Available online at www.sciencedirect.com
ScienceDirect
Animal Feed Science and Technology
135 (2007) 222–235
ANIMAL FEED SCIENCE AND TECHNOLOGY
www.elsevier.com/locate/anifeedsci

Malic acid supplementation in growing/finishing feedlot bull calves: Influence of chemical form on blood acid–base balance and productive performance

C. Castillo [a,*], J.L. Benedito [a], V. Pereira [a], P. Vázquez [a], M. López Alonso [a], J. Méndez [b], J. Hernández [a]

[a] *Departamento de Patología Animal, Facultad de Veterinaria, Universidad de Santiago de Compostela, Campus Universitario s/n, 27002 Lugo, Spain*
[b] *Departamento Técnico de COREN, SCL. c/Juan XXIII 33, Orense, Spain*

Received 24 January 2006; received in revised form 15 June 2006; accepted 20 July 2006

Abstract

The aim of the present study was to evaluate the effects of two chemical forms of malate (malic acid and a commercial malate salt) on acid–base balance and productive performance in cattle maintained in a commercial feedlot system, taking into account the entire productive cycle (i.e., the growing and finishing periods). Thirty-eight Belgian Blue bull calves were utilized for a 148-day feedlot study. Animals were allotted randomly to one of three experimental groups: (1) control group (C, no supplementation, $n = 10$), (2) DL-malic acid supplementation (MA, $n = 14$; 4 g/kg DM basis) and (3), supplementation with a commercial salt of DL-malic acid (MS, $n = 14$; 4 g/kg DM basis). Blood pH, pCO_2, HCO_3^-, base excess (BE) and serum L-lactate were determined. Productive data were also evaluated as complementary information for understanding internal changes associated with supplementation. Although no differences (P>0.1) were found in performance parameters, results

Abbreviations: ADF, acid detergent fibre expressed exclusive of residual ash; ADG, average daily gain; BE, base excess; BW, body weight; C, control diet (non-supplemented); CP, crude protein; DM, dry matter; EE, ether extract; HCO_3^-, actual bicarbonate; MA, diet supplemented with 4 g of DL-malic acid; MS, diet supplemented with 4 g of disodium malate–calcium malate; NDF, neutral detergent fibre expressed exclusive of residual ash; pCO_2, partial pressure of CO_2

* Corresponding author. Tel.: +34 82 285900; fax: +34 82 285940.
E-mail address: ccasti@lugo.usc.es (C. Castillo).

0377-8401/$ – see front matter
doi:10.1016/j.anifeedsci.2006.07.010

were numerically better for supplemented animals than for controls. The efficiency of the organic acid supplementation varies depending on its chemical form and on productive stage: while similar results were observed using the salt form or the free acid in the growing period, better results were obtained with the acid form in the finishing period. Looking at blood parameters, the malate salt seems to be more effective than the acid form due to the fact that the latter tended to decrease blood bases (although the possibility that the malate salt may cause blood alkalinization due to decreased pCO_2 needs to be further explored). Finally, the effect of supplementation on blood L-lactate was shown ($P<0.05$) from the first week of the study: controls showed higher values than supplemented animals. In the growing period, differences were observed between C and MA steers, and between C and MS in the finishing period. In our opinion, there is a clear need for research evaluating the effects of organic acids on ruminant health *in vivo*.

Keywords: Malate salt; Malic acid; Beef cattle; Acid–base balance

1. Introduction

The economics of feedlot beef production dictate that cattle must gain weight at their maximum potential; this involves getting them quickly onto a high-energy diet containing a high concentration of grain. Economics also favour processing of grain by available methods to increase the digestibility of starch (Castillo et al., 2006). All these factors may lead to ruminal disturbances in feedlot cattle (Owens et al., 1998).

Extensive research over recent years has explored the effects of antibiotic feed additives on ruminal fermentation, and such additives have become essential management tools for preventing or controlling ruminal acidosis (Martin, 1998). However, increasing concern over the widespread use of such additives and the corresponding new regulations proposed by the European Commission has prompted an interest in possible alternatives, such as organic acids (Castillo et al., 2004). One such organic acid is malate, a key metabolite of the citric acid cycle of ruminal bacteria; it stimulates lactate uptake by *Selenomonas ruminantium*, the main bacteria within the rumen, improving the ruminal environment and increasing propionate production (Callaway and Martin, 1996; Martin, 1998).

Nevertheless, compared with the amount of research, both *in vivo* and *in vitro*, that has been conducted with other feed additives, very little research has been done to evaluate dietary supplementation with the organic acid. Several important questions regarding the use of malic acid as a feed additive remain unanswered. Notably, what is the most appropriate chemical form of malic acid to add to the diet?

As pointed out by Flores (2004), organic acids can be added to the diet either as the free acid (in this case $C_4H_6O_5$), or as a salt (in this case, for example, calcium malate or sodium malate). Previous studies carried out *in vitro* (Martin and Streeter, 1995) have shown that when incorporated into the ruminal fluid medium, the effects of free malic acid are similar to those of the disodium salt, although their different chemical form implies different effects on the ruminal fluid. Nevertheless, several questions remain unanswered.