A survey of Canadian dairy nutritionists to assess current trace element formulation practices

Mélissa Duplessis,1* Tom C. Wright,2 and Masoumeh Bejaei3
1Agriculture and Agri-Food Canada, Sherbrooke Research and Development Centre, Sherbrooke, Québec, J1M 0C8, Canada
2Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph, Ontario, N1G 4Y2, Canada
3Agriculture and Agri-Food Canada, Summerland Research and Development Centre, 4200 BC-97, Summerland, British Columbia, V0H 1Z0, Canada

ABSTRACT

The purpose of this study was to identify current practices and perceptions around trace element feeding for dairy cows through a Canadian dairy nutritionist survey. An online survey with 23 questions was used to collect data from Canadian dairy nutritionists with the help of professional associations and social media. The survey was active from November 2021 to April 2022. The first 7 questions collected descriptive information on respondents, and the subsequent 16 questions focused on trace element feeding. A total of 92 participants from all over Canada filled out the survey, and about 26% of Canadian herds and cows were represented by these respondents. The participants had diverse views on the importance of diet formulations for trace elements to optimize cow health and productivity, with perceptions varying from very important to not important. In comparison, macronutrients and selenium were consistently rated as very important by between 58% and 74% of respondents. Software reference values were used by 54%, 72%, and 73% of participants to estimate trace element concentrations of forages, cereals, and protein sources, respectively, highlighting the importance of regularly updating the feed library of the software. More than 60% of nutritionists participating in this study had intentionally formulated diets above trace element software recommendations, considered mineral interactions occurring in the rumen, and used a trace element source known for its better bioavailability (e.g., organic, chelate) when they formulated diets. Herds with more than 80 cows were more likely to be given trace element supplements known for their greater bioavailability. The most used supplement with enhanced bioavailability was selenium. In addition, different trace element feeding strategies pertaining to different stages of lactation and breeds were reported. This finding can be explained by the absence of clear recommendations on trace element feeding by breed. The participants who adjusted trace element feeding according to the stages of lactation considered the transition period as the most challenging period, and they identified the need for a source of trace element known for its greater bioavailability for this period. Further research should aim to identify environmental risk of trace element overfeeding using the One Health approach. Moreover, strategies to avoid trace element overfeeding should be evaluated.

Key words: dairy cattle, questionnaire, trace mineral, advisor, recommendation

INTRODUCTION

With the growing application of technologies on dairy farms, the concept of precision nutrition has emerged. It is defined as meeting animal nutrient requirements more accurately on an individual basis to increase animal health, ensure production sustainability, and decrease feeding cost (White and Capper, 2014). Detrimental environmental impacts caused by overfeeding N and P have been particularly evaluated in recent decades (Arriaga et al., 2009; Powell and Broderick, 2011), and reducing dietary N and P by applying precision feeding has been suggested to mitigate water eutrophication risk and environmental concerns (Cerosaletti et al., 2004; Biagini and Lazzaroni, 2018). Previous studies have surveyed dairy nutritionists to assess N and P feeding practices in the United States (Harrison et al., 2012; Prestegaard-Wilson et al., 2021). Results from American and British surveys have shown that the lack of knowledge on P bioavailability of feedstuffs is one barrier to P precision feeding (Harrison et al., 2012; Harrison et al., 2021). Nevertheless, a cross-sectional study involving 100 Canadian dairy herds has demonstrated that dietary concentrations of P are closer to the recommended values than those for trace...
elements (Duplessi et al., 2021). Indeed, the median percentages of dietary P, Co, Cu, Fe, Mn, and Zn concentrations exceeded NRC (2001) recommendations by 8%, 405%, 52%, 1,346%, 372%, and 65%, respectively (Duplessi et al., 2021). A similar conclusion was reported by Castillo et al. (2013) in Californian herds. In addition, Li et al. (2005) and Sinclair and Atkins (2015) also reported that most trace elements were fed above the recommended levels in Wisconsin and the United Kingdom, respectively. Hence, trace elements are often oversupplied in the diets of dairy cows, which is not in line with precision nutrition.

Formulating a dairy diet in line with trace element recommendations offers challenges to nutritionists. In some cases, trace element concentrations of forages are not known because the near-infrared method, which is routinely used to quickly and inexpensively estimate major nutrients, is not reliable for estimating trace elements (Cozzolino and Moron, 2004). However, the reference method for analyzing trace element concentrations of forages, which uses inductively coupled plasma MS, is expensive and time consuming. Hence, the diet is formulated based on software reference values for ingredient trace element concentrations. In addition, knowledge on trace element bioavailability of feedstuffs and trace element interactions occurring in the rumen is limited, which impedes the ability of models to accurately predict trace element requirements (Weiss, 2017).

