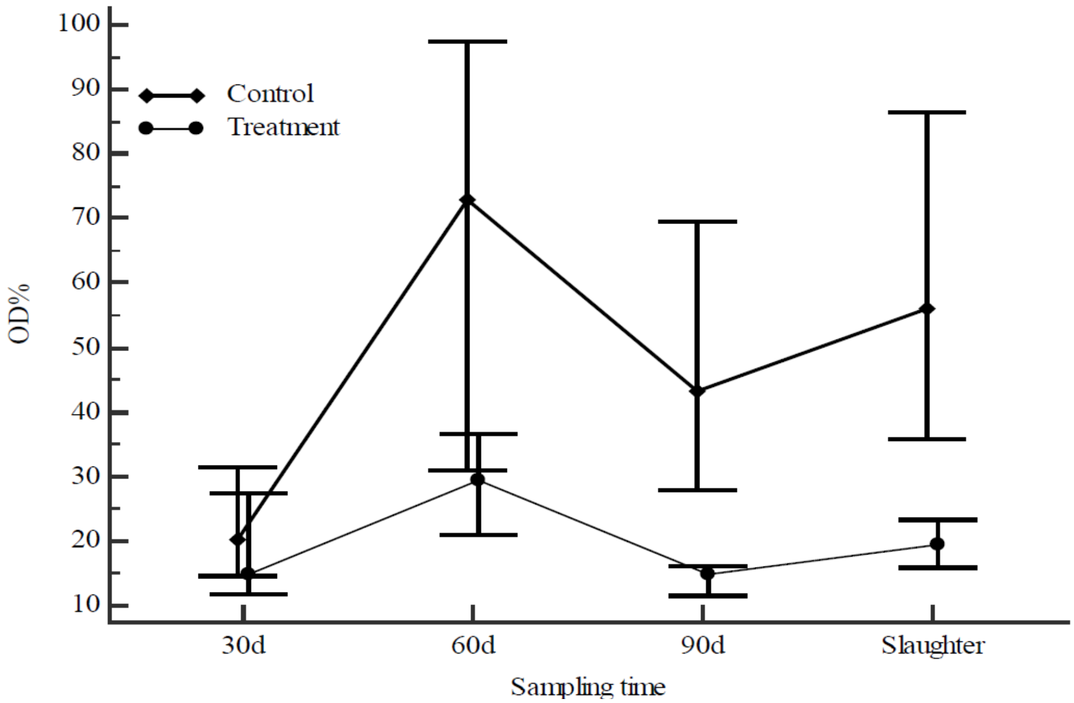
Microbiological Effect

Molds are present in feed ingredients and will grow when environmental conditions allow. It's important to ensure they are controlled in order to avoid deterioration of feeds. The addition of propionic acid is suitable onto high moisture whole cereal grain where mold growth is very likely and a rapid control measure is needed. Combining different short chain fatty acids (e-g. propionic in combination with acetic or formic acid) is known to enhance the mold-reducing effect of individual acids (Fefana, 2014).
Salmonella, *Campylobacter* and *Escherichia coli* are the most common bacteria that affect the intestinal health and are important for public health.
Odd-numbered medium-chain fatty acids (MCFA), such as C7 and C9 could have potential as feed additives but are poorly described. In a *in vitro* digestion test both compounds showed a significant reduction of analyzed bacterial count (*Coliforms*, *Streptococci*, *Lactobacilli*) in the stomach and small intestine (De Smet et al., 2016).
In challenging tests in poultry with *Salmonella*, feed supplementation with acetic and formic acid resulted in an increase colonization of ceca, liver and spleen while birds receiving propionic acid as feed supplement were colonized to the same extent as control group. However, butyrate in feed, resulted in a significant decrease of colonization by *S. enteritidis* in the ceca but not in internal organs (Van Immerseel, 2014).
Protected sodium butyrate demonstrated a significant reduction of *Salmonella* infection in birds with better results than non-protected presentation (Fernández-Rubio et al., 2009). In a similar way, different presentations of butyrate (protected with sodium salts of palm fatty acids distillates or coated with vegetable fat) and protected sodium heptanoate showed a significant reduction of *Salmonella* presence in internal organs (spleen and liver) of birds challenged with *Salmonella* (Puyalto et al., 2016).
The dietary administration of protected sodium butyrate during the whole fattening pigs period was able to reduce significantly the seroprevalence and shedding of *Salmonella*, which may reflect a positive effect on the control of *Salmonella* at the end of this period (Casanovas-Higes et al., 2017a) (Figure 1).



