**Running head**

DAIRY INDUSTRY TODAY

**Interpretative summary**

Dairy Industry Today:

Survey design and implementation quantifies winter housing and bedding types used on Vermont organic dairy farms.Andrews. At least 27% of Vermont dairy farms are certified organic, and there is a knowledge gap regarding the types of indoor housing used for lactating dairy cattle on these farms. In Vermont, winter weather can be severe and cattle may be housed indoors due inclement weather, especially during non-grazing seasons. We report on our successful survey approach and questionnaire obtaining estimates of the frequency and diversity of winter housing and bedding types and systems for lactating dairy cows on Vermont organic dairy farms.

**Survey design and implementation quantifies winter housing and bedding types used on Vermont organic dairy farms**

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**ABSTRACT**

We conducted a descriptive observational survey to quantify the frequency and diversity of winter housing and bedding types used by organic dairy farmers in Vermont. This report describes the survey methods, results, successes, limitations, and lessons learned from administering the survey. Beginning in December 2018, a short questionnaire was administered by web, mail, and telephone to a source population defined as all producers of organic dairy cow milk in Vermont (*n* = 177) listed in the United States Department of Agriculture Organic Integrity database. Our approach yielded an 82% (*n* = 145) response rate from certified organic farms producing cow’s milk in Vermont at the time of the survey.

The three most common housing and bedding material combinations used by respondents were tiestall housing with wood (sawdust or shavings) bedding materials (45%), freestall housing with wood bedding materials (14%), and freestall housing with sand bedding (12%). Fifteen percent of respondents reported using more than one type of facility for winter housing of lactating cattle. The median number of lactating cows on farms among respondents was 59.5 (range 2 to 400), and the odds of using more than one type of facility to house lactating cows increased positively with the number of lactating cows reported for a herd. Four primary categories of cattle breeds were identified among the respondents’ herds: 1) Holstein cattle only; 2) Jersey cattle only; 3) mixed Holstein and Jersey herds with crosses; and 4) mixed Jersey and Holstein herds with one or more additional breeds. Breed distribution was similar across the housing and bedding type categories. An association between frequency of individual cow milk somatic cell count testing and housing type was identified; respondents using freestall sand facilities tested less frequently than herds in tiestalls with wood bedding. While the questionnaire length limited the amount of information gathered, the response proportion was exceptional and overall our survey results provide valuable insight on Vermont organic dairy housing and bedding practices that should inform future extension and outreach efforts for this sector of the dairy industry.

*Key words.* cattle, organic farms, dairy, survey, animal housing

**INTRODUCTION**

Dairy cattle housing and bedding systems influence animal health, reproduction, milk quality, animal well-being, productivity and farm profitability (Bewley et al., 2017). Future trends of dairy cattle housing will reflect consumer demands, animal behavior, and environmental impact (Bewley et al.,2017). The long-term sustainability of the dairy industry depends on the extent that housing systems reflect these priorities (Beaver et al., 2020). In 2014, tiestall housing systems were the most common housing types for lactating cows among all dairy operations in the US and foremost among operations with less than 100 cows (USDA 2016). Tiestall or stanchion barns were reported as the most frequent milking facility for organic farms in New York, Oregon and Wisconsin (Stiglbauer et al., 2013), while a freeestall system was the primary lactating cow housing for 17% of organic herds in New York, Oregon and Wisconsin. Regional differences in herd size and types of facilities exist among US dairy operations (USDA 2016), and it is unclear how Vermont organic dairy farms compare to other northern tier US states that lead in organic dairy production (O’Hara and Parsons, 2013; Richert et al., 2013). Vermont ranks sixth by number of certified organic dairy farms per state and first by number of certified organic dairies per square mile in the US (USDA-NASS, 2017). In 2019, the number of certified organic dairy farms was 177, 26% of the total 675 cow dairy farms in the state.

US organic production regulations stipulate living conditions provide “year-round access for all animals to the outdoors, shade, shelter, exercise areas, fresh air, clean water for drinking, and direct sunlight, suitable to the species, its stage of life, the climate, and the environment” and pasture access providing “a minimum of 30 percent of a ruminant's dry matter intake (DMI), on average, over the course of the grazing season(s)” (USDA, 2020). In the northern US, including Vermont, where inclement weather and heavy snowfall may dominate during winter months and pasture access may be limited from November to March or April, organic dairy herds may be housed indoors for extended time periods. As animal welfare, health and productivity measures appear to be influenced by both type of bedding material and facility (Leso et al., 2020), the conditions in which organic dairy cows are housed during these months of inclement weather can have significant ramifications. To date, how the relationship between animal health and productivity outcomes such as hygiene, mastitis, and milk production and quality differs between freestalls, tiestalls and compost bedded pack facilities remains unclear (Leso et al., 2020).