Due to the relatively low bioavailability of trace elements in feedstuffs, an oversupply directly increases their excretion in manure (Marchand et al., 2022) and causes their enrichment in the environment through manure spreading, which can have deleterious effects on the ecosystem (Brugger and Windisch, 2015) and increase feed costs. We hypothesize that the trace element overfeeding observed in previous studies might be due to knowledge gaps related to trace element feeding and thus the application of overly cautious safety margins to ensure that the trace element needs of animals are fulfilled. The objective of this study was to identify current practices and perceptions around trace element feeding for dairy cows through a survey of Canadian dairy nutritionists.

**MATERIALS AND METHODS**

**Survey and Data Collection**

An online 23-question survey was developed to address the study objective (Supplemental Materials S1, https://data.mendeley.com/datasets/9dnuy6f1mm/1; Duplessi et al., 2023). The first draft of the questionnaire was revised by 3 Canadian dairy nutritionists (from Ontario, Québec, and Saskatchewan) with more than 10 yr of experience in dairy diet formulation. Their role was to make sure that all questions were clear and to suggest any improvements or additions in line with the objectives of the study. Before the survey was launched, the questionnaire was reviewed and approved by the Agriculture and Agri-Food Canada Human Research Ethics Committee (#2021-D-006). The consent form and all questions were entered in the Qualtrics software (Qualtrics).

To reach a substantial number of Canadian dairy nutritionists, the invitation to fill out the survey containing the online link was distributed by different professional associations to their members [Animal Nutrition Association of Canada (Ottawa, ON, Canada), Ordre des Agronomes du Québec (Montréal, QC, Canada), Ordre des technologues professionnels du Québec (Montréal, QC, Canada)] and through professional pages on social media (Twitter and Facebook). Each association sent the survey participation invitation by email once to their members who were known to formulate dairy cow diets in Canada, and 2 invitations were posted on social media pages, with an interval of 2 mo, aiming to reach Canadian agriculture professionals. The invitation included a link to an anonymous online survey that was available from November 2021 to April 2022. The invitation was sent by email to 547 experts in dairy production, but due to the use of social media to distribute the invitation, accurately evaluating the response rate was not possible.

The first page of the online questionnaire included the consent form information, and at the end of the consent form, respondents had to check boxes to confirm that they met the participation requirements (i.e., formulating dairy diets in Canada and voluntary participation). This confirmation was required for their responses to be included in the study.

The survey was divided into 2 sections. The first section had 7 questions that were intended to obtain a description of the population of respondents for classification purposes. These questions asked participants about the province(s) they were working in, years of experience, number of farm clients serviced, number of milking cows they formulated diets for, herd size of their clients, the type of feeding systems of their clients, and the percentage of clients using a single-group TMR. The 16 questions in the second section were about trace element feeding and addressed the importance of some nutrients and trace elements when diets were being formulated, the frequency of sampling feedstuffs for trace element analysis, the frequency of the use of the feed library of a diet formulation software for trace element concentrations of feedstuffs, feeding management by stages of lactation and breed, and other topics. All
questions were developed to address the study objectives in identifying current practices and perceptions around trace element feeding. The online survey was conducted using an interactive questionnaire, and questions were displayed according to the participants’ responses to previous questions to ensure they were relevant. The research team used an anonymous survey link to avoid personal information being collected that would identify respondents. However, respondents were invited to send an email to the research team if they were interested in obtaining the results of the survey.

**Data Handling and Analysis**

Qualtrics data were exported in an Excel Spreadsheet (Microsoft 365, version 2203) for data analysis. Descriptive data were obtained by Proc MEANS of SAS (version 9.4, SAS Institute Inc.). Further analyses were conducted using the JMP software (version 16.2.0, SAS Institute Inc.). Years of experience of Canadian dairy nutritionists (median = 10 yr) and herd size of clients serviced (median = 80 cows) were divided into 2 categories based on their median value for further analysis: (1) respondents below the median, and (2) respondents at or above the median. For each question, analyses were conducted based on complete responses only, and incomplete responses were discarded. Different analyses were performed depending on the scale used in each question and its main objective. Dairy nutritionists were asked to use a scale of 1 to 5 (1 = not important; 2 = slightly important; 3 = moderately important; 4 = important; 5 = very important; or no opinion) to rank the importance of some macronutrients [i.e., protein, fiber (ADF and NDF), energy, and macro-minerals (Ca, P, and K)] and micro-elements (i.e., Cr, Co, Cu, I, Fe, Mn, Mo, Se, and Zn) for optimizing animal health and productivity when they formulated a cow diet. For analysis purposes, the category of “no opinion” was removed to classify data based on ordinal scales in performing a principal component (PC) analysis to find similarities and differences among ranking patterns of nutrients. An eigenvalue > 1 was required for a PC to be retained. To facilitate PC interpretation, a varimax rotation was applied, and the inclusion of a variable in one PC was based on its highest loading value among the PC obtained (Jolliffe, 2002).

