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A meta-analysis on the effect of dietary application of exogenous fibrolytic enzymes on the performance of dairy cows

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ABSTRACT

The aim of this study was to use meta-analytical methods to estimate effects of adding exogenous fibrolytic enzymes (EFE) to dairy cow diets on their performance and to determine which factors affect the response. Fifteen studies with 17 experiments and 36 observations met the study selection criteria for inclusion in the meta-analysis. The effects were compared by using random-effect models to examine the raw mean difference (RMD) and standardized mean difference between EFE and control treatments after both were weighted with the inverse of the study variances. Heterogeneity sources evaluated by meta-regression included experimental duration, EFE type and application rate, form (liquid or solid), and method (application to the forage, concentrate, or total mixed ration). Only the cellulase-xylanase (C-X) enzymes had a substantial number of observations (n = 13 studies). Application of EFE, overall, did not affect dry matter intake, feed efficiency but tended to increase total-tract dry matter digestibility and neutral detergent fiber digestibility (NDFD) by relatively small amounts (1.36 and 2.30%, respectively, or <0.31 standard deviation units). Application of EFE increased yields of milk (0.83 kg/d), 3.5% fat-corrected milk (0.55 kg/d), milk protein (0.03 kg/d), and milk lactose (0.05 kg/d) by moderate to small amounts (<0.30 standard deviation units). Low heterogeneity (I^2 statistic <25%) was present for yields and concentrations of milk fat and protein and lactose yield. Moderate heterogeneity (I^2 = 25 to 50%) was detected for dry matter intake, milk yield, 3.5% fat-corrected milk, and feed efficiency (kg of milk/kg of dry matter intake), whereas high heterogeneity (I^2 > 50%) was detected for total-tract dry matter digestibility and NDFD. Milk production responses were higher for the C-X enzymes (RMD = 1.04 kg/d; 95% confidence interval: 0.33 to 1.74), but were still only moderate, about 0.35 standardized mean difference. A 24% numerical increase in the RMD resulting from examining only C-X enzymes instead of all enzymes (RMD = 1.04 vs. 0.83 kg/d) suggests that had more studies met the inclusion criteria, the C-X enzymes would have statistically increased the milk response relative to that for all enzymes. Increasing the EFE application rate had no effect on performance measures. Application of EFE to the total mixed ration improved only milk protein concentration, and application to the forage or concentrate had no effect. Applying EFE tended to increase dry matter digestibility and NDFD and increased milk yield by relatively small amounts, reflecting the variable response among EFE types.
Key words: fibrolytic enzymes, cellulase, digestibility, xylanase, fiber

INTRODUCTION

Several studies have examined the efficacy of using exogenous fibrolytic enzymes (**EFE**) to improve milk production by lactating dairy cows. Milk production was increased by dietary application of EFE in some studies (Rode et al., 1999; Kung et al., 2000; Yang et al., 2000) but not others (Beauchemin et al., 2000; Kung et al., 2002; Sutton et al., 2003). Also, EFE application improved DM digestibility in some studies (Rode et al., 1999; Yang et al., 2000; Arriola et al., 2011) but not in others (Lewis et al., 1999; Weiss et al., 2011). Notable increases in feed efficiency were reported in some studies (Lewis et al., 1999; Klingerman et al., 2009; Arriola et al., 2011) but not in others (Schingoethe et al., 1999; Rode et al., 1999; Kung et al., 2002). This inconsistency in response has been attributed to differences in enzyme activity, application rate and composition, stage of lactation of dairy cows, mode and time of EFE delivery, ruminal microbial activity, ruminal EFE stability, EFE-feed specificity, and the portion of the diet

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to which EFE are applied (Beauchemin et al., 2004; Adesogan, 2005). Additional factors that may explain the variability include using experiments with insufficient statistical power, inappropriate experimental designs and or durations, inappropriate enzyme choices, as well as use of inappropriate measures of enzyme activity and misleading enzyme designations (Adesogan et al., 2014).

