Results of the addition of Malate to the diet of dairy cows

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INTRODUCTION

The feed strategy in ruminants is based in the symbiosis between ruminal microorganisms and the animal. The objective of this symbiosis is to get the highest quantity of energy and protein from the ruminal ecosystem.

For the development of the ruminal fermentation, the microorganisms need carbohydrates as energy source and protein or non proteic nitrogen as a source of aminoacids. The end product used by the animal is the volatile fatty acids (VFA) from which the animal gets more than 60% of the energy and the microbial protein of high biological value which will be absorbed in the intestine.

The objective of the regulation of the ruminal fermentation is to maximise the level of energy and protein in the cow optimising microbial development, keeping favourable conditions for the rumen and the microbiota and improving the fermentation of the different carbohydrate fractions.

The salts of dicarboxylic acids such as sodium or calcium malate are amongst the additives used in the feed of dairy cows. These salts have an activity in the ruminal ecosystem increasing the microbial population, improving the digestibility of the different nutrients and increasing the quantity of microbial protein in the intestine.

ORGANIC ACIDS SALTS AND RUMINAL FERMENTATION

The use of malate as ruminal fermenter started in the 70’s. It was found that the supplementation of feed with malate had a stimulant effect in certain microbial populations which modified the fermentation patterns in the rumen.

Paynter and Elsden in 1979 observed that bacteria of the Selenomona family increased the propionate and acetate production by direct oxidation of lactate. The requirements of the Selonomas were studied by Linehan et al. in 1978 who discovered that substrates such as malate stimulated the growth of Selenomonas in in vitro cultures.

The first studies in dairy cows were performed by Kung et al. in 1982. They observed an increase in the persistence of the lactation curve in dairy cows when malate was added to the diet.

Russel and Van Soest (1984) demonstrated that the addition of malate to in vitro cultures increased the production of volatile fatty acids which is the main source of energy for dairy cows.
The studies performed by Nisbet et al. (1990) concluded that the consumption of lactate by Selenomona increased when malate was added. From these studies malate was started to be used with the aim of reducing the lactic acid in the rumen which is the main cause of acidosis. Malate has been used for many years to increase the ruminal pH without taking into account the advantages that it had as a substrate for different bacteria populations which became the most important use of malate.

In 2006, the studies by Khampa et al., demonstrated that the addition of malate to calves feed significatively increased the microbial population of the rumen and the amilolytic and cellulolytic flora and that it decreased protozoal population.

When the flora in charge of carbohydrate digestion increases, there are two different outcomes at the same time: first, an increased digestion of carbohydrates and secondly an increased production of microbial protein available in the intestine.

A second study by Khampa published in the same year, showed that an increased dose of sodic malate from 10 to 20 grams produced a significant increase of Megasphera and Selenomona, two bacteria families which produce volatile fatty acids as a final product of fermentation.

These increases in microbial population have also been reported in other malate studies: Sniffen et al. (2006) observed an increase in the microbial protein when malate was added to a dairy cows diet. The results were reported by Tejido et al. and by Gomez et al. Both authors had similar results when they added malate to diets with different levels of forage and concentrate.

Malate acts as substrate for different microbial populations by stimulating bacterial growth and improving the conditions in the rumen.

**DIGESTIBILITY AND VOLATILE FATTY ACIDS**

There are numerous studies showing improved digestibility of different fractions of the diet by adding malate; there is evidence of increased digestibility of the dry matter (Liu 2009, Sniffen 2006, Carro 1999, Newbold 2005), of the organic matter (Liu 2009, Sniffen 2006), of the neo-detergent fiber (Liu 2009, Sniffen 2006, Carro 1999), of the acid detergent fiber (Sniffen 2006) and of the hemicellulose (Carro 1999). These increases in the digestibility fit with the idea of malate as stimulant of the growth of different microbial populations which are involved in the degradation of carbohydrates.

