

NUTRITION: *Original Research*

A survey of United States dairy cattle nutritionists' practices and perceptions of reducing crude protein in lactating dairy cow diets

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ABSTRACT

Objective: The objective was to assess if US dairy nutritionists' approaches toward balancing CP in lactating cow diets are influenced by demographic information, feelings toward environmental nitrogen (N) excretion, and dietary CP cost.

Materials and Methods: An electronic survey was sent to 886 US certified dairy nutritionists through the database of the American Registry of Professional Animal Scientists (ARPAS) via email. For survey data analysis, a nonparametric statistic was used to check whether the responses to each question were independent. Relationships among demographic data and responses to other questions were performed using Spearman's correlation. Poisson regression and least squares means were used to identify statistically meaningful differences between response counts within each respective question.

Results and Discussion: A total of 77 nutritionists representing 1,065 herds from 28 states with a total of 521,000 total lactating dairy cows responded to the questionnaire. Eighty-nine percent of nutritionists balanced diets based on one or more individual AA requirements of dairy cows. Most respondents (72%) reported that they are currently formulating diets with lower dietary CP than they were 3 to 5 yr ago. The primary concern with formulating lower CP diets was the cost per unit of MP, likely due to the high and fluctuating cost of high-RUP feedstuffs.

Implications and Applications: Currently, the impetus to reduce dietary CP in lactating cow diets is primarily financially, rather than environmentally, driven. Nutrition models that accurately predict individual AA requirements of dairy cows will allow nutritionists to develop even lower

CP diets than is presently possible. Monitoring income over feed cost of low-CP diets supplemented with AA is critical to support the sustainability of the dairy industry.

Key words: nutritionist, survey, nitrogen efficiency, amino acids, protein

INTRODUCTION

Dairy cattle in the United States waste a great deal of the dietary protein they consume, leading to low N use efficiency (NASEM, 2001). Dietary protein may contribute up to 69% of a diet's total cost, but on average, 75% of each dollar spent on dietary protein ends up in the manure pit in a nitrogenous form, unused by the animal (Hanigan et al., 2004). The estimated 1.36 million tonnes of reactive N released by US dairy cattle each year prompt environmental legislation to protect major water sources from nitrate, N oxide, and ammonia pollution (Knowlton and Denckla Cobb, 2006; Arriola Apelo et al., 2014a).

Waste N excretion can be significantly reduced with the adoption of diet formulation practices that aim to improve N efficiency. Within the CP chain, ruminants have requirements for individual AA in specific amounts. Consequently, balancing for adequate AA supply helps ensure unneeded N is not fed and wasted. However, it is unclear how nutritionists prioritize N-conservancy in diets. We hypothesized that nutritionists are shifting away from using CP as a benchmark in diets, but a host of doubts and obstacles prevents a collective push toward metabolizable AA-conscious diets. Further, we believe the decisions they make regarding dietary protein may be influenced by demographic factors such as herd size serviced, years of experience as nutritionists, diet balancing program or nutrient requirement model, and farm location. Therefore, the objective was to characterize whether US dairy nutritionists' approaches toward balancing CP in lactating cow diets are influenced by demographic information, feelings toward environmental N excretion, and dietary CP cost.

MATERIALS AND METHODS

Data Collection

An electronic survey containing 32 questions was created to collect information regarding US dairy nutritionists' diet balancing strategies with specific emphasis on dietary CP (Supplemental Material S1; <https://doi.org/10.15232/aas.2021-02179>). The participants were asked to describe their current occupation to ensure that responses were from only those actively working as dairy nutritionists in the United States and not retired, and so trends specific to the current US dairy industry were measured. Successive questions included a mixture of ranking, multiple choice, and short answers. Several ranking and multiple-choice questions asked participants to further elaborate their selection in a text box. The final 7 questions collected demographic information such as average lactating herd size serviced and years served as a dairy nutritionist.

The survey questions were drafted in fall 2018 using Qualtrics software (Qualtrics). Questions were developed using the Dillman method (Dillman et al., 2014) and piloted and revised by 3 experts in dairy nutrition, all of whom had at least 5 yr of experience in the industry. The nutrition experts revised the wording of each question to improve clarity and provided suggestions to achieve the objective of this study. In 2019 the survey link was emailed to 886 members of the American Registry of Professional Animal Scientists (ARPAS), one of the largest known standardized sources of individuals registered as dairy nutritionists in the United States. Those respondents had ARPAS certification in Dairy Nutrition and participated in the required annual continuing education units (ARPAS, Champaign IL, personal communication). Surveys were distributed anonymously by an ARPAS coordinator; thus, researchers were completely blind to survey takers and had no access to their contact information. Informed consent was implied if the participant followed the survey link. Human subject review protocol was approved by Virginia Tech's Institutional Review Board (IRB protocol #18-613).

Data Analysis

Participants may provide low-quality responses or leave a survey incomplete if they are forced to answer a question before progressing to the next one (Décieux et al., 2015). Dillman et al. (2014) also advises against requiring responses "unless absolutely necessary for the survey." As such, in this study, participants were not required to answer all questions. Further, there was no penalty for not completing the whole survey. The statistical analysis was based on the number of responses to each respective question.

Data were downloaded from Qualtrics software and stored in an electronic spreadsheet (Microsoft Excel v. 2101). Responses that were either unrelated to the question or left blank were not used. Consequently, data anal-

ysis was based on the sample of complete responses to each respective question. The intent of each short-answer response was interpreted to create measurable categories.

For multiple-part questions that required a "yes/no" or "yes/no/unsure" along with an elaboration, the response was first grouped into the appropriate "yes/no/unsure" category and then clustered into subcategories according to the respective reason for their response. For short-answer questions, a "yes/no" or "yes/no/unsure" response that did not include an elaboration was categorized as "other" or "other/unspecified." Moreover, Chi-squared tests require an expected count of at least 5 observations in each category for sufficient statistical power (Fisher, 1934), so responses with 5 or fewer observations were also described as "other/unspecified."

Dairy nutritionists were asked whether they believed N excretion would be more tightly regulated within the next 3 to 5 yr. If nutritionists believed tighter N regulations were a future possibility, they were also asked how they believed such regulations would be enforced. The responses fell into categories of "sampling only," "modeling only," a combination of both "modeling and sampling," or "unspecified" (respondents chose not to elaborate). "Sampling" included actual analyses of mixed rations, individual feedstuffs, manure, milk, soil, runoff, or combinations of those factors. "Modeling" included theoretical prediction of nutrient content, excretion, or both from diets, feedstuffs, manure, milk, soil, runoff, or any combination of those factors.

Data were analyzed in RStudio (v 1.2.5033) with R 3.2.6 (R Core Team, 2020). Frequencies and descriptive statistics were calculated for demographic data to describe the sample population (psych library; Revelle, 2017). For data visualization, distribution of states in which nutritionists reported having clients was plotted on a US map (usmap library; Di Lorenzo, 2018). Demographics that did not follow a normal distribution curve were transformed using Tukey's Ladder of Powers (rcompanion library; Mangiafico, 2018). Then, the linear relationships between transformed demographics data and categorical responses were evaluated. Confidence intervals among means were created using Tukey Honest Significant Difference tests (ggpubr library; Kassambara, 2018).

