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Review Article

The Role of Zeolite as Feed Additive in Finishing Diets for Ruminants: An Approach Under Energetic Perspective

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Abstract

The estimation of dietary net energy (NE) based on measures of growth-performance and the ratio of observed-to-expected dry matter intake (DMI) which describe the apparent energy retention per unit DMI) reveal differences in the efficiency of energy utilization of the diet itself, independently of confounding effects of daily weight gain (ADG) and DMI associated with gain efficiency measures (gain-to-feed ratios). Thus, it provides important insight into potential treatment effects on the efficiency of energy utilization. In this mini-review we evaluate the role of zeolite as feed additive in finishing diets for ruminants with respect to changes in energetic efficiency (observed vs expected dietary NE). Accordingly, we find that zeolite supplementation of high-energy finishing diets for feedlot cattle and feedlot lambs increases the efficiency of dietary energy utilization by ≈ 4.5%. The basis for this improvement requires further study. But may be attributable to improved ruminal N economy and enhanced digestible and metabolizable energy.

Keyword: *Zeolites; Ruminants; Finishing Diets; Energetics*

Abbreviations

NE: Net Energy; DMI: Dry Matter Intake; ADG: Average Daily Weight Gain; VFA: Volatile Fatty Acids; CEC: Cation Exchange Capacity

Introduction

Natural zeolites are crystalline aluminosilicates composites of volcanic origin [1]. Their dimensional structures enable zeolites to lose and gain water reversibly and to exchange cations [2]. Clinoptilolite is the most abundant natural zeolite. Its high cation-exchange properties (about twice the CEC of bentonite clay) [3] and in particular, its binding capacity with ammonia-N, has attracted interest for its use as a feed additive in ruminant nutrition [4]. As a supplement to high-grain finishing diets, zeolite enhanced ruminal starch digestion, and shifted ruminal VFA molar proportions, decreasing the acetate-to-propionate ratio [5,6]. This later effect may reflect ruminal proton competition, decreasing methanogenesis. Notwithstanding potential beneficial effects on aspects of ruminal fermentation, the net effect of supplemental zeolite on animal performance has not been consistent. In some instances zeolite supplementation enhanced gain efficiency [7]. However, in other growth-performance trials involving feedlot cattle [5,8,9] and feedlot lambs [10-12], the effect of supplemental zeolites (up to 4% of diet dry matter) on gain efficiency has not been appreciable.

What is the explanation for the absence of improvement in gain efficiency with zeolite supplementation in the face of observed enhancements in characteristics of digestion? The answer lies in a limitation of gain efficiency as a measure of feeding value. Because zeolite is a "functional" feed ingredient, having no intrinsic energy value, its substitution in the diet as a replacement for grain will reduce the energy density of the diet in proportion to the replacement. In this mini-review we will evaluate the role of zeolite as feed additive in finishing diets for ruminants approached from the perspective of energetics.

Estimation of dietary energetics

Many researchers are less familiar with applied energetics and how truly predictable growth performance is based on energy intake. If all performance studies were to actually compare observed intake with an expectation there might be considerably less publication bias in the literature. And, publication bias is becoming an ever increasing concern as we move to more and more meta-analysis. Expected DMI refers to how much DM the animals are expected to consume based on their average shrunk weight, observed ADG, and tabular NE value of the diet [13]. Observed-to-expected DMI and observed-to expected dietary net energy is important and practical applications of current standards for energetics in nutrition research [13,14]. The estimation of dietary NE based on measures of growth-performance and the ratio of observed-to-expected DMI (apparent energy retention per unit DMI) reveal differences in the efficiency of energy utilization of the diet itself, independently of confounding effects of ADG and DMI associated with gain efficiency measures (gain-to-feed ratios). Thus, it provides important insight into potential treatment effects on the efficiency of energy utilization. An observed-to-expected dietary NE ratio of 1.00 indicates that performance is consistent with dietary NE values based on tables of feedstuff standards and observed DMI. A ratio that is greater than 1.00 is indicative of greater efficiency of dietary energy utilization. Whereas, a ratio that is lower than 1.00 indicates lower than expected efficiency of energy utilization. In the case of the observed-to-expected DMI, the interpretation of the ratio is exactly the opposite. Values below 1.00 mean greater energy retention per unit of DMI.

Reports by Zinn., *et al*. [13] and Estrada-Angulo., *et al*. [14] provide, in detail, the equations used in the determination of expected DMI and dietary NE have for feedlot cattle and feedlot lambs, respectively. We respectfully encourage readers to review those articles. The magnitude of dietary energy changes by zeolite inclusion is presented as a percentage over the expected dietary energy of the test diet once zeolite was included. For this review, only studies performed with feedlot cattle and feedlot lambs fed finishing diets containing ≥ 70% concentrates were considered. Data included were from peer-reviewed articles published in indexed journals that included finishing phase of feedlot and lambs, in which animals received a basal diet as a control group and zeolite as tested group that direct replaces some ingredient or as a top dressed added. Data include for energetic calculations were: average initial weight, final weight, DMI, ADG, and type (breed and sex) of animal used.

Applying energetic concepts to zeolite reports

When the impact of zeolite supplementation is analyzed from the perspective of gain efficiency (gain-to-feed ratio), reported differences in gain efficiency were not appreciable. Viewed differently, however, supplementation with zeolite (that of itself does not contribute energy) did not reduce gain efficiency. Accordingly, with zeolite supplementation, the observed dietary NE was greater than expected.