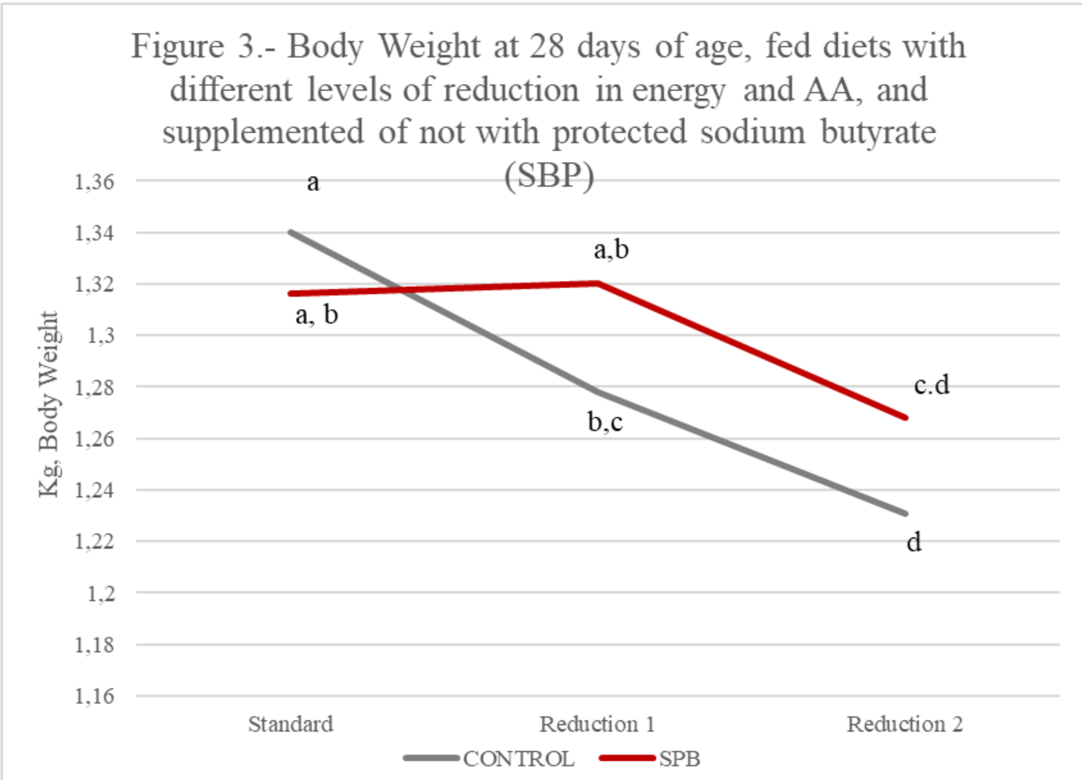
Organic acids can be used in combination with MCFA. MCFA have larger molecules compared with organics acids with slower breakdown and with the capacity to reach the lower part of the intestinal tract where can exert an antimicrobial effect, while organic acids (with no protection or encapsulation) are present at the beginning of the small intestine. The inclusion of sodium salts of coconut fatty acids distillates (3 Kg/t) with high level of MCFA (mainly C12) in swine, significantly reduced coliforms in ileum and in caecum (Sol et al., 2016). In addition, MCFA are effective against Gram + bacteria, such as *Clostridium perfringens* (Sol et al., 2017). It has been demonstrated that, a new form of sodium butyrate protected with sodium salt of coconut fatty acid distillate (3 Kg/t) controls *Salmonella* infection in fattening pigs with a significant reduction in the number of infected pigs (4% vs. 61%; P<0.01). The median OD% value for both groups was similar at 30 days, but in subsequent samplings median OD% values remained significantly lower for the group supplemented with the additive (Figure 2) (Casanovas-Higes et al., 2017b).

Figure 2.- Median OD% values for the control and treatment group (sodium butyrate protected with sodium salts of coconut fatty acids distillate) in fattening pigs



Nutrient Digestibility Effect

Organic acids are an option for improving nutrient digestibility. In poultry diets, dietary 0.5% fumaric or 2% citric acid increased digestibility of CP and EE and 0.5% of fumaric acid or 2% citric acid increased ME (Ghazala et al., 2011). Moreover, supplementation with 0.5% or 1% formic acid (Hernández et al., 2006 and Garciá et al., 2007) in broiler finisher diets was found to improve apparent ileal digestibility (AID) of dry matter (DM; 67.8% or 68.8%, respectively) and crude protein (CP; 72.5% or 73.5%) as compared with control (56.4% DM and 60.7% CP). Lohakare et al. (2005), found at 19 days that gross energy (GE), CP and ether extract (EE) in supplemented group with 2% ascorbic acid was higher than non-supplemented group. The addition of sodium butyrate at 1 Kg/t of feed, showed a significant digestibility improvement of energy (5.8%) and protein (4.7%) in broilers (Mallo et al., 2011). It may be related by the better development of the intestinal epithelium showing an increased intestinal surface that was in contact with the feed bolus ensuring a better digestion (Pluske et al., 1997). This diet digestibility improvement may explain the reduction in feed conversion ratio that is normally observed with the use of sodium butyrate (Mallo et al., 2011). Considering those facts, it was designed a trial to prove, that the addition of protected sodium butyrate could reduce the energy and protein content of the diets without negative effects on performance of broilers. The results showed that sodium butyrate in protected form (1 Kg/t) improved the performance of nutritionally reduced feed broiler (- 60 and 120 Kcal of ME and - 2.3% and 4.6% of total amino acids) (Bortoluzzi et al., 2017).