Count data were analyzed using the chi-squared goodness-of-fit test to assess whether the observed frequency followed the expected distribution (Petrie and Watson, 2013). If a frequency was less than 5 within a category, it was merged with the most similar category when possible. A 2 × 2 contingency table was used to evaluate the frequency of feedstuffs analysis for trace elements according to years of experience or average herd size of client serviced categories. “Never” and “sometimes” options were merged together, and “most of the time” and “always” were also merged. “About half of time” was dropped to overcome the low sample frequencies in some cells of the contingency table. Diet formulation relative to the software criteria was also conducted using a 2 × 2 contingency table by considering whether the respondents provided nutrients “above the software criteria” or not, and the “below the criteria” category was removed from the analysis because only one respondent selected this option. It is noteworthy that several recommendation references, such as NRC (2001), might be used by different companies as the basis for their software criteria. Responses to the question related to rationales behind a strategy (e.g., ensure animal health, increase milk production, optimize reproduction performance, mitigate the impact of trace element feeding on the environment, adjust for knowledge of trace element status of local soil content, ensure requirements are fulfilled) were also analyzed using contingency tables. The same tests were applied to the results of questions related to the diet formulation relative to the stages of lactation (“never” and “sometimes” options were merged, “most of the time” and “always” were merged, and “about half of time” was dropped to overcome the low sample frequencies in some cells of the contingency table), formulation relative to the breed (“yes” or “no”; the “maybe” response was merged within the “yes” category because it could indicate a possibility), and mineral interaction considerations (“yes” or “no”; the “maybe” response was merged within the “yes” category) in relation to categories of years of experience of nutritionists or to the herd size of their clients. In all of these tests, a chi-squared test was used when the criterion of at least 5 observations per cell was met; otherwise, the Fisher’s exact test (2 tailed) was applied (Petrie and Watson, 2013). Wilcoxon rank sum test was used to evaluate the impact of years of experience or herd size categories on the percentage of herds using trace element supplements known for its better bioavailability. Significance was considered at $P \leq 0.05$ and tendencies at $P \leq 0.10$.

**RESULTS AND DISCUSSION**

A total of 92 participants filled out the consent form to take part in the survey. Respondents spent about 13 min (SD = 16) to fill out the questionnaire. As respondents were not required to answer all the questions, the number of responses per question varied. Based on the number of email invitations sent, the response rate was estimated to be less than 17% (92 responses out of 547 invitations). Calculating the response rate for the number of respondents based on social media invitations
was not possible. In addition, because invitations were made through different associations and social media posts, the same individual might have been reached several times. Social media was used to increase the visibility of our survey and to enhance the response rate. Harrison et al. (2012) reported a response rate of about 19% for their survey related to precision P feeding by American dairy nutritionists. A recent survey of dairy nutritionists reported a response rate of about 9% (Prestegaard-Wilson et al., 2021), and a recent survey of veterinarians had a response rate of 30% (Jorritsma et al., 2021). These results highlight variation in the response rates between studies and indicate that our response rate for email invitations falls within the range defined by similar studies. The greater response rate in the assessment of Jorritsma et al. (2021) may be partially explained by a reminder invitation having been sent to nonresponders 2 wk after the initial invitation, which was not the case in the present study.