Feedlot trials

McCollum and Galyean [5] evaluated clinoptilolite (from Nevada, USA) supplementation (1.25 and 2.5% of diet DM) in feedlot cattle fed a sorghum-based finishing diet. Dietary starch concentration in diets decreased up to 6% with zeolite inclusion (equivalent to remove 4% grain). Gain efficiencies were similar for control vs zeolite treatments (0.119 vs 0.122 kg gain/kg DMI, respectively). However, from the standpoint of energetics, supplemental zeolite increased (3.4%) the observed-to-expected dietary NE. Sherwood., *et al.* [8] evaluated clinoptilolite (from South Dakota, USA) supplementation (1.2% of diet DM), replacing corn in the finishing diet fed to crossbreed cattle.

Numerically, the zeolite supplementation enhanced ADG (3.4%) and gain efficiency (2.9%). However, from the standpoint of energetics, zeolite supplementation resulted in a 4.4% increase in the observed-to-expected dietary NE. This improvement is equivalent to a 3.5% increase in the level of dietary corn. In a 292-d study, Koknaralog., *et al*. [15] evaluated clinoptilolite at 1% of diet DM (no origin specification) as a replacement for sugar beet pulp a finishing diet fed to Brown Swiss cattle. They did not observed detect differences in gain efficiency (0.114 vs 0.116 kg gain/kg DMI) between treatments. Nevertheless, the observed dietary NE was 3.21% greater than expected with zeolite supplementation. In a 224-d of a trial evaluating up to 2% supplemental kaolinite (source Ion mineral, CA, USA) as a replacement for flaked corn in finishing diets fed to Holstein steers, Ortiz *et al*. [16] observed a linear increase (up to 3.1%) in observed-to-expected dietary NE ratio. Yazdani., *et al.* [9] report both increased gain feed efficiency (16.7%) and observed dietary NE (12.6%) with clinoptilolite (Anzymite, Theran, Iran) supplementation (up to 5%) of otherwise isocaloric finishing diets fed to Holstein steers.

More research is needed to more fully elucidate the basis for increased energy utilization with zeolite supplementation. As mentioned previously, the supplemental zeolite may enhance ruminal N economy [17], digestible energy [7] and metabolizable energy through favorable alterations in ruminal VFA molar proportions [5].

Finishing lambs trials

As with feedlot cattle, studies of zeolite supplementation in finishing lambs are limited. In a 70-d trial, Pond [10] evaluated 2% clinoptilolite (from Wyomin, USA) supplementation as a replacement for corn in finishing diets fed to lambs. They did not detect an effect of zeolite supplementation on lamb gain efficiency. However, inclusion of zeolite in diets that contained soybean meal as a protein source resulted in a 3.4% increase in the observed-to-expected dietary NE. Whereas, with diets containing fishmeal as the supplemental protein source, supplemental zeolite inclusion resulted in a 14.2% increase in observed-to-expected dietary NE ratio. The very large improvement with zeolite supplementation with fish meal supplemented diets although unexpected, might be attributable to the effects of zeolite on ruminal N economy when degradable intake protein is potentially limiting. Forouzani., *et al*. [11] evaluated up to 6% supplemental clinoptilolite (Anzymite, Tehran, Iran) as a replacement for barley in a corn-silage and barley-based finishing diet. They did not detect treatment effect on lamb gain efficiency. However, supplemental zeolite resulted in a 12% increase in observed-to-expected dietary NE. Toprak., *et al.* [12] evaluated the inclusion of micronized clinoptilolite (from northern Croatia) in wheat and barley-based diets fed to Merino X lle de France lambs. Inclusion of 1% micronized zeolite resulted in a 4.2% increase in the observed-to-expected dietary NE. The positive effects of supplemental zeolite on energetic efficiency in finishing lambs have been confirmed in studies conducted by our research team [18,19]. In trials, we evaluated a natural clinoptilolite from Mexico (ZEO-ZIL, TCDN Group, Puebla Mexico) utilizing Pelibuey × Katahdin lambs. In the first experiment, we evaluated the inclusion levels of 0, 1, 2 and 3% (DM basis) of clinoptilolite replacing soybean meal in corn-based finishing diets in a 56-d feeding trial. The ratio of observed-to-expected dietary NE increased linearly from 2 to 6% as zeolite inclusion increased in diets increased from 1 to 3%. In other 75-d finishing trial, we tested inclusion levels of 0, 1.5, 3 and 4.5% zeolite, replacing equal portions of corn and soybean meal in lambs. There was a quadratic response to zeolite supplementation level. Improvements in gain efficiency, dietary net energy and apparent energy retention per unit of DMI were maximal at the 3% level of supplementation (averaging improvements of 4.5, 6.4 and 7.4%, respectively).

Conclusion

The concept of feed efficiency has a limitation to evaluate the changes on energy utilization when inert ingredients (i.e. clays) replaces conventional ingredients that contain energy (i.e. grains or protein concentrates). Applying energetic concepts (observed-to-expected dietary energy) to several reports in which zeolite was evaluated in high-energy diets for cattle and for lambs, zeolite supplementation increases the efficiency of dietary energy utilization by ≈ 4.5%. The basis for this improvement is not fully understand and requires further studies. But may be attributable to improved ruminal N economy, and enhanced digestible and metabolizable energy, mainly by changes on passage of digesta rate.

Conflict of Interest Statement

The authors declare that this paper was written in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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