Reduction 1: - 60 Kcal of ME and - 2.3% of total amino acids
Reduction 2: - 120 Kcal of ME and – 4.6% of total amino acids

Effect on immune response

Organic acids may stimulate the natural immune response in poultry and swine. Houshmand et al. (2012) found that at 21 days of age of broilers, dietary addition of organic acids (combination of Formic, Lactic, Malic, Tartaric, Citric and Orthophosphoric acid (0.15% starter diet) resulted in significant increases in antibody titres against Newcastle disease. Abdel-Fattah et al. (2008) and Ghazala et al. (2011) reported that birds fed an organic-acid-supplementation diet (formic or acetic or citric or fumaric) had heavier immune organs (bursa of Fabricius and thymus) and higher level of globulin in their serum. Concentration of globulins is used as an indicator for measuring immune response. Citric acid supplementation (0.5%) in poultry diets enhanced the density of the lymphocytes in the lymphoid organs, enhancing the non-specific immunity (Haque et al., 2010).

Dietary substances can manipulate the expression of endogenous host defense peptides (HDPs), which may provide a promising strategy for disease control and prevention, especially for antibiotic-resistant infection. Feed supplementation with 0.1% butyrate led to a significant increase in HDP gene expression in the intestinal tract of chickens (Sunkara, et al. 2011).

Butyrate in piglets (Xiong et al., 2015) enhances disease resistance promotes clearance of *E. Coli* O157:H7 and alleviates clinical symptoms of hemolytic uremic syndrome and inflammation partially by affecting endogenous HDP expression.

Performance Effect

The multifactorial analysis of Partanen et al. (2001) demonstrated that organic acids improved all performance parameters in weaned and fattening pigs compared to non-acidified control diets.
In 2008, it was applied to a dataset collected from all available published material on the use of acidifiers in pigs using 458 publications and comprising nearly 38,000 pigs (Rosen, et al., 2008). Most of these tests included fumaric, citric, formic or propionic acids, calcium formate, potassium diformate and propionic salts and were performed with weaners. The holo-analytical models derived demonstrate that using acids in pig diets improves the productivity parameters of greatest importance to economic success. The magnitudes of improvements were: 1.2% on feed intake, 5.5% on weight gain and 3.7% on feed conversion ratio (FCR).

On the other hand, the addition of 0.4% of butyrate in broiler diets was similar to antibiotics in maintaining body weight gain (Panda et al., 2009). The use of sodium butyrate protected with sodium salt of palm fatty acids and Zinc Bacitracin combination, resulted in a significant improvement of FCR when compared with the control treatment without additives (Ortiz et al., 2014). In other study, broilers fed with sodium butyrate in protected form showed significantly higher EPEF (European Production Efficiency Factor) than animals receiving the control diet (Mallo et al., 2010). Chicks fed with organic acids (3% Fumaric or 3% Lactic acid) showed a significant improvement in the FCR versus the control diet (Adil et al., 2010 and 2011b) found that the highest weight gains were achieved in the birds fed fumaric compared to lactic acid. Another trial in which broilers were given basal diet supplemented with 2-3% each of butyric, fumaric and lactic acid (Adil et al., 2011a) showed a significant improvement in FCR as against the chicks fed the control diet. Fascina et al. (2012) reported that the use of an organic acid mixture (comprising 30% Lactic acid, 25.5% benzoic acid, 7% formic acid, 8% citric acid and 6.5% acetic acid) in broilers diets improved its performance as compared to the control at 42 days. An increase of body weight gain was observed in broilers fed with added and acidifier mixture (formic, phosphoric, lactic, tartaric, citric and malic acids) in the broiler diet at the rate of 0.15%.

Conclusion

Organic acids and their salts are active ingredients available for the feed. Their effects are far beyond the control of mold and bacteria in the feed and are basic for the new age of production without the use of medicines. Which organic acid or combination, their presentations and doses, depend on the species, environment and diet formulation among other parameters, and every nutritionist must think, evaluate and find which is the best solution for their situation.

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