Although there have been several excellent reviews on effects of EFE application on forage quality and animal performance (McAllister et al., 2001; Beauchemin et al., 2003; Meale et al., 2014), which provide a synopsis of the literature, they only provided qualitative summaries. To our knowledge, no study has summarized published responses to EFE application to dairy cow diets using a statistically robust approach such as meta-analysis. Meta-analyses are a more rigorous alternative to narrative discussions of research studies (Glass, 1976). Methods for applying meta-analysis in animal and veterinary science have been described (Lean et al., 2009).

We hypothesized that across studies, EFE application would improve DM and NDF digestibility and hence improve the performance of dairy cows. The objective of this paper was to review critically and summarize published research studies on effects of dietary treatment with EFE on diet digestibility and the performance of lactating dairy cows. A second objective was to examine the existence of heterogeneity and publication bias among the studies.

MATERIALS AND METHODS

Relevant papers were identified by searching for peer-reviewed manuscripts that were published in English using online manuscript retrieval databases [Web of Science (https://login.webofknowledge.com), PubMed (https://www.ncbi.nlm.nih.gov/pubmed), Scirus (http://www.sciencedirect.com/scirus/), Google Scholar (http://www.scholar.google.com/), ScienceDirect (http://www.sciencedirect.com/)]. Up to 114 publications were retrieved using search terms including "fibrolytic enzyme," "dairy cow," and "fiber" and "fibre." We also contacted researchers and organizations involved with this field of study for input. Of the papers that were retrieved, only those that satisfied the predetermined inclusion criteria were included in the analysis.

The study selection criteria were (1) publication in English in a peer-reviewed journal, (2) use of concurrent negative control and treatment groups, (3) use of confined or housed lactating dairy cows, (4) use of continuous experimental designs rather than change-over or Latin square studies, (5) use of at least one fibrolytic enzyme as a dietary treatment, (6) description of the main enzyme activity(ies) that were applied, and (7) presentation of least squares means and standard errors of the means for DMI, milk yield, FCM, and feed efficiency (FCM/DMI). The study exclusion criteria were: (1) did not involve feeding a TMR, (2) involved a study that was not randomized, (3) involved animals on pasture, and (4) involved low genetic merit dairy cows.

We only included peer-reviewed publications in the study because the peer review process is a proxy for assessing the quality of studies (Weisz et al., 1995). In addition, more heterogeneity existed among non-peer-reviewed studies in a similar meta-analysis on effects of yeast culture products on the performance of dairy cows (Poppy et al., 2012).

Data Extraction

Data for DMI, milk yield, milk composition, feed efficiency, total-tract DM digestibility, and total-tract NDF digestibility were used to estimate outcomes.

Sources of variability in the data set included the EFE type, form (liquid vs. solid), composition, microbial source, application rate and method, as well as the designation of the main EFE activity and the duration of the experiments. Consequently, the data were classified based on these factors. The types of EFE identified by the authors were as follows: xylanase (**X**), cellulase-xylanase (**C-X**), ferulic acid esterase (**FAE**), cellulase-FAE (**C-FAE**), endoglucanase-xylanase (**En-X**), and amylase-exogenous proteolytic enzyme (**A-EPE**). Certain EFE that included nonfibrolytic activities such as amylase and protease or bacteria were retained in the analysis because relatively few studies met our selection criteria. Rate of application was calculated for each treatment as grams of EFE/kilogram of total diet DM. Methods of EFE application examined were application to the forage, concentrate, or the TMR. Effects of such methods on the performance of cows were only analyzed for experiments in which the EFE was applied to diets in each of the 3 methods. The form of EFE application was classified as liquid or solid.

Statistical Analysis and Effect Sizes

Statistical analysis was conducted on the extracted data using Stata software version 14.1 (StataCorp LP, College Station, TX). The Z score was used to examine the null hypothesis that EFE treatment had no effect. In addition to the significance of the relationships, the magnitude of the relationships (effect size) was examined using the standardized mean difference [**SMD**; SMD = raw mean difference (**RMD**) between EFE treatment and control means divided by the pooled