Count data were evaluated using the Chi-square goodness of fit test to determine whether observed counts within each question matched the expected distribution. Further, Poisson regression was used to model statistical differences between response counts to questions addressing which nutrient requirement model they used, which diet balancing software they used, for which AA they balanced in lactating dairy cow diets, which high-protein feedstuffs they used in lactating cow diets, whether or not the CP in their lactating cow diets was lower compared with 3 to 5 yr ago, and whether or not they believed N would be regulated on dairy farms within the next 3 to 5 yr. Then, multiple comparison of means (emmeans library; Lenth et al., 2019) were performed between frequency of

response counts using Tukey's method (multcomp library; Hothorn et al., 2008), and a significance level of 5% was adopted. For questions with multiple answers, both Spearman's correlation analysis and Poisson regression were performed. Moreover, correlation analyses were obtained using the Hmisc library (Harrell, 2019).

There were 2 questions in which nutritionists were given a list of factors to rank. A rank scoring system described by Taticchi et al. (2013) and Pretty et al. (1995) was used to determine which factor was collectively most important to respondents. Briefly, the number of responses in each respective ranking was multiplied by its assigned weight (i.e., for a list of 5, first = 5, second = 4, third = 3, and so on), and the corresponding value for each ranking was then summed across each response. The resulting sums, when ordered from greatest to least, represent the most to least important factor.

For data visualization, all comparisons were performed based on Poisson models, but to better interpret the results, the raw data were plotted (as opposed to logarithmically transformed data).

RESULTS AND DISCUSSION

Dairy nutritionists must balance the systems of ruminant digestive physiology, nutrient content of feedstuffs, environmental conditions, ingredients costs, and milk production to make a dairy operation profitable. The goal of this study was to quantify common rationales and strategies employed by US dairy nutritionists to balance those systems as they relate to CP. This section is composed of 4 parts to describe the perspectives of survey respondents regarding CP in lactating cow diets. First, demographic information is described to visualize the survey sample and to aid in quantifying the respondents' common practices and philosophies. Second, dairy nutritionists' perceived role in environmental mitigation of N excretion from dairy operations is outlined. Next, their perceived

roles in environmental stewardship may affect the methods by which they balance lactating cow diets. Finally, protein and AA sources incorporated into those diets are examined, as feedstuff choice affects N flux in the animal, overall diet cost, and milk production.

Demographic Data

The demographic information of US dairy nutritionists is shown in Table 1. A total of 77 individuals either fully or partially completed the survey between February 2019 and April 2019, resulting in an estimated response rate of 9%. There are several potential reasons why response rate was low for this survey. It is unknown how many surveys were undeliverable due to misspelled email addresses, inactive email addresses, unresponsiveness of a recipient's email server, a full inbox, or some other issue. Thus, it is likely the percentage of completed questionnaires relative to the total number of successfully delivered surveys is greater than 9%. Still, if contact information of potential participants is known, response rate of future surveys can be increased by implementing a combination of administration methods, such as mail, email, telephone, in person, or social media (Fincham, 2008). However, researchers were not permitted to receive personal information of respondents in the member database of ARPAS.

The response rate of this survey was less than half of similar agriculture-related surveys (Harrison et al., 2012; Weber and Clay, 2013; Buza and Holden, 2016). However, similar questionnaires selected participants based upon past willingness to complete questionnaires (Buza and Holden, 2016); personal information of dairy nutritionists including past survey response was not available in the present survey. Additionally, Dillman et al. (2014) reported increased survey participation and, thus, a reduction of nonresponse error when follow-up reminders were sent. However, we did not request that ARPAS send a follow-up reminder email to its dairy nutritionist members. Future

Table 1. Demographics of nutritionists in the survey (n = 77 respondents)

Item	No. of responses ¹	Mean	Median	SE	Min	Max	Total
Years served ²	51	24	27	1.5	1.0	40	1,259
Herds serviced ³	44	24	20	2.6	2.0	70	1,065
Cows serviced ⁴	43	10,200	5,000	1,485	400	32,000	521,400
Herd size ⁵	47	708	287	158	60	6,000	—
Milk yield, ⁶ kg/cow per day	49	36	36	0.59	20	43	—

¹Number of responses to each demographic inquiry.

²Total number of years working as a nutritionist.

³Total number of lactating herds currently servicing.

⁴Total number of lactating cows currently servicing.

⁵Average size of each client's herd (total lactating cows divided by number of clients).

⁶Average milk yield estimate across all clients' herds.

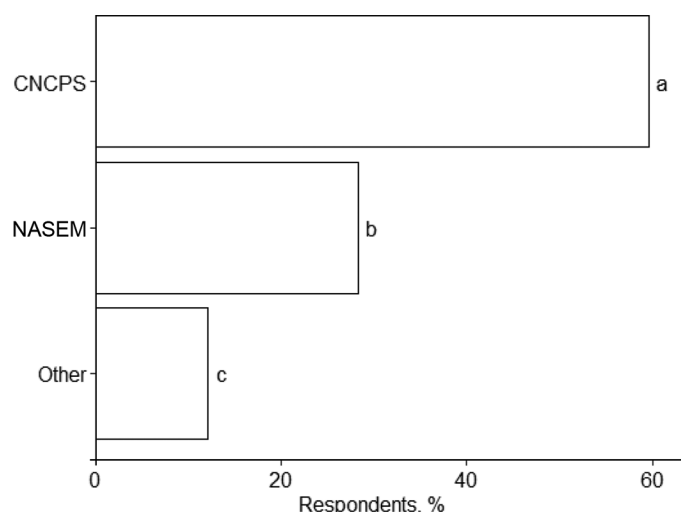


Figure 1. Percentage of US dairy nutritionists who use various nutrient requirement models for lactating dairy cows ($n = 62$ responses). CNCPS = Cornell Net Carbohydrate and Protein System (Cornell University); NASEM = National Academies of Sciences, Engineering, and Medicine (NASEM, 2001); Other = any reported model with less than 5 responses. Letters (a–c) denote pairwise differences at $P < 0.05$ using a Poisson model.

studies should include at least one follow-up reminder and consider a financial incentive to complete the questionnaire to encourage participation (Dillman et al., 2014).

Nutritionists were asked to report how many years they have been working in the field, how many total herds they service, the total number of lactating animals for which they develop diets, average size of each client's lactating herd, and average milk yield across all lactating cows in their herds. The respondents had from 1 to 40 yr of dairy nutrition experience. Further, participants in this sample reported overseeing a range of 2 to 70 total herds with averages of 400 to 32,000 lactating cows. Although the average herd size was 708, the median herd size was 287, which indicated that a few of the dairy nutritionists worked with large herds ("large" classified as $n > 16,000$ lactating cows; 25% of respondents). The median herd size in this data set (287) closely reflects the US average herd size reported by USDA NASS (2020) of 273 cows. Moreover, the total cows reported by survey participants accounted for approximately 6% of the total lactating cows in the United States based on a nationwide inventory of 9.3 million cows. Also, it is necessary to consider that 9 nutritionists did not provide the total number of cows for which they formulated diets; thus, the percentage of US dairy cows in this survey is likely greater than 6%.