**Description of Respondents**

Dairy nutritionists working in all provinces of Canada took part in the survey [Alberta (9.1%; n = 9), British Columbia (4.0%; n = 4), Manitoba (5.1%; n = 5), New Brunswick (3.0%; n = 3), Newfoundland and Labrador (3.0%; n = 3), Nova Scotia (2.0%, n = 2), Ontario (27.0%; n = 27), Prince Edward Island (2.0%; n = 2), Quebec (38.4%; n = 38), and Saskatchewan (6.1%, n = 6)]. Out of 67 responses for the question about which province(s) or territory(ies) they provided services to their clients, 53 respondents were working in one province, 5 of them worked in 2 provinces, 5 in 3 provinces, and 4 in more than 4 provinces. The percentage of respondents per province roughly represents the percentage of dairy cows per province. For instance, 32% and 37% of Canadian dairy cows are in Ontario and Quebec, respectively (Canadian Dairy Information Centre, 2021b). Participants had a broad range of years of experience and number of farm clients serviced, from 1 to 45 yr and from 1 to 350 farm clients, respectively (Supplemental Materials S2, https://data.mendeley.com/datasets/9dmyy6fhmn/1; Duplessis et al., 2023). The maximum of 350 farm clients may seem to be an unrealistic number of farm clients to be advised by one nutritionist. Reporting of such a high number of farm clients could be a misunderstanding of the question “How many dairy cattle farm clients do you personally have?” by some respondents. Some respondents may have considered the total number of clients serviced by their company or included different farm services offered to different farm clients. According to the total number of farms and cows serviced by the participants, approximately 26% of Canadian herds and cows were represented (Canadian Dairy Information Centre, 2021b). The average herd size (103 cows) reported by the nutritionists was similar to the Canadian herd size average of 98 cows per herd in 2021 (Canadian Dairy Information Centre, 2021b). Thus, responses from the survey were a good representation of the Canadian dairy production. The most popular feeding system was TMR followed by partial mixed rations (Supplemental Materials S2). Moreover, about 60% of TMR feeding system users offered one-single TMR to the lactating group.

**Trace Element Feeding Strategy**

Dairy nutritionists were asked to rate the importance of selected nutrients for optimizing cow health and productivity in diet formulation. A PC analysis was run on these data to identify similar ranking patterns between nutrients. Eigenvalues were lower than 1 after 3 PC. Hence, 3 PC explaining 68.8% of the total variation were retained (36.6% in the first, 19.4% in the second, and 12.9% in the third PC; Supplemental Materials S3, https://data.mendeley.com/datasets/9dmyy6fhmn/1; Duplessis et al., 2023). The PC analysis revealed that the first PC included Co, Cu, I, Fe, Mn, Mo, and Zn; the second PC was related to protein, fiber (NDF and ADF), energy, macro-minerals (Ca, P, and K), and Se; and the third PC was related to Cr. Notably, Fe and Mo had similar loadings after rotation in PC 1 and 3, although loadings were slightly greater in PC 1. This finding suggests that nutrients in the same PC had a similar ranking pattern.

A visual pattern assessment indicated that macronutrients and Se included in PC 2 were the factors most commonly ranked as “very important” [between 58% (n = 38) and 74% (n = 48) of respondents; Figure 1]. For nutrients included in PC 1, which included all trace elements, a more diverse response pattern was observed, and no consensus was observed among nutritionists regarding their importance. This finding highlights that the majority of nutritionists perceived nutrients given in greater quantities in a cow’s diet, such as macronutrients, as being more important and more related to animal health and productivity. In addition, outcomes of trace element nutrition changes might be indirect or subtle (Overton and Yasui, 2014), probably causing the impression that they are less important. Most survey participants (58%) rated Se as “very important” when formulating dairy cow diets. This perception could be related to the fact that this micro-element has been well studied (Weiss, 2017) because of its important role in antioxidants and immune functions, as well as its narrow safety margin between requirements and toxicity (NRC, 2005). Only 1.5% of respondents rated Cr
as “very important,” which is in line with the NASEM (2021) position stating that no clear data support routine Cr supplementation. Although the majority of micronutrients have essential roles to play in dairy cow health and productivity (NASEM, 2021), they are only needed in trace amounts in the diet, and nutritionists’ continuing education programs should include the importance of formulating diets with balanced trace element nutrients.

Dairy nutritionists were asked how frequently they sampled forages or home-grown ingredients or recommended that their clients analyze those ingredients for trace elements. The following question was about the frequency of their use of trace element concentrations from standard reference values in the feed library of their diet formulation software. Trace element concentrations of forages and other feedstuffs are not routinely obtained by regular near-infrared reflectance spectroscopy laboratory analysis because it is not a reliable technique for that purpose (Cozzolino and Moron, 2004). To obtain actual trace element concentrations of feedstuffs, inductively coupled plasma MS can be used, but it is a costly and time-consuming technique. Therefore, we first hypothesized that most nutritionists would not routinely analyze feedstuffs for trace element concentrations and would use software reference values to formulate diets. The findings supported our hypothesis as 51% of dairy nutritionists (n = 34) did not routinely analyze feedstuffs for their trace element concentrations and selected either “never” or “sometimes” in answer to the question on trace element analysis frequency (Table 1). However, about a quarter of them (n = 15) answered that they “always” analyzed feedstuffs for their trace element concentrations. Neither years of experience of participants nor average herd size of their clients had a significant effect on the frequency of trace element analysis (chi-squared 2 × 2 contingency table, $P > 0.20$). With regard to the frequency of using