Reported frequencies of milking facility types (e.g., parlor vs. tiestall or stanchion milking) on organic dairy farms in other northern states may provide a crude estimate of the corresponding housing facilities, but do not provide specific estimates of winter housing or bedding materials (Stiglbauer et al., 2013; Sorge et al., 2016). For example, pasture or dry-lot was designated as the primary housing type (110 of 192 farms) for lactating cows on organic farms in New York, Oregon and Wisconsin (Richert et al., 2013). Because only 22% of farm visits were conducted in the winter for this survey, it is possible that seasonality of the survey biased the primary housing type reported. Further, these prior surveys did not appear to capture the type of bedding material used, and some styles of housing (e.g., loose- or open-housing pack barns) appear to be reported infrequently. Although it is unclear how many US organic dairy farms have adopted bedded pack loose-housing systems for lactating cattle, non-freestall loose-housing is on the rise. Between 2007 and 2014, non-freestall loose-housing increased from 3.4% to 6.4% of all dairy facilities, and from 3.5% to 8.5% of facilities for dairies with a herd size less than 100 cows (USDA 2010, 2016).

In Vermont and nationally, extension publications have promoted the construction and use of bedded pack or compost bedded pack facilities as an alternative to traditional housing systems (Bewley et al., 2012; Gilker at el., 2012; Ogejo, 2018; Endres and Janni, 2019). However, a paucity of information on the distribution and types of bedding materials used on organic dairy farms nationally or regionally in the US makes it a challenge to properly design and conduct observational studies to identify associations between housing systems and productivity or health and welfare outcomes. The primary objective of this descriptive study was to gain a reliable estimate of the frequency of housing and bedding material types used on organic dairy farms in Vermont, specifically aiming to quantify the number of producers using a bedded pack system. Due to a small target population, confidence in our results depended on a high response rate. To address this challenge, we designed and implemented a short format questionnaire that was administered by multiple methods with two follow-up communication. Therefore, a secondary objective of this work was to report on the methods we applied in an attempt to achieve a response from at least 40% of the source population. Additional factors addressed in this survey were years of farming experience, herd size, breed(s) of cattle, and the frequency of use of individual cow somatic cell count (SCC) testing through Dairy Herd Improvement providers among farmers using different housing and bedding types. This report discusses both methodology of administration and results of the Vermont Organic Dairy Winter Housing and Bedding Survey.

**MATERIALS AND METHODS**

With input from social scientists, a survey tool was developed to estimate the frequency of different housing and bedding types used on organic dairy farms in Vermont in the winter of 2019. The survey tool was a short questionnaire designed to be administered by multiple methods (mailed, internet-based, telephone interview). The process included initial outreach, survey distribution through online access and mailed paper copies, follow-up mailings and telephone reminders with the opportunity to complete the questionnaire by telephone interview. Survey methodology was approved by the Institutional Review Board at the University of Vermont (CHRBSS: 19-0057), and respondents received no reimbursement for completion of the survey. The Strengthening the Reporting of Observational Studies in Epidemiology statement checklist for Veterinary medicine (STROBE-Vet; O’Connor et al., 2016) was considered during survey design and for reporting results.

***Sampling Method***

The target population was organic dairy farms in Vermont, USA, with possible relevance to organic dairy farms in the northeastern United States. The source population was farms in Vermont, USA that were producing and shipping certified organic cow milk at the time of the survey. We hypothesized bedded pack systems would be used less frequently compared to tiestall or freestall housing systems. Sustainable agriculture extension experts provided estimates that approximately 30 dairy farms used bedded pack systems in Vermont, with the majority being used on organic dairy farms. Therefore, the target number of survey respondents was at least 77 organic dairy farmers, based on an *a priori* estimate of 20 (10%) dairy farmers using bedded pack systems in a fixed population of approximately 200 organic dairy farms, an allowable margin of error of 2.5%, and assuming Type I error of 5% (Zα = 1.96).

Obtaining contact information for farmer populations can be a challenge, as state agricultural agencies may not share dairy farmer contact information and because farmer populations may be dynamic. For example, the number of organic dairies in Vermont identified in state government data increased from 184 in 2015 to 203 in 2016, and then declined to 190 by the first quarter of 2019 (Vermont Dairy Data, 2020), although the list of individual farms is not freely accessible through state agencies. In comparison, the USDA Organic Integrity (USDA-OI) database (<https://organic.ams.usda.gov/integrity/>) is publicly accessible. USDA-OI data are provided by USDA-Accredited Certifying Agents (certifiers) and databases are updated by certifiers monthly or more frequently. Dairy farm names and addresses were retrieved from the database using terms “Dairy cow: milk” and “VT-Vermont.” Two searches were performed. First, a search of the USDA-OI database, conducted 10 October 2018, yielded 197 farms. At the time of our initial USDA-OI database search, it was unclear when the database had last been updated. A second search of the same database on 10 January 2019 reflected an update in December 2018, yielding a smaller pool of 177 farms. Contact information from the first search was used for the mailing list for the initial questionnaire, and information from the second search of the updated database served as a reference for verification and defined the source population of certified organic dairy farms producing milk in Vermont for this study.