In the same way there are a number of studies that have reported increases in the production of total volatile fatty acids when malate was added in vitro (Martin Streeter 2005, Carro 1999, Carro and Ranilla 2003, Gomez 2005) or in vivo in calves (Vicini 2003, Khampa 2006, Liu 2008) and in dairy cows (Kung 1982, Martin 1999, Khampa 2006). This increase in volatile fatty acids (VFA) give extra energy to the cows.

**Effects on milk production in dairy cows**

Four studies including 516 dairy cows were performed in order to evaluate the effect of the use malate in milk production. For the 4 studies, two treatments were used: a control group and a treatment group. The treatment group consisted in the control diets supplemented with malate (48-84 grams per cow per day depending on the study). The four studies were similar in design and treatments; the selected groups were equivalent in variables such as number of calvings, milk production before the start of the study and the lactation period (in days). Three studies consisted in supplementing the diet with 48 grams of sodic-calcic malate per cow per day and one study consisted in supplementing the diet with 84 grams per cow per day.

Milk production was measured every day until day 90 in lactation and the weekly average production was also calculated during this period.

The homogeneity of the data was assessed; the data was then integrated and combined in a meta analysis.
The combined result of the analyses of all the studies was a significant increase in milk production; 43.85 litres per cow per day in the malate treated group versus 41.81 litres (p=0.0107; ES=0.346) in the control group. There was an increase of 2.3% in the weeks of the studies. There were interactions between the treatment and the production week (p=0.0015).

As it can be seen in figure 1, the inclusion of malate increased milk production from the first week of its use until the fourth week and then it kept the increase during all the period of the study.

The conclusion is that the inclusion of malate in high producing dairy cows diets increases milk production.

Similar results had been already reported by Kung 1982 who observed that the inclusion of malate increased the persistence of the production curve. Studies performed by Sniffen et al. (2006) showed statistically significant increases in milk production (p<0.01) of 1.5 litres when malate was added (36.8 control group vs 38.3 malate group). Wan et al. (2009) observed an increase in milk production in dairy cows with higher doses of malate in the diet (p<0.05).

Peripartum biochemistry parameters

The postpartum in the ruminants is characterized by a period of negative energy balance (NEB). The levels of non-esterified fatty acids (NEFA) and betahydroxybutirate (BHB) are negatively correlated with the negative energetic balance; therefore the levels of NEFA and BHB can be used as energy balance indicators.

The levels of BHB are also used for the diagnostic of postpartum ketosis. In the NEB period the cow mobilises fat and the incomplete oxidation of the NEFA results in an increased plasmatic level of BHB; increased levels of BHB are the cause of ketosis in dairy cows.

Wang et al. (2009) investigated the effects of the addition of malate on blood parameters such as BHB, NEFA, glucose and insulin during the peripartum period and observed that the addition of malate increased the levels of glucose and insulin in blood and reduced the levels of BHB and NEFA.

They also observed a decrease in weight loss in the peripartum period when the dose of malate was increased. The loss of weight was lower when increasing the doses of malate per cow and day. (Figure 2)

Based on these results, the authors concluded that the inclusion of malate improved the energetic balance, decreased the fat mobilisation during the postpartum period and improved the biochemical parameters indicators of ketosis.

Therefore, malate can be an effective tool in improving the NEB during the prepartum and peripartum periods. Malate can also be used as a preventative of ketosis and to improve the NEB in the postpartum.

CONCLUSIONS

The addition of malate in the diet of dairy cows increases the amylolytic and cellulolytic microbial flora which improves the digestibility of several nutrients which in turn, increases the production of microbial protein and the production of VFA. This improves the energy and protein metabolism of ruminants. The improvements in metabolism have a beneficial effect in the energy balance of the dairy cows in the postpartum period by improving blood parameters and reducing the risk of metabolic diseases. The use of malate increases milk production and the persistence of the lactation curve.
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