**Figure 1.** The percentage of Canadian dairy nutritionists (n = 65) who rated macronutrients (protein, fiber, energy, and macro-minerals) and micronutrients (chromium, cobalt, copper, iodine, iron, manganese, molybdenum, selenium, and zinc) as very important, important, moderately important, slightly important, not important, or no opinion. Ninety-two individuals participated in the survey, but not all respondents answered all questions.
trace element concentration references from the feed library of their diet formulation software, 9.5%, 3.2%, and 4.8% of respondents mentioned that they “never” used it for forages, cereals, and protein source ingredients, respectively (Table 2). Based on the percentages of respondents from the “never” and “rarely” categories, a total of 30.1%, 14.3%, and 15.9% of respondents were obtained for forage, cereal, and protein source software reference use, respectively (Table 2). This finding is in line with the previous answer that 23% of dairy nutritionists always analyze forages or home-grown ingredients for trace element concentrations. As expected, most Canadian nutritionists who participated in this study indicated that they “very often” or “always” use software references of trace element concentrations for forages, cereal, and protein sources (54.0%, 71.5%, and 73.0% of respondents, respectively). This also reveals that probably fewer cereal and protein source are laboratory analyzed for trace, therefore more of the feed categories listed in the question related to the frequency of the use of standard reference values. They were asked to select one or more of the following 4 choices to indicate their reasons for not using the references: (1) I use trace element levels based on laboratory analysis, not the trace element concentration in the feed library of the diet formulation software (57% selected this choice, n = 4); (2) Trace element availability of home-grown ingredients is too low to consider them as trace element source (14%, n = 1); (3) Knowledge gaps on actual cow intestinal absorption of trace elements in home-grown ingredients (29%, n = 2); and (4) Other, please specify (14%, n = 1). The explanation provided for the “other” option was that the respondent provided 100% of the animal trace element requirements in the trace element supplement, hence, they did not consider home-grown ingredients as a trace element source. However, the number of respondents to the question about not using the references was too low to make any inferences.

We found that 66% (n = 41) of Canadian dairy nutritionists had intentionally formulated a diet above their software criteria for some trace elements based on their experience; 2% (n = 1) answered that they had intentionally formulated a diet below criteria; and 32% (n = 20) answered that they had not. When excluding the category chosen by only one participant, the percentages for responses in the other 2 categories were significantly different from the expected 50% (chi-squared goodness-of-fit test, P = 0.007), meaning that more

<table>
<thead>
<tr>
<th>Item</th>
<th>No. of responses(^1)</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Very often</th>
<th>Always</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace element analyses(^2)</td>
<td>66</td>
<td>24 (16)</td>
<td>27 (18)</td>
<td>8 (5)</td>
<td>18 (12)</td>
<td>23 (15)</td>
<td></td>
</tr>
<tr>
<td>Stage of lactation(^3)</td>
<td>63</td>
<td>16 (10)</td>
<td>29 (18)</td>
<td>11 (7)</td>
<td>29 (18)</td>
<td>16 (10)</td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\)Ninety-two individuals participated in the survey, but not all respondents answered all questions.  
\(^{2}\)Canadian dairy nutritionists were asked how frequently they sampled forages or home-grown ingredients or recommended that their client analyze those ingredients for trace mineral analyses.  
\(^{3}\)Canadian dairy nutritionists were asked how frequently they adjusted their recommendations according to the stages of lactation when they formulated rations with regard to trace minerals.

Table 1. Percentages (n within parentheses) of how frequently Canadian dairy nutritionists analyzed forages or home-grown ingredients for trace elements and used the results to adjust their recommendations according to the stages of lactation

<table>
<thead>
<tr>
<th>Item</th>
<th>No. of responses(^1)</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Very often</th>
<th>Always</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage(^2)</td>
<td>63</td>
<td>9.5 (6)</td>
<td>20.6 (13)</td>
<td>15.9 (10)</td>
<td>25.4 (16)</td>
<td>28.6 (18)</td>
<td>0.0 (0)</td>
</tr>
<tr>
<td>Cereal(^3)</td>
<td>63</td>
<td>3.2 (2)</td>
<td>11.1 (7)</td>
<td>12.7 (8)</td>
<td>30.2 (19)</td>
<td>41.3 (26)</td>
<td>1.6 (1)</td>
</tr>
<tr>
<td>Protein source(^4)</td>
<td>63</td>
<td>4.8 (3)</td>
<td>11.1 (7)</td>
<td>7.9 (5)</td>
<td>27.0 (17)</td>
<td>40.0 (29)</td>
<td>3.2 (2)</td>
</tr>
</tbody>
</table>