***Questionnaire Design***

The survey tool was designed to be administered as a mailed questionnaire with the option for participants to complete an internet-based version. We opted for a short-format questionnaire (8 questions) with the goal of achieving a high response rate, accepting the trade-off of accumulating limited specific data (Supplemental Figure S1; https://doi.org/10.3168/jds.20XX-XXXXX). Questions were crafted using the fewest words necessary, using terms assumed to be understood by dairy farmers, and limited in scope to avoid the need for a respondent to seek other sources of information such as farm records. Multiple question types were used, e.g., open “fill-in-the-blank” questions on number of lactating cows, years of farming experience and breed(s) of cattle, and closed multiple choice questions on winter housing type, bedding material use and milk somatic cell count testing frequency. A third option “other, fill-in-the-blank” was included for multiple choice questions on housing and bedding types because we anticipated a possible range of responses beyond the categorical choices we provided.

The survey tool began with a statement informing participants of confidentiality and introduced the goals of the study and the URL address of the web survey version (Supplemental materials S1). Personal identifiable information was limited to farm name and location. This information was included to identify and eliminate duplication of results across the three administration methods (e.g., if a farm completed both the mailed and internet-based versions). The assurance of confidentiality was reiterated at the end of the question section, just before a boxed section that asked for contact information for the farm. The questionnaire was pre-tested for clarity with members of the research team not involved in the initial question design and with the herd managers of the conventionally-managed University of Vermont dairy research herd.

***Questionnaire Administration***

The survey tool was distributed through direct individual mailings and as an online version shared through social media. The web-based questionnaire content was identical to the paper version and was created using Lime survey software (<https://www.limesurvey.org/>). The web-based questionnaire format was tested by research team members prior to opening for public access.

The web-based questionnaire went live on 7 December 2018 and was available until 1 May 2019. During the week following live access to the web-based survey, the source population was informed of the study via announcements on University of Vermont Extension social media platforms and newsletters, and through a press release sent to local newspapers, agriculturally focused web-based news outlets, stakeholder email listserves, and organic association e-newsletters. Digitized announcements included a URL link to the web-based questionnaire.

The first mailing, including the questionnaire, study goals description and a separate stamped, self-addressed return envelope, was mailed on 21 December 2018 to the 197 farms in the USDA-OI database from the October 2018 search (Figure 1). A telephone call reminder was made the week of 21 February 2019 to farms that had not yet responded to either the mailed or web-based forms. Respondents who answered the call were given the opportunity to complete the questionnaire as a telephone interview; otherwise, if possible, a reminder message was left with a telephone number to call if the farmer preferred a telephone interview. After cross-referencing the updated USDA-OI database, a second mailing was distributed on 6 March 2019 to farms that had not yet responded (87 farms of the 177 in the December 2018 updated USDA-OI database). To eliminate duplicate contact attempts, identifying information (farm name) from completed questionnaires was used to identify non-responding farms for each successive administration of the survey, but this private information was not included in any downstream analyses. The second mailing included an additional notice to apologize if the recipient had already completed the survey in another format and to prevent multiple submissions from the same farm.

***Analyses of Survey Responses***

Individual farms were identified by a numerical code and questionnaire response data were separated from identifying information and digitally entered using Microsoft Excel*.* Data from the web-based questionnaire was exported as a CSV file and merged into a single file with the mailed and telephone response data. The format for survey completion was recorded for each respondent and occasional duplications removed (i.e., farms that responded by more than one method). Missing data for individual questions were identified and excluded from statistical analysis. All statistics were performed using R 4.0.2 software.