Diet Formulation

Survey respondents indicated that the Cornell Net Carbohydrate and Protein System (CNCPS; Van Amburgh et al., 2015) model was more frequently used for diet formulation than the National Academies of Sciences, Engineering, and Medicine (NASEM) model (2001; Figure 1,

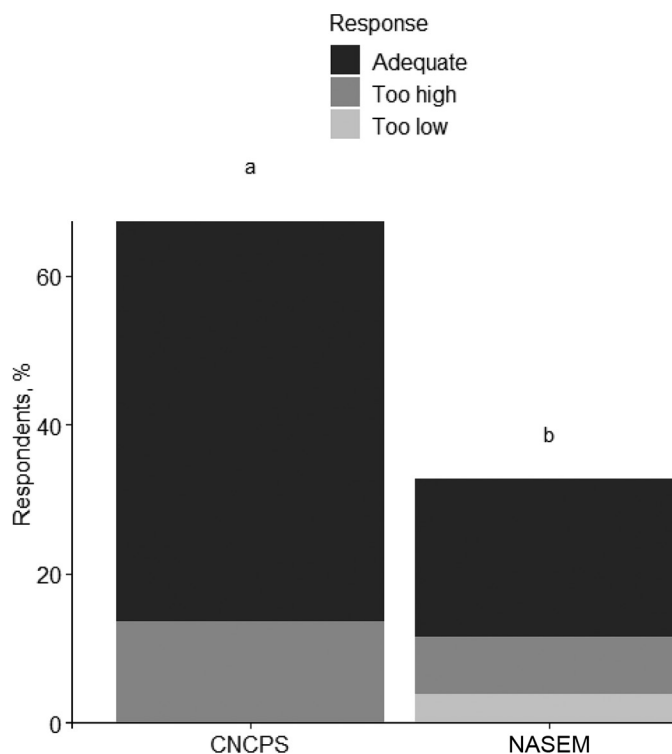


Figure 2. Percentage of nutritionists who use various diet models for lactating dairy cows ($n = 52$ responses). CNCPS = Cornell Net Carbohydrate and Protein System (Cornell University); NASEM = National Academies of Sciences, Engineering, and Medicine (NASEM, 2001). Within each model, respondents reported whether they believed its respective recommendations for MP were "too high," "too low," or "adequate" for lactating dairy cows. Letters (a, b) denote pairwise differences between model use at $P < 0.05$ using a Poisson model.

$n = 62$ responses, $P < 0.05$). Regardless of which model was used, most nutritionists reported that they believed MP recommendations were adequate (65% and 80% of NASEM and CNCPS users, respectively; Figure 2). Twelve percent of NASEM users and 0% of CNCPS users reported believing model recommendations for MP were too low. Some CNCPS users (20%) and some NASEM users (24%) described each respective models' MP recommendations as too high. It is important to consider that these results could be influenced by sample size (nonresponse bias) and location.

Linear relationships were tested between each transformed demographic set (average lactating herd size, total number of lactating cows serviced, average milk yield across herds, or years of service) and categorical responses to survey questions. No linear relationships existed between any of these demographic variables and software used, whether nutritionists balanced for AA, the AA for which nutritionists do balance in diets, whether the respondents believed N would be regulated within the next 3 to 5 yr, or whether the respondents reduced CP in diets within the last 3 to 5 yr. This suggests that within this data set, dairy nutritionists shared similar perceptions

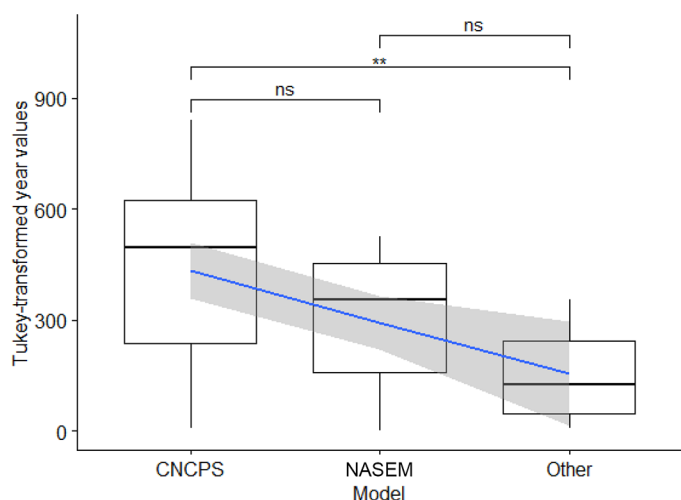


Figure 3. Effect of US dairy nutritionist years in service on model type used for balancing diets. CNCPS = Cornell Net Carbohydrate and Protein System (Cornell University); NASEM = National Academies of Sciences, Engineering, and Medicine (NASEM, 2001); Other = any other reported model with less than 5 observations. Year values on the y-axis were transformed using Tukey's Ladder of Powers to normalize data. Linear regression was used to model effect of transformed years on model type. Pairwise comparisons were obtained through ANOVA. The diagonal line represents linear regression through the data; the shaded area represents 95% CI. The lower and upper limits of the box represent the first and third quartile of the transformed year values, respectively. Midlines in the boxes represent the median transformed year values, and whiskers represent 1.5 times the interquartile range of the transformed year values. Two asterisks indicate significance between variables at $P < 0.05$.

regarding CP regardless of herd size, milk yield of their clientele, or years serving the dairy industry.

Notably, respondents who have been working as dairy nutritionists longer used the CNCPS model (n nutritionists = 31) more frequently than "other" models (n nutritionists = 7; Figure 3; $P < 0.05$). There was no difference in experience years of those who used NASEM (n nutritionists = 15) versus CNCPS models. "Other" primarily included proprietary company models, so this difference suggests that newer nutritionists more often work for companies that use their own balancing models, which likely are based on either NASEM or CNCPS models, or a mix of both. Some companies develop their own requirement models or interfaces and require their dairy nutritionists to use them. Nutritionists who select their own software may make their choice based on license price, software marketing and benefits, previous experience with a program, and ease of use. Most often, either the NASEM, CNCPS, or some other proprietary nutrient requirement model is built into a ration balancing program, and the user cannot modify its equations or toggle between models. Thus, frequency of nutrient requirement model use among nutritionists may be secondary to ration balancing software preference.

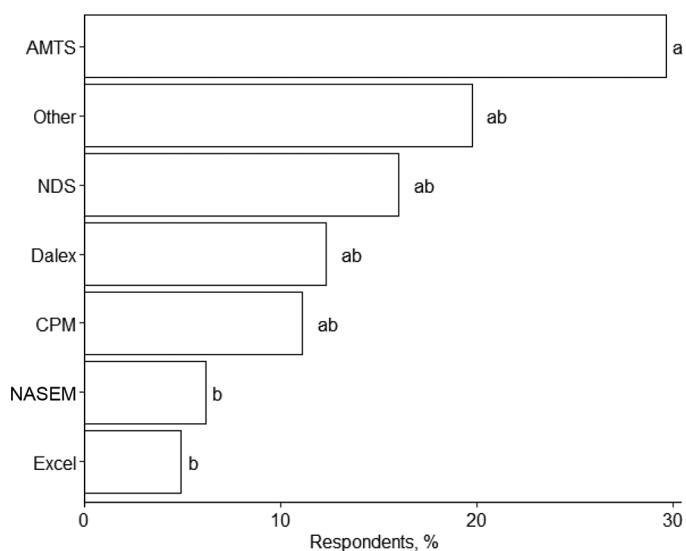


Figure 4. Dairy cow diet balancing program use by US dairy nutritionist survey respondents. AMTS = Agriculture Modeling and Training System (AMTS LLC); Other = any reported software with less than 5 responses; NDS = Nutritional Dynamic System (RUM&N); Dalex = Dalex Livestock Solutions LLC; CPM = Cornell-Penn-Miner; NASEM = National Academies of Sciences, Engineering, and Medicine (NASEM, 2001); Excel = self-generated Excel workbook. Letters (a, b) denote pairwise differences at $P < 0.05$ using a Poisson model.

It is possible that participants adopted the CNCPS model more than the NASEM model because the former model is updated more frequently to include new information from research than the latter (Van Amburgh et al., 2015). Another reason the CNCPS model may be more used than the NASEM model is due to the greater integration of CNCPS in commercial diet balancing software such as Agriculture Modeling and Training System (AMTS; AMTS LLC). The most-reported diet formulation software used was AMTS (Figure 4, 29%). Dalex (Dalex Livestock Solutions LLC) and Nutritional Dynamic System (RUM&N) also use CNCPS (Van Amburgh et al., 2015). The next commonly used (aside from "other," which included responses of less than 5 diet balancing software) was Nutritional Dynamic System. The use of AMTS, other software, Nutritional Dynamic System, Dalex, and CPM (Cornell-Penn-Miner) were all similar ($P > 0.05$), but the use of AMTS versus self-generated Excel workbooks or the 2001 Dairy NASEM software was different ($P < 0.05$). "Other" software reported included Brill (Cargill), NittanyCow (NittanyCow Software Services), and other proprietary company software.

Reducing the amount of N dairy cattle excrete through reduction of dietary CP is possible but complex. It is understood that cattle and the microbes within their rumens will only use N they need and either recycle or excrete what they do not need. As a result, feeding only the required fractions will result in minimal N waste. However, the full spectrum of the types and amounts of N needed by cows and their rumen microbes, in the form of AA,

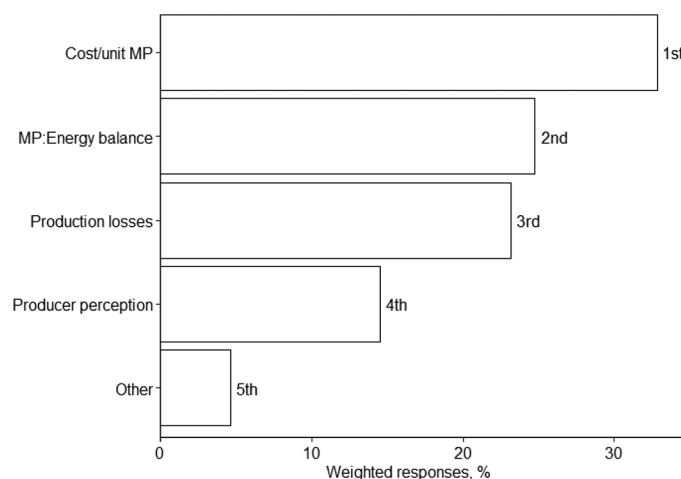


Figure 5. Ranking of US dairy nutritionists' primary challenges with reducing CP in lactating cow diets. Nutritionists were asked to rank each response from 1 to 5, with 1 being most challenging. Weights of 1 to 5 were assigned to each rank, where a greater weight was applied to a higher rank.

ammonia, and peptides, are not as well understood as in nonruminants. Many of the minimum AA requirements of lactating cows can be determined but microbial transformation of feed nutrients before absorption by the animal is not easily predicted. Although the nutrient profile of a feedstuff is important, the amount of the feedstuff included and its interaction with other dietary components will affect nutrient availability. As such, mixtures of feeds with different AA contents are fed to achieve the desired MP profile needed by the animal. Requirement models such as NASEM and CNCPS have been developed and updated over several decades to predict the cow's nutrient needs, including the metabolism of nutrients into energy and AA for maintenance, growth, pregnancy, and lactation. These models are published in the scientific literature and incorporated into commercial software to predict nutrients supplied from the diet, animal requirements, diet cost, and estimated production level for each animal category.

Nutritionists were asked to rank on a scale of 1 to 5 what they believed were the biggest challenges associated with reducing dietary CP in lactating diets (Figure 5).

Collectively, cost per unit of MP was the top concern. This reflects the high importance that nutritionists place on maximizing income over feed cost for producers. Further, relative to forages and high-energy feeds, the prices of feedstuffs that improve a diet's MP profile are relatively high and volatile (Tebbe, 2018). Ranked second was the challenge of properly balancing MP with energy in the diet. This likely arises from the observation that milk production depends on the most limiting factor between protein and energy (Tedeschi et al., 2006; Brun-Lafleur et al., 2010). This is associated with the third-place ranking, concern for production losses with less dietary CP. Producer perception of a lower CP diet was ranked fourth, which suggests nutritionists' clients trust their recommendations.

The NASEM (2001) aggregated nutrient analyses of thousands of feed samples to estimate nutritive content of feed ingredients. While those textbook values provide a starting point from which to develop a diet, nutrient profiles of the same feedstuff can vary considerably from farm to farm. Feed sampling and analysis allows nutritionists to use more accurate inputs and to better achieve the desired production outputs predicted by their balancing model. Table 2 shows the frequency by which nutritionists reported sampling their clients' forages, whole TMR, individual ingredients, and vitamin/mineral premixes. Forages were sampled more often than any other ingredient class (98.4% of respondents) and were more likely to be sampled on a monthly basis (60.3% of respondents; $P < 0.01$) than on a weekly or annual basis. Fifty-eight percent of respondents reported sampling TMR, where those who sampled annually (38.1%) did so more than those who sampled on a weekly basis (3.17%; $P < 0.01$). Of the 70.5% of nutritionists who reported individual ingredient sampling, most reported doing so annually (47.5%); this differed from those who sampled monthly (19.7%) or weekly (3.28%; $P < 0.01$). Vitamin/mineral premixes were sampled the least, where 81% of nutritionists reported never doing so. Those who do either sample annually (15.9%) or monthly (3.17%; $P < 0.01$).

Because nutritionists placed a high value on cost per unit of MP and MP:energy balance, it can be assumed the

Table 2. Frequencies by which US dairy nutritionists conduct laboratory analyses of their clients' diets or dietary components (n = 63 responses)

Feed type	% of responses				SE	P-value
	Weekly	Monthly	Annually	Never		
Forage	15.9 ^{bc}	60.3 ^a	22.2 ^b	1.59 ^c	14.0	<0.01
TMR	3.17 ^c	17.5 ^{bc}	38.1 ^{ab}	41.3 ^a	24.0	<0.01
Individual ingredients	3.28 ^c	19.7 ^b	47.5 ^a	29.5 ^{ab}	29.0	<0.01
Vitamin/mineral premixes	—	3.17 ^c	15.9 ^b	81.0 ^a	10.0	<0.01

^{a-c}Different superscripts denote pairwise differences $P \leq 0.05$ within row using a Poisson model.

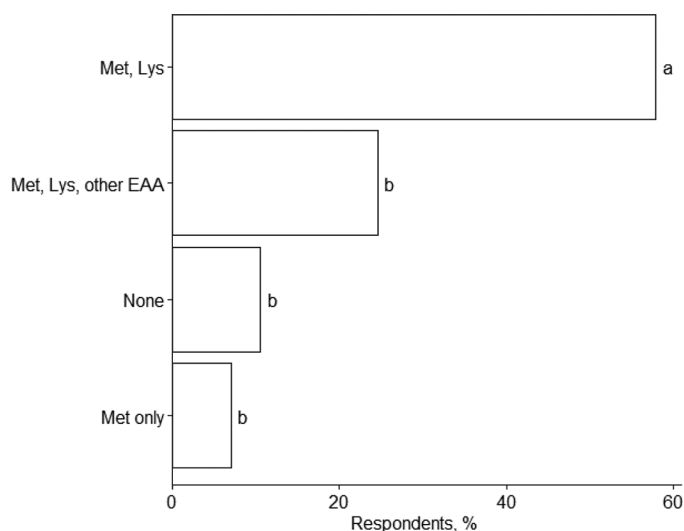


Figure 6. Percentages of US dairy nutritionist survey respondents who balance lactating dairy cow diets for various AA. Letters (a, b) denote pairwise differences $P < 0.05$ using a Poisson model.

vast majority of them understand the effect of balancing for limiting AA rather than CP as a whole. Only 11% of participants reported not balancing for AA at all in lactating cow diets (Figure 6), and 58% reported that they consider both methionine (Met) and lysine (Lys), which was a greater frequency (pairwise difference $P < 0.05$) than those who also balanced for other EAA, Met alone, or no AA at all. Across all responses, 89% of nutritionists consider Met requirements when balancing diets, whether solely for Met, in conjunction with Lys solely, or in conjunction with other EAA.

Fifty-two percent of nutritionists ($n = 19$) who considered cow AA requirements during diet development reported overall lower diet CP content as well. When asked how their diets' CP content changed in the last 3 to 5 yr, 69% reported it as "lower" (Figure 7) and 21% reported that CP content of their diets had not changed over the last 3 to 5 yr. The remaining 10% of nutritionists had not decidedly lowered CP, primarily citing the cost of high-RUP feedstuffs and maintaining an overall nutrient balance rather than focusing on a lower percentage CP in a diet (pairwise difference between those who decidedly answered "lower" $P < 0.05$).

Separate from implementing lower CP diets, most participants (90%, $n = 60$) reported a specific desire to reduce dietary CP in their diets. The most frequent reasons for why nutritionists do/do not value the reduction in dietary CP is presented in Table 3. A wide spectrum of reasons was described, but unsurprisingly, diet cost was the most important concern. The second top response was preference for balancing AA, MP, or RDP requirements (19%), reflecting the recognition of the value of AA balancing. Only 10% of participants ($n = 7$) reported not considering reducing dietary CP in their clients' diets.

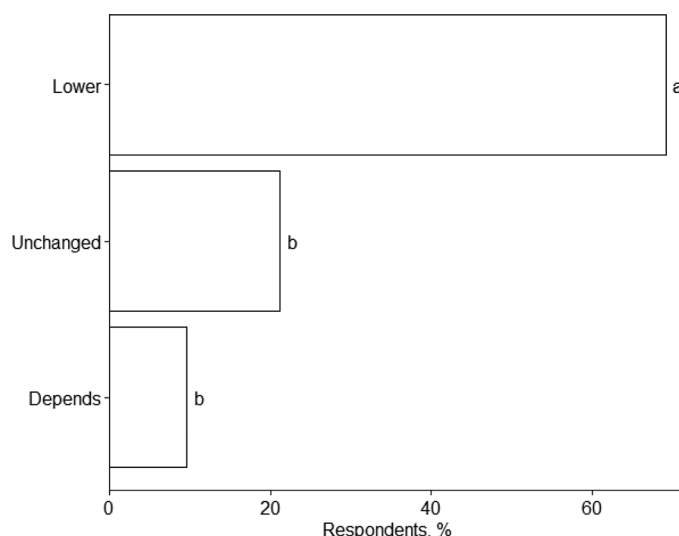


Figure 7. Percentages of US dairy nutritionist survey respondents who reported lower CP in lactating cow diets currently compared with the last 3 to 5 yr ($n = 52$ responses). "Lower" = nutritionists' diets are lower in CP than they were 3 to 5 yr ago; "Unchanged" = diet CP has not changed in the last 3 to 5 yr; "Depends" = in certain cases dietary CP has changed, in certain cases it has not. Letters (a, b) denote pairwise differences $P < 0.05$ using a Poisson model.

Table 3. Reasons why nutritionists consider reducing dietary CP in lactating cow diets¹

Reason	Count of responses	Relative frequency, %	Cumulative frequency, %
To lower diet cost	17	25.4	25.4
Other ²	17	25.4	50.8
Prefer AA, MP, RDP, or a combination ³	13	19.4	70.2
N efficiency ⁴	7.0	10.4	80.6
Do not consider ⁵	7.0	10.4	91.0
Environmental concerns ⁶	6.0	9.00	100
Total	67	100	100

¹Number of respondents = 48; number of responses = 67 (many nutritionists listed multiple reasons). No pairwise differences in frequency detected in Poisson model ($P > 0.05$).

²Aggregation of any reasoning with <5 responses.

³Reported preference for balancing AA, MP, RDP, or a combination of requirements, which subsequently lowers CP%.

⁴Nitrogen (N) efficiency; balancing N in diet to minimize N excretion.

⁵Reported not intentionally considering lower CP diets.

⁶Explicitly mentioned environmental mitigation of N.

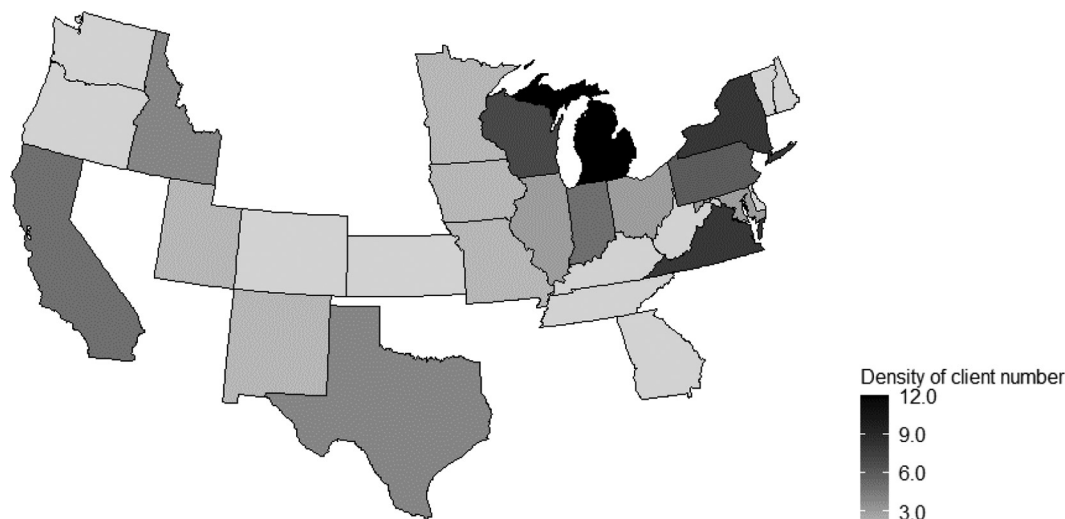


Figure 8. Distribution of states in which dairy nutritionist respondents have clients ($n = 89$ responses). Darker shades indicate greater client density, and blank states represent zero clients. Units are number of clients within each state, where the darkest state has 12 herds.

Environmental Concerns

In the current survey, a total of 28 states were represented (Figure 8), including the top 10 dairy-producing states in the United States (USDA NASS, 2020). The greatest concentrations of herds were in the upper Midwest and Northeast regions. Several northeastern states' agricultural runoff flows into the Chesapeake Bay, the world's largest estuary. Additionally, the Great Lakes, which account for 84% of North America's fresh surface water (US EPA, 2019), lie within both the Northeast and the upper Midwest. As a result, several states in those regions have some of the country's most sweeping water quality regulations.

Agriculture is a major cause of eutrophication, the excess growth of toxic algal blooms and oxygen-devoid "dead zones" in water bodies caused by overly rich nutrient runoff from the land (USDA ERS and NASS, 2010). It is estimated that 1.36 million tonnes of reactive N in the form of nitrous oxides, ammonia, and nitrates are excreted by dairy cattle in the United States each year (Arriola Apelo et al., 2014b). The remaining fraction is lost through urine and feces (manure), which if not managed properly may find their way into aquatic ecosystems, causing nutrient imbalances that damage native flora and fauna. The primary cause of nitrate pollution of both the Chesapeake Bay and the Great Lakes is agricultural runoff from crops and farmland.

Several states designate nutrient water quality criteria for lakes, rivers, and streams. These criteria help guide nutrient management planning for dairy concentrated animal feeding operations. For example, Minnesota and Wisconsin, which together lie along 4 of the 5 Great Lakes, have statewide lake and river/stream P criteria. For the other states surrounding the Great Lakes, N and P water quality criteria of lakes, rivers, and streams vary. These standards are generally regulated according to specific qualities of each respective water body, including temperature, pH,

erosion, aquatic life, and use for high-quality drinking water (US EPA, 2020). Currently, no state in the continental United States has statewide N criteria for bodies of water (US EPA, 2020). This is likely because during the N cycle, some volatile forms of N escape to the atmosphere and evade contamination of aquatic ecosystems. However, no gaseous forms of P escape to the atmosphere during the P cycle, so any P runoff from farms can transfer directly to water bodies. Consequently, although it is known that both N and P contribute to a host of water quality issues in excess, more efforts and regulations have focused on P mitigation (Ngatia et al., 2019).

In the present survey, we found that 58% of the dairy nutritionists believed N regulations for dairy farms would become more tightly regulated in the next 3 to 5 yr, and 28% believed they would not (Figure 9). The difference in response frequencies was significant when a Poisson regression model was fitted ($P < 0.05$). Those who answered "yes" did so more frequently ($P = 0.05$) than those who answered "no" or "unsure." The frequency that those who responded either "no" or "unsure" did not differ ($P = 0.22$). The interpretation of "unsure" is subjective as the answer may vary depending on the region in which they believe it may or may not become more regulated. Dairy nutritionists who completed the survey were aware that tighter N regulation could be a possibility in the future. The confidence in their responses may be greater when asked whether regulations would occur in the next 10 rather than 5 yr.

Many states mandate regular manure nutrient testing as part of a concentrated animal feeding operation's nutrient management plan (Hellerstein et al., 2019). A decade ago, 22% of US dairies sampled manure for N or P content, and only 7% of dairies adjusted manure nutrient content via diet formulation (USDA ERS and NASS, 2010). Our survey asked dairy nutritionists by which methods they

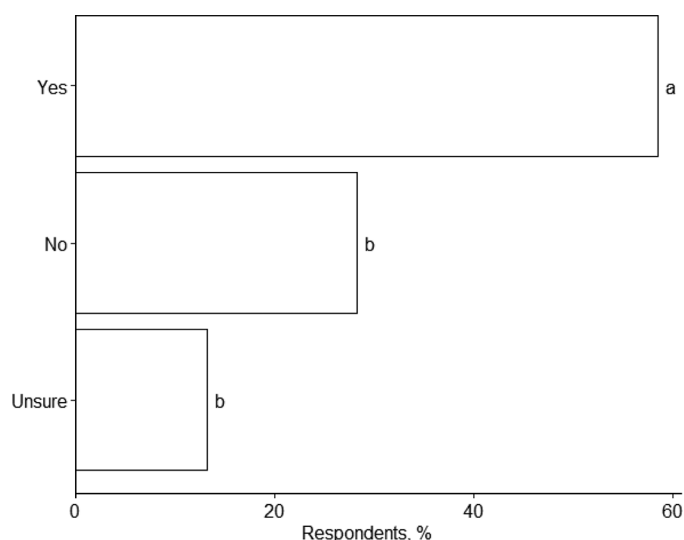


Figure 9. Percentage of US dairy nutritionists who believe that nitrogen excretion will be regulated in the next 5 yr ($n = 53$ responses). “Yes” = belief it will become more regulated; “No” = belief regulations will stay the same; “Unsure” = undecided. Letters (a, b) denote pairwise differences $P \leq 0.05$ using a Poisson model.

believed N would be regulated on dairy farms in the next 3 to 5 yr (Figure 10). Most dairy nutritionists in our survey (42%) speculated both sampling and modeling means would be used to regulate N excretion on farms within the next 3 to 5 yr. However, the frequency of responses between these categories did not differ from each other ($P = 0.14$). Dairy nutritionists typically balance diets through both actual and theoretical means (via analyzed nutrient content of feed or milk samples and diet balancing models), so this majority recognizes the utility of using both methods to accurately monitor N input and output on dairies. In our survey, 23% of respondents believed only sampling measures would be used to enforce such regulations; 13% believed only modeling measures would be used, and 23% did not elaborate on their reasoning. A larger sample of respondents is needed to more accurately monitor this trend of reasoning. Still, our results show that most dairy nutritionists were aware that environmental regulations may extend wider across N over time.

Protein and AA Sources

Common feedstuffs used to increase the CP content of dairy diets are shown in Figure 11. The 2 protein sources commonly used in dairy diets were rumen-protected methionine (**RPMet**) and rumen-protected soybean meal (pairwise difference $P > 0.05$), and those were used to improve the AA profile of the MP. Methionine was reported as being the first limiting AA in dairy diets because it is highly influential in milk production (NASEM, 2001). Therefore, RPMet supplements are concentrated sources of Met that can increase the amount of ruminal escape Met without taking up large space in the diet formula.

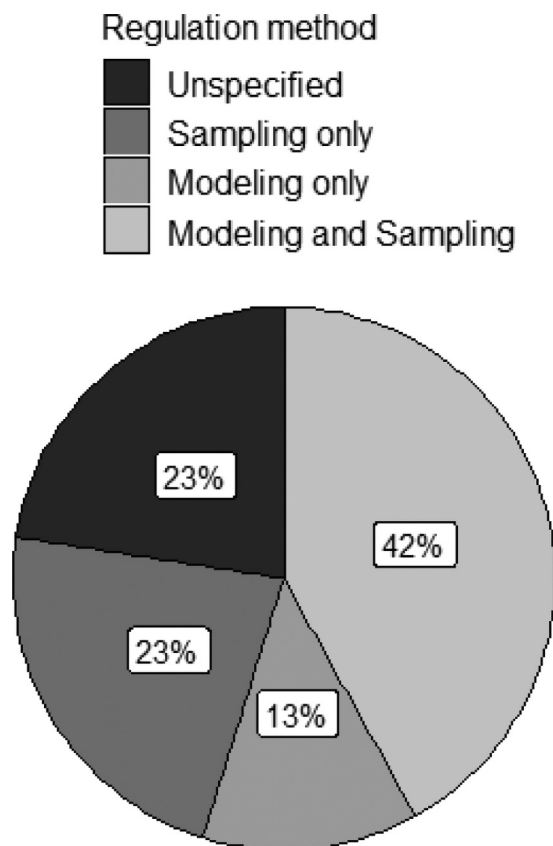


Figure 10. Methods by which US dairy nutritionists believe nitrogen will be regulated within the next 3 to 5 yr ($n = 31$ responses). Unspecified = respondents who believe nitrogen will be regulated within the next 3 to 5 yr but did not provide follow-up reasoning; Sampling only = respondents who believe nitrogen will be regulated through sampling feedstuffs, manure, soil, water, or a combination of farm inputs and outputs; Modeling only = respondents who believe nitrogen will be regulated by theoretical means such as diet evaluation or modeling of farm inputs and outputs; Modeling and Sampling = respondents who believe nitrogen will be regulated by a combination of modeling and sampling methods, such as nutrient or waste management plans.

In terms of commercially available rumen-protected AA products, RPMet sources took up the greatest share of the feeds, followed by rumen-protected Lys (**RPLys**) sources. This fact could be associated with studies that identified Lys as the second-most-limiting AA in lactating cow diets (NASEM, 2001). Further, RPLys supplements have relatively consistent digestibilities, nutrient profiles, and availabilities relative to Lys-rich protein feedstuffs such as fish or blood meal (Whitehouse et al., 2017). Therefore, in the present study, more nutritionists reported using RPMet sources to improve diet protein profiles than RPLys sources ($P < 0.05$). However, there was a strong positive correlation between nutritionists who used RPLys in addition to RPMet (Figure 12, Spearman correlation (r_s) = 0.64; $P < 0.05$).

Nutritionists were also asked which type of rumen-protected feeds they typically added to diets (Table 4).

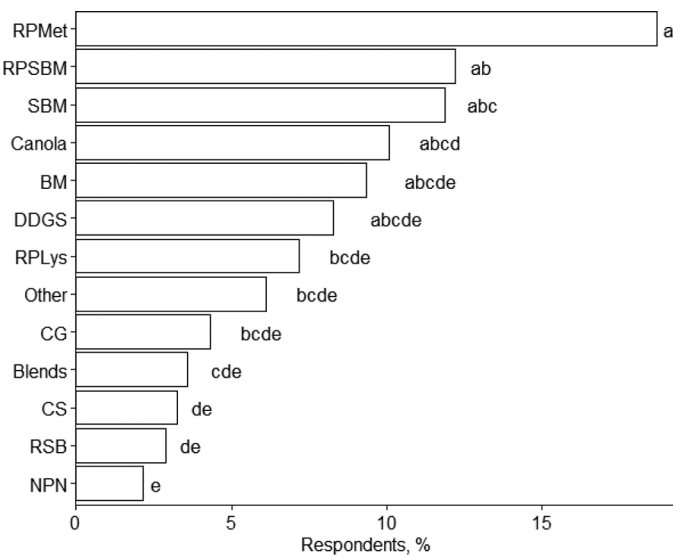


Figure 11. Common high-protein feedstuffs used by US dairy nutritionists in lactating cow diets. RSB = roasted soybeans; CS = cottonseed; Blends = commercial blends of animal or plant proteins or both; DDGS = dried distillers grain and solubles; SBM = soybean meal; Canola = canola meal or canola by-products; RPLys = rumen-protected lysine; RPMet = rumen-protected methionine; RPSBM = rumen-protected soybean meal; BM = blood meal; Other = any ingredient reported by <3 respondents; CG = corn gluten products. Letters (a–e) denote pairwise differences significant at $P < 0.05$ using a Poisson model.

This question was intended to specifically characterize the frequency with which nutritionists add feedstuffs specifically branded to increase RUP in a diet. The frequencies of reported high-RUP feedstuffs were statistically similar (pairwise differences $P > 0.05$ between all sources). However, many participants responded generically to this open-ended question [written as “Have you ever used rumen-protected sources of amino acids (encapsulated/heat-treated feedstuffs)? If so, please list:”]. For example, answers such as “rumen-protected methionine” were written instead of a specific product such as “Mepro[®]n” (Evonik Industries). Further, some participants (5%) only responded “yes” without giving a specification at all; these responses were categorized with “other/unspecified” (O/U). As a result, 40% of all responses to this question were classified as “Escape Soy O/U,” “RPLys O/U,” “RPMet O/U,” or simply “O/U.” To avoid this issue, it is recommended that future studies provide a list of feed ingredients to the respondents using checkboxes.

The use of both RPMet and blood meal had a moderate positive correlation (Figure 12; $r_s = 0.43$; $P < 0.05$). As expected, the correlation between blood meal and RPLys was weakly positive ($r_s = 0.28$, $P = 0.30$), but not negative, indicating that both may be used together as a source of Lys and RUP in diets for dairy cows. The decision to use blood meal or RPLys could be associated with availability, product cost, and animal performance (Whitehouse et al., 2017). There was also a strong positive correlation

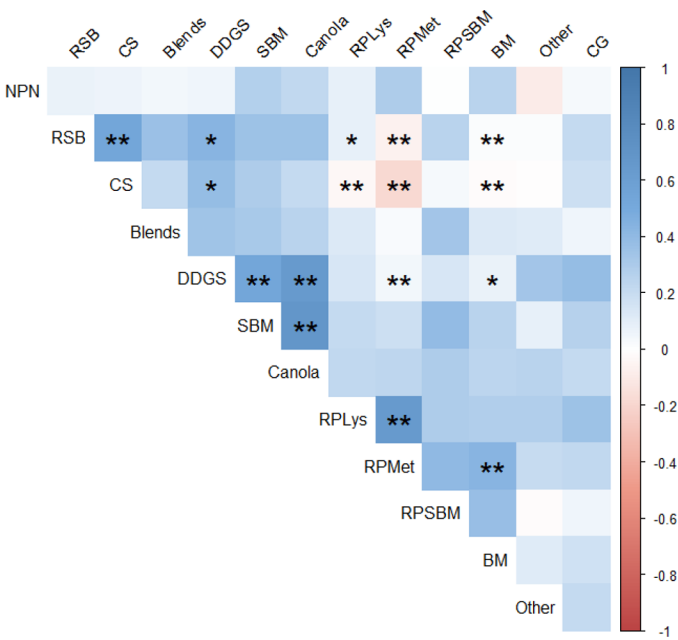


Figure 12. Correlations between common high-protein feedstuffs used in lactating cow diets. Blue shades signal positive correlation, and red shades signal negative correlation. RSB = roasted soybeans; CS = cottonseed; Blends = commercial blends of animal or plant proteins or both; DDGS = dried distillers grain and solubles; SBM = soybean meal; Canola = canola meal or canola by-products; RPLys = rumen-protected lysine; RPMet = rumen-protected methionine; RPSBM = rumen-protected soybean meal; BM = blood meal; Other = any ingredient reported by <3 respondents; CG = corn gluten products. Spearman correlation is significant at ** $P < 0.05$; * $P < 0.10$.

between the use of soybean meal (SBM) and canola ($r_s = 0.68$, $P < 0.05$) and dried distillers grains with solubles (DDGS) and canola ($r_s = 0.64$, $P < 0.05$) and a moderate positive correlation between SBM and DDGS ($r_s = 0.54$, $P < 0.05$) and roasted soybeans and cottonseed ($r_s = 0.54$, $P < 0.05$). Of these feeds, blood meal has the highest CP content, followed by SBM and then canola meal (NASEM, 2001). Because of their high concentration of CP, these can be relatively expensive feedstuffs. Further, along with the price of corn, the cost of soybeans usually dictates the price of other protein feedstuffs (USDA ERS, 2020). By-product feedstuffs such as DDGS and cottonseed can be supplemented to diets as economical nutrient sources for dairy cattle (Banaszewska et al., 2014). The decision to add one or more of these feeds to a diet depends on price and availability, which vary according to such factors as market trends and geographical location. Dairy nutritionists often monitor the nutrient profiles of batches of each by- or co-product, as they may fluctuate depending on the process by which they were produced (Kononoff, 2017).