\(^{1}\)Ninety-two individuals participated in the survey, but not all respondents answered all questions.  
\(^{2}\)Including silages and hays.  
\(^{3}\)Including corn grain, barley, and wheat.  
\(^{4}\)Including soybean and canola sources.
dairy nutritionists intentionally formulated diets above their software criteria. This result agrees with previous studies showing that most dairy cows were fed above trace element recommendations (Castillo et al., 2013; Sinclair and Atkins, 2015; Duplessis et al., 2021). Long-term trace element overfeeding may have deleterious impacts on animal health due to hepatic accumulation (López-Alonso, 2012). Formulating above the software criteria was not related to respondent years of experience or to average herd size categories (chi-squared 2 × 2 contingency table, \( P > 0.56 \)). A selection of software is available for formulating cow diets based on different references (e.g., Volden, 2011; INRA, 2018; NASEM, 2021). Unfortunately, no data were collected on which software nutritionists used on a regular basis. Based on the previous question about whether they formulated diets above their software criteria for trace elements, participants were asked to indicate the reasons behind their strategy. They were provided with a list of 7 options from which they could select one or more options (Table 3). Among dairy nutritionists who had never intentionally formulated a diet above or below software criteria for trace elements, 75% did not select that they aimed to mitigate the impact of trace element feeding on the environment. However, the remaining 25% (\( n = 5 \)) tended to be more likely to respond to the stage of lactation as an environmental factor than those who selected that they had formulated a diet above criteria (7%, \( n = 3 \); Fisher’s exact test, \( P = 0.10 \)). This result shows the importance of raising awareness of the potential negative impacts of trace element overfeeding on the environment, which might have long-term consequences (Benke et al., 2008). In a comprehensive review, Weiss (2017) stated that a holistic approach to evaluating the impact of trace element overfeeding is needed. Adjusting trace element recommendations according to trace element status of local soil content was selected more frequently by dairy nutritionists who had intentionally formulated a diet above software criteria for trace elements (34%, \( n = 14 \)) compared with those who had never intentionally formulated a diet above or below software criteria (10%, \( n = 2 \); Fisher’s exact test, \( P = 0.06 \); Table 3). This finding suggests that some nutritionists are aware that soil trace element concentrations differ within regions and counties (Lèvesque, 1974) and that this variation can affect trace element concentrations of crops and resulting feedstuffs (Antoniadis et al., 2017). Other options were not significantly different between participants with different trace element formulation strategies (Fisher’s exact test, \( P > 0.12 \)). Those who selected “other” were asked to explain their choice (\( n = 6 \)). Respondents who had intentionally formulated a diet above criteria said that their software criteria were too low or not up-to-date (\( n = 2 \)) or that forage trace element concentrations were uncertain (\( n = 2 \)); the 2 respondents who had never intentionally formulated a diet above or below criteria left the cell blank (\( n = 2 \)). High percentages of respondents who had intentionally formulated a diet above their software formulation criteria reported that they did it to ensure animal health and reproduction and to fulfill animal requirements (Table 3). This approach may reflect a lack of confidence in their software criteria or recommendations.

Most dairy nutritionists mentioned that they considered mineral interactions that could occur in the rumen when they were formulating a diet (“Yes”: 60%, \( n = 35 \); “Maybe”: 16%, \( n = 9 \); and “No”: 24%, \( n = 14 \)). For instance, high dietary S and Mo concentrations have negative effects on Cu absorption (NASEM, 2021). No significant effect of average herd size or years of experience categories was observed on mineral interaction considerations (Fisher’s exact test, \( P > 0.27 \)).

**Trace Element Feeding and Stage of Lactation**

The management of trace element feeding according to the stage of lactation is variable among Canadian dairy nutritionists. Indeed, 29% (\( n = 18 \)) of participants responded that they “sometimes” adjust their trace el-

### Table 3. Percentages (n within parentheses) of Canadian dairy nutritionists who provided rationales for formulating diets above or below their software formulation criteria for trace elements