Descriptive summary statistics were calculated for each question. Calculation of 95% confidence intervals (CI95) on reported proportions for types of housing and bedding systems and frequency of SCC testing was performed using the DescTools package (Signorell et al., 2020). Independence of categorical variables was assessed with Pearson’s chi-square test, or Fisher’s exact test when count data include small numbers. Kruskal-Wallis (K-W) rank sum test was used to test associations between ordinal dependent variables and independent variables with multiple categories, and when significant differences were observed the Dunn test for multiple comparisons with adjustment was applied using the FSA package (Ogle et al., 2020). Relationships between categorical independent variables with two or more levels and continuous dependent variables were assessed using one-way analysis of variance (ANOVA), and when a significant effect was observed, post-hoc pairwise associations were tested using Tukey’s Procedure (TukeyHSD function). When extreme outlier observations were identified the effect of removing outliers from the data was considered. Tests of data normality and homogeneity of variance were performed and where assumptions of normality appeared to be violated the data was transformed to approximate a normal distribution. Possible associations between SCC testing frequency category and independent predictors were tested by multinomial logistic regression. Because herd size and housing type were associated and were *a priori* identified as possible explanatory variables for SCC testing frequency, a multivariable model was employed to investigate the relationship between housing, herd size and SCC testing frequency. Since we were interested in whether herds used SCC testing at least monthly or not, the responses to the question on SCC testing frequency were reduced to a binary categorical variable, SCC testing less than (0) vs. greater than or equal to approximately monthly (1) and entered as an outcome variable in binary logistic regression models. A forward stepwise variable selection process was used, and the final model was selected based on lowest Akaike information criteria, with final model fit assessed by plotting the deviance residuals. Goodness of fit for the final model was evaluated with the Hosmer-Lemeshow method. Wald test was used to evaluate the statistical significance of each predictor in the model. *P-*values were assigned to assess significance of association, with significance at *P* ≤ 0.05.

**RESULTS AND DISCUSSION**

***Survey Methodology***

The overall response rate was 82% (*n* = 145) of 177 certified organic dairy farms producing cow milk in Vermont. Three producers reported they were no longer active dairy producers via the first mailed survey and two reported selling their herd when responding by phone (excluded from analysis). Four additional farms that were located outside of Vermont and were not included in the mailings responded to the web survey (excluded from analysis because they were not part of the source population). Based on the response to this survey we suggest the USDA-OI database is an acceptable source of contact information for research on organic dairy farms because it is publicly accessible, includes farm contact information and is updated regularly using data submitted by organic farm certifiers.

The initial response to the web-based questionnaire was 26 farmers, 15% of the source population. Web responses were received between days 4 and 45 of the 144-day live period of the survey. In contrast, the response to the first mailing was 75 participants or 42% of the source population within 75 days of the initial mailing. Telephone and mailed reminders accounted for 18 and 26 additional responses, respectively.

The rate of response far exceeds what is described and has been reported previously for mailed questionnaires administered to farmers (Pennings et al., 2002; Pereira et al., 2013). While mailed questionnaires are most commonly used, at least partly due to cost and convenience advantages, their low response rate can be a barrier to obtaining a representative sample (Pennings et al., 2002). Potential factors that influence response to mail surveys among farmers include: 1) timing of administration in context of seasonal farm production schedules, 2) length of the questionnaire and amount of time perceived to complete the mail survey, 3) potential compensation for participation, and 4) limiting questions to those that do not require farmers to consult records for factual information (Pennings et al., 2002). The subject’s interest in the topic of the questionnaire, content of the cover letter introducing the study, its “sponsors,” and the stated goals of the study (including intended use of the data) also influence response, as does the use of follow-up reminders (Pennings et al., 2002). We suspect the same factors may apply to farmers’ response to questionnaires administered by other methods, such as the internet or telephone, although in a review of the literature we were unable to find published research exploring these factors. Response frequency and timing appeared to differ among the administration methods, suggesting variation among organic dairy farmers in their proclivity to respond to different questionnaire administration methods, although our study was not designed to test this hypothesis. Further research seems warranted to explore dairy farmer preferences for questionnaire formats and administration methods and the effect of using multiple methods on survey response frequencies.

Additional factors that may have contributed to a high response frequency for this survey include relatively short length of the questionnaire, and advertisement and administration of the survey in the “slower” winter season. Timeliness of the topic and interest to members of the source population, also known as “selection by the respondent,” may have also been a factor (Pennings et al., 2002). Producer interest in the subject matter was measured by question 8 and appeared to be ‘high’ with greater than 65% of respondents overall indicated they were “somewhat” or “very” interested in the survey results. Respondent interest was associated with the method of administration (K-W chi square = 14.35, *P <* 0.01) (Table 1). The proportion of respondents indicating “very” interested in the survey results was highest for those completing a web-based questionnaire, and pairwise comparisons indicated the distribution of responses among web-based respondents differed from those who responded to the first and second mailings (adjusted *P* = 0.02 and < 0.01, respectively). This suggests an interest in the study may have motivated web-based participation, although it is likely other factors influenced the choice between completing a survey on the internet or by mail. Neither years of dairy farm management experience nor total years of organic dairy farming experience were associated with method of survey response (*P* = 0.73 and 0.74, respectively).

Completion of 70% of web-based questionnaires occurred between 10-13 December 2019, when the first media communication went out, and 21-23 December 2019, when the first mailing was delivered. While this suggests the importance of multiple reminders from varied media, no additional web-based participation occurred after the telephone reminder or second mailing, further supporting our speculation that web-based participation was related to interest level, or to timing of initial social media advertisements, among other factors. In contrast, respondents to the second mailing had the lowest proportion of “very” interested and a high proportