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Meta-analysis to predict the effects of metabolizable amino acids on dairy cattle performance

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ABSTRACT

Meta-analytic methods were used to determine statistical relationships between metabolizable AA supplies and milk protein yield, milk protein percentage, and milk yield in lactating dairy cows. Sixty-three research publications (258 treatment means) were identified through a search of published literature using 3 search engines and met the criteria for inclusion in this meta-analysis. The Cornell Net Carbohydrate and Protein System (CNCPS) version 6.5 was used to determine dietary nutrient parameters including metabolizable AA. Two approaches were used to analyze the data. First, mixed models were fitted to determine whether explanatory variables predicted responses. Each mixed model contained a global intercept, a random intercept for each experiment, and data were weighted by the inverse of the SEM squared. The second analysis approach used classical effect size meta-analytical evaluation of responses to treatment weighted by the inverse of the treatment variance and with a random effect of treatment nested within experiment. Regardless of the analytical approach, CNCPS-predicted metabolizable Met (g/d) was associated with milk protein percentage and yield. Milk yield was positively associated with CNCPS-predicted metabolizable His, Leu, Trp, Thr, and nonessential AA (g/d). Milk true protein yield was also associated with CNCPS-predicted metabolizable Leu (g/d). Predicted metabolizable Lysine (g/d) did not increase responses in production outcomes. However, mean metabolizable Lys supply was less than typically recommended and the change with treatment was minimal (157 vs. 162 g; 6.36 vs. 6.38% metabolizable protein). Experiments based solely on Lys or Met interventions were excluded from the study database. It is possible that the inclusion of these experiments may have provided additional insight into the effect of these AA on responses. This meta-analysis supports other research indicating a positive effect of Met and His as co-limiting AA in dairy cows and suggests Leu, Trp, and Thr be given greater consideration in future research.
Key words: amino acids, milk protein, meta-analysis, lactating dairy cow

INTRODUCTION

With the development of more refined nutrition models, increased feed prices, the greater value placed on milk protein as well as a greater awareness of the consequences of excess N feeding, nutritionists and dairy producers desire a better understanding of AA that increase milk protein and milk yield in dairy cows to enhance productivity while feeding diets with less CP content. Lysine and Met have been considered the most limiting AA in North American diets for lactating dairy cows (NRC, 2001) with recent experiments reinforcing this conclusion (Noftsger and St-Pierre, 2003; Socha et al., 2005; Appuhamy et al., 2011). Two independent assessments of AA research have determined Lys and Met requirements of 7.2 to 7.3 (%MP) and 2.5 (%MP; Rulquin et al., 1993; Doepel et al., 2004) similar to those of NRC (2001; 7.2 and 2.4% MP). However, the meta-analysis of Patton (2010) concluded that rumen-protected Met supplementation (2.35% MP) increased milk true protein percentage and yield, but Lys at 7.3% MP was not required for this response, suggesting that other nutrient effects may need more consideration.

Other AA may limit or co-limit milk and milk protein yield in the dairy cow. Histidine has been identified as an AA that may increase production (Chamberlain and Yeo, 2003; Weekes et al., 2006; Lee et al., 2012a,b). Giallongo et al. (2015) observed no response to rumen-protected Met supplementation and slow-release urea when a MP-deficient diet based on corn silage was fed, but added rumen-protected Met and His fed together

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with a slow-release urea increased DMI, milk protein concentration, and yield. Doepel et al. (2004) recommended a dietary His concentration of 2.4% of the MP. Arginine has been suggested as an important AA for milk protein synthesis especially as a precursor for Orn, Pro, and Glu (Mepham, 1982). However, milk protein responses to changing Arg supplies have been limited (Doepel and Lapierre, 2011; Haque et al., 2013). Increases in Ile supply have increased milk yield perhaps by increasing milk lactose production (Robinson et al., 1999). Others reduced Ile supply with no negative effect, but recognized that relationships among other branched-chain AA (Val and Leu) may be involved in defining Ile needs (Haque et al., 2013). The effects of the aromatic AA, Phe and Trp, have not been extensively researched in dairy cows. However, their importance in swine nutrition has long been known (Lellis and Speer, 1987; Guzik et al., 2002). Interestingly, Holstein steers given an abomasal infusion of Phe had improved ruminal NDF digestion because of reductions in rumen passage rates (Vite et al., 2013).

Our objective was to predict the metabolizable AA (g/d) most likely to affect milk and milk protein production of dairy cattle based on Cornell Net Carbohydrate Protein System (**CNCPS**) version 6.5 model predictions of nutrients supplied from individual treatments described in a large number of published experiments. Changes to the CNCPS model and feedbank to CNCPS 6.5 have been published and evaluated (Higgs et al., 2012, 2015; Van Amburgh et al., 2015). It was hypothesized that milk protein yield would be predicted by dietary factors, DIM, recombinant bST (**rBST**) use, and estimated metabolizable AA flux (g/d). Further, differences in milk protein yield between protein or AA intervention groups and controls would be predicted by the same dietary factors. These different hypotheses required different statistical approaches; the first hypothesis was evaluated using mixed models and the second using classical meta-analytical methods. Similar hypotheses were explored for the secondary outcomes of milk yield and milk protein percentage.

MATERIALS AND METHODS

Literature Search and Diet Description

A comprehensive literature search of English language literature published before 2015 was conducted to identify dairy cattle research studies involving treatments designed to produce variable intestinal AA supplies, as assessed using the CNCPS 6.5 model, by using protein and AA alterations to diets or by infusion. Three search engines, Science Direct, Google Scholar, and PubMed, were used with a defined and repeatable search strategy using the terms “dairy cow,” “dairy cattle,” “amino acid,” “milk yield,” and “milk production” to identify relevant studies.

Inclusion and Exclusion Criteria

All published studies were screened using standardized criteria. For inclusion into the meta-analysis, studies needed to have the following: English language, diet definition that specified individual dietary ingredients and provided forage analyses, detailed production responses including DMI, milk yield, and milk components with measures of variance, and an experimental design that included a negative control group. Experiments included in the meta-analysis represented a typical range in productivity and diet composition observed on commercial dairies. Experiments involving primarily transition cows (immediately postcalving) were excluded. Experiments that altered only Met or Lys intakes were excluded. It was a concern that the large number of studies that solely altered Met or Lys intakes may provide a database that would not allow an effective evaluation of the role of other AA on production. It was, further, considered that the effects of Met and Lys interventions would be evident, if such effects were strong. Further, because the CNCPS 6.5 model relies on the definition of specific protein and carbohydrate fractions and their corresponding rates of degradation (Van Amburgh et al., 2013), experiments in which these fractions could not be confidently predicted, such as those with poorly described heat-treated proteins or uncommon ingredients that were not present in the CNCPS 6.5 feedbank such as palm kernel meal, were excluded. Both randomized and Latin square design studies were included after investigation of the standard errors of each and the effect of study design on outcomes. One hundred ninety experiments were initially identified for review. One hundred twenty of these experiments were rejected due to limited diet definition, very low DIM, or changes only in Met or Lys intake. Seven experiments that were improperly controlled were rejected, leaving 63 experiments. Appendix Table A1 lists the experiments that were rejected and reasons for rejection.

Data Extraction

Response means and measures of variance (SD or SE) were organized into an Excel (Microsoft Corp., Redmond, WA) spreadsheet with experiment, experimental design, cows per treatment, DMI, milk yield, milk components, BW, DIM, rBST treatment, and dietary parameters. Diet nutrient profiles were obtained by entering diet and feed analysis data from each experiment into CNCPS 6.5 (NDS platform, RUM&N Sas, Reggio