<table>
<thead>
<tr>
<th>Item</th>
<th>No. of responses(^1)</th>
<th>Animal health</th>
<th>Milk production</th>
<th>Reproduction</th>
<th>Environment</th>
<th>Soil content</th>
<th>Requirement</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>20</td>
<td>60.0 (12)</td>
<td>20.0 (4)</td>
<td>55.0 (11)</td>
<td>25.0 (5)</td>
<td>10.0 (2)</td>
<td>85.0 (17)</td>
<td>10.0 (2)</td>
</tr>
<tr>
<td>Yes, above criteria</td>
<td>41</td>
<td>80.5 (33)</td>
<td>17.1 (7)</td>
<td>73.2 (30)</td>
<td>7.3 (3)</td>
<td>34.2 (14)</td>
<td>68.3 (28)</td>
<td>9.8 (4)</td>
</tr>
<tr>
<td>Yes, below criteria</td>
<td>1</td>
<td>100.0 (1)</td>
<td>0.0 (0)</td>
<td>100.0 (1)</td>
<td>100.0 (1)</td>
<td>0.0 (0)</td>
<td>0.0 (0)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Ninety-two individuals participated in the survey, but not all respondents answered all questions.

\(^2\) The 7 options provided were the following: ensure animal health, increase milk production, optimize reproduction performance, mitigate the impact of trace element feeding on the environment, adjusting for knowledge of trace element status of local soil content, ensure to fulfill requirements, and others. Respondents could select as many options as applicable.
ment recommendations according to the stage of lactation when formulating a diet, and the same proportion of respondents selected the “most of the time” option. Meanwhile, 16% (n = 10) responded that they “never” adjust their recommendations, and 16% also indicated that they “always” adjust their recommendations based on lactation stage (Table 1). The observed frequencies tended to differ from the hypothesized probability of 20%, if responses would have been evenly distributed (chi-squared goodness-of-fit test, \( P = 0.08 \)). Based on the 95% confidence intervals, it appears that the frequencies of “sometimes” and “most of the time” are different from the frequencies of the other choice categories. The wide variability between responses might be explained by dairy nutritionists using different recommendation references. Indeed, some references use a fixed recommendation for trace element concentrations in the diet (e.g., INRA, 2018), while others use the factorial approach based on maintenance, lactation, pregnancy, and growth requirements to compute total requirements (e.g., NASEM, 2021). In the factorial approach, the recommendations are adjusted according to the stage of lactation as milk yield is included in the equation. Moreover, trace elements are involved in several biological functions, such as oxidative and immune functions, that are particularly challenged around calving, such that the classical factorial approach fails to measure the actual requirements (Overton and Yasui, 2014). No significant impact of years of experience or average herd size categories was noted on trace element feeding strategy according to the stage of lactation (chi-squared \( 2 \times 2 \) contingency table, \( P > 0.68 \)). From the 10 nutritionists who indicated that they “never” adjust their recommendations based on lactation stages, 70% (n = 7) mentioned that most of their clients have one-TMR lactating cow group, 10% (n = 1) indicated that trace element requirements do not vary within the lactation cycle, 10% (n = 1) reported that they do not know, and 20% (n = 2) selected the “other” option and specified that adjusting trace element recommendations to stages of lactation would unnecessarily complicate diet formulations.

Fifty-three participants who reported that they “sometimes,” “about half the time,” “most of the time,” or “always” adjust their recommendations according to the stage of lactation were invited to clarify which stage is the most critical period regarding trace element feeding in a multi-choice question. As expected, the transition period from dry to calving (92% of those respondents, n = 49) was chosen as the most critical period, followed by the onset of lactation (74%, n = 39). The dry period was selected by 55% (n = 29) of nutritionists and about 6% (n = 3) chose the middle or the end of lactation. Accordingly, in a cross-sectional study involving 100 dairy herds, dietary Cu, Mn, and Zn concentrations were greater between 0 and 21 DIM than after 200 DIM (Duplessis et al., 2021). Similar results were obtained by Sinclair and Atkins (2015). The first recommended change during the period(s) selected in the previous question regarding trace element feeding was to use a trace element source known for its better bioavailability (e.g., organic, chelate) by 78% (n = 40) of respondents, while 14% (n = 7) mentioned that they did not have a special recommendation and 8% (n = 4) selected the “other” option. Half of the latter group specified that the change was dependent on the situation, and the other half mentioned that they increased trace element supply without clarifying which source (organic or inorganic) they used. None of the respondents selected the recommendation option of increasing inorganic trace mineral supply in the diet based on lactation stages. Some studies have shown that providing a trace element supplement that is considered to be potentially more bioavailable during the transition period can have positive effects on oxidative metabolism and immune function (Yasui et al., 2014; Batistel et al., 2016, 2017; Osorio et al., 2016), while other studies have shown a modest or no impact (Weiss and Hogan, 2005; Ogilvie et al., 2022).