Nonprotein N was the least-supplemented N source (pairwise difference between NPN and canola, SBM, rumen-protected soybean meal, and RPMet $P < 0.05$). This

Table 4. Common rumen-escape-protein feedstuffs supplemented by US dairy nutritionists in lactating cow diets (n = 46 responses)¹

Feedstuff	Count of responses	Relative frequency, %	Cumulative frequency, %
Smartamine ²	22	18.5	18.5
Mepron ³	16	13.4	31.9
Other/unspecified (O/U) ⁴	14	11.7	43.7
AjiPro ⁵	12	10.1	53.8
RPLys O/U ⁶	12	10.1	63.9
RPMet O/U ⁷	12	10.1	74.0
Escape Soy O/U ⁸	11	9.24	83.2
SoyPlus ⁹	10	8.40	91.6
MetaSmart ¹⁰	5.0	4.20	95.8
AminoPlus ¹¹	5.0	4.20	100
Total	119	100	100

¹Most nutritionists listed multiple feedstuffs. No pairwise differences in frequency detected in Poisson model ($P > 0.05$).

²Smartamine-M; Adisseo Inc.

³Mepron; Evonik Industries.

⁴Other/unspecified = commercial escape blends or instances where respondents reported "yes" to using commercial escape products but did not specify commercial name.

⁵AjiPro-L; Ajinomoto Heartland Inc.

⁶RPLys O/U = rumen-protected lysine reported by <5 respondents or commercial name was not specified.

⁷RPMet O/U = rumen-protected methionine reported by <5 respondents or commercial name was not specified.

⁸Escape Soy O/U = escape soybean products reported by <5 respondents or commercial name was not specified.

⁹SoyPlus; Landus Cooperative.

¹⁰MetaSmart; Adisseo Inc.

¹¹AminoPlus; Ag Processing Inc.

could be because nutritionists did not have limitations in meeting RDP requirements using traditional sources of dietary RDP, such as SBM. However, there was a potential bias of the question, "List commonly used protein sources in lactating cow rations," which may lead nutritionists to not include NPN in their answer because NPN is not technically "protein." Therefore, future surveys should describe sources of NPN, urea, protected urea, or ammonium-based products as an individual category.

In the current study, dairy nutritionists were asked to rank on a scale of 1 to 7 their primary sources of dairy nutrition news and research information (Figure 13). As expected, the highest-ranked category was conferences, in which the Cornell Nutrition Conference (Ithaca, NY; 24% of responses) and the Tri-State Dairy Nutrition Confer-

ence (Fort Wayne, IN; 15% of responses) were most frequently reported. Participants selected academic journals as their second most important source of information, which suggests their desire to gain information from an unbiased and peer-reviewed scientific publication. Websites were ranked as the third category, where Hoard's Dairyman (Fort Atkinson, WI) was mentioned the most (22% of responses). Feed company updates, email newsletters, and extension personnel were not the main sources of information from this survey. Although dairy extension agents help farmers with innovations and education in many areas, dairy nutritionists were looking for advanced knowledge in specialized areas such as dairy nutrition or management.

APPLICATIONS

The current survey represented about 1,065 herds from 28 states (about 6% of US lactating cows), which collected information on dietary protein use from 77 dairy nutritionists that supported dairy farms mainly in the upper Midwest and Northeast regions. Most dairy nutritionists (89%) reported accepting AA diet-balancing strategies as opposed to meeting CP benchmarks. However, there was some concern that low-CP diets may result in a decrease in milk production, as 52% of respondents ranked concern over production losses in their top 3 most challenging aspects for reducing dietary CP. The prevalent use of one TMR for all lactating cows on many dairy farms may contribute to the lack of influence of milk yield on AA balancing strategies.

The total number of cows and herds serviced and the average daily milk yield per cow did not influence CP balancing strategies of dairy nutritionists. Nutritionists who worked in the field for fewer years were less likely to use CNCPS than "other" models but were just as likely to use NASEM as they were to use both CNCPS and "other" models. In this survey, 58% of dairy nutritionists believed tighter legislation on nutrient runoff from dairy farms was a real possibility in the future.

The cost per unit of MP was a relevant fact for respondents, and formulation strategies for dietary protein supply may vary depending on feed costs. Overall, dairy nutritionists reported that volatile commodity markets that influence the price of high-RUP feedstuffs will influence their decisions to balance diets for both N efficiency and maximum income over feed cost for their clients.

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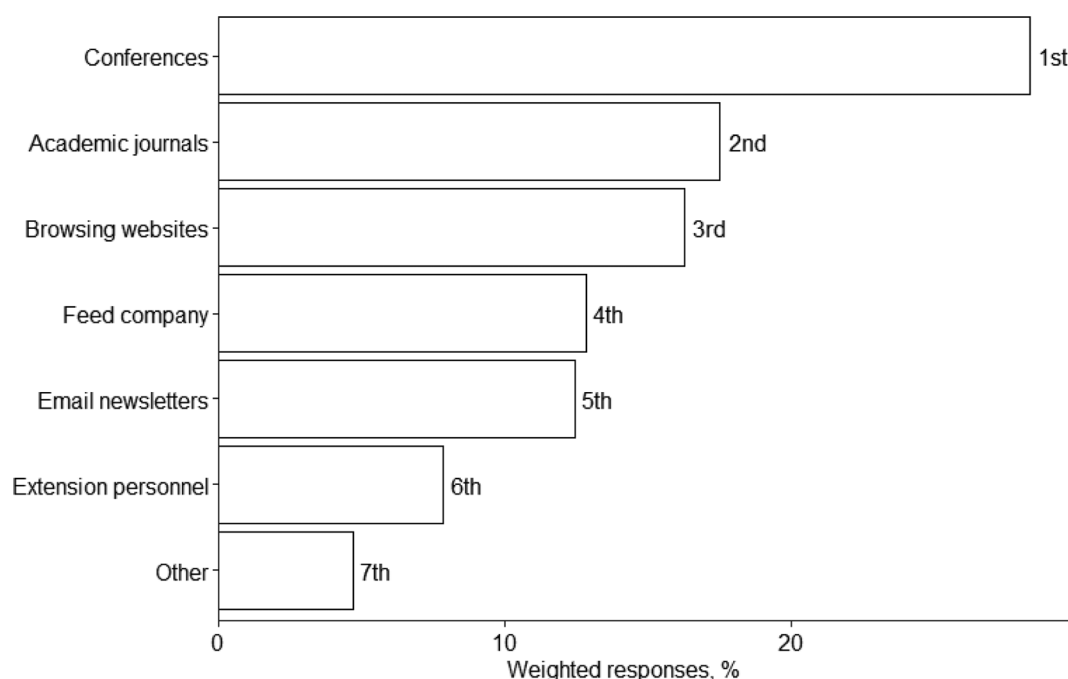





Figure 13. Ranking of US dairy nutritionists' primary sources of current nutrition research. Nutritionists were asked to rank each response from 1 to 5, with 1 being most challenging. Weights of 1 to 5 were assigned to each rank, where a greater weight was applied to a higher rank. Other = any reported model with less than 5 responses.

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