Sources of Trace Element Supplement

On average, 71% (median, 80%; SD, 33 percentage points; minimum, 0%; and maximum, 100%; n = 59) of the herds serviced by respondents were using a trace element source known for its better bioavailability (e.g., organic, chelate) for all or some of the mineral supplement included in the diet. Among respondents, 14%, 8%, 14%, 15%, and 49% stated that the percentage of their farm clients using a trace element supplement known for its better bioavailability was between 0% and 20%, 20% and 40%, 40% and 60%, 60% and 80%, and 80% and 100%, respectively. The number of years of respondent experience did not have an impact on the percentage of those using a trace element supplement known for its better bioavailability (\( P = 0.97 \)). However, a tendency was observed for using more trace element supplements known for their better bioavailability for herds with a greater number of cows (\( P = 0.06 \)). The use of more bioavailable trace element supplements was about 63% (SD, 34 percentage points) in herds with a herd size smaller than 80 cows and was about 79% (SD, 27 percentage points) in herds with more than 80 cows. The most popular trace element supplement used for its better bioavailability was Se (90%, n = 55), followed by Zn (74%, n = 45), Mn (59%, n = 36), and Cu (51%, n = 31; Figure 2). These findings are not surprising because several studies reported beneficial effects of
these trace elements on cow health and productivity (Overton and Yasui, 2014). Some trials also combined supplements that had more bioavailable Cu, Mn, and Zn with supplements that had more bioavailable Co (Rabiee et al., 2010), with 34% of respondents selecting Co. However, the combination of several trace elements in the same treatment do not allow discriminating the effects of individual trace elements on animal performance and health. The concept of supplementing Cr has not been extensively studied, which explains the relatively low use of supplements with more bioavailable Cr (21%, n = 13) in the current study. However, some research has shown positive effects of its use on milk production and reproduction (Overton and Yasui, 2014).

Trace Element Feeding and Breed

Survey responses revealed that 56% (n = 35) of participants did not use different inclusion rates of trace elements in diet formulation considering the cow breed, 8% (n = 5) “maybe” used different inclusion rates, and only 35% (n = 22) used different inclusion rates. As 93% of Canadian cows are Holsteins (Canadian Dairy Information Centre, 2021a), some dairy nutritionists who did not use different inclusion rates for different breeds may have only formulated diets for Holsteins, and thus, the question was not applicable for them. Average herd size and years of experience categories had no significant impacts on the diet formulation according to the breed (chi-squared 2 × 2 contingency table, $P ≥ 0.12$). Limited knowledge exists on trace element absorption efficiency related to the breed. Du et al. (1996) showed that Cu absorption and postabsorption metabolism between Holstein and Jersey cows were different, with Jerseys probably being more susceptible to Cu toxicity. Another study also suggested a difference in Se metabolism between Holstein and Jersey cows (Bass et al., 2000). However, no clear recommendations exist regarding trace element concentrations in diet according to differences among breeds. This lack of recommendations explains the high percentage of respondents not considering the breed when formulating a diet for non-Holstein cows. Research on sheep and beef cattle demonstrated that breed differences exist in trace element metabolism (Wiener, 1979; Pogge et al., 2012; Ranches et al., 2021).

Respondents who reported that they adjust their recommendations according to the breed were asked what kind of changes they applied for typical breeds found in Canada in comparison with the Holstein breed (Table 4). About 67% of respondents (n = 16) mentioned that they formulated a diet with lower trace element concentrations for Jerseys in comparison with Holsteins (Table 4), which is in line with results of Du et al. (1996). When applicable, most dairy nutritionists formulated a diet with either lower or equal trace element concentrations for non-Holstein compared with Holstein cows.
Further research should aim to identify environmental risk of trace element overfeeding using the One Health approach. Moreover, strategies to avoid trace element overfeeding should be evaluated to get closer to the precision nutrition approach.

CONCLUSIONS

About 26% of the Canadian herds and cows were covered by the respondents. Results showed that most respondents rated macronutrients as very important for animal health and productivity, but there were diverse responses regarding the importance of trace elements, varying from very important to not important. As between 54 and 73% of nutritionists use the standard software reference values of their feed library to estimate trace element concentrations of ingredients used to formulate the diets, it is important to make sure that the references are representative of the farm region. More than 60% of respondents had intentionally formulated a diet above their software criteria regardless of possible environmental concerns, had considered mineral interactions occurring in the rumen, and had used a source of trace elements known for its better bioavailability in cow diets. Farms with greater herd size tended to use more trace element supplements known for their better bioavailability. The survey revealed that diverse strategies existed regarding trace elements at different stages of lactation as well as considering the breed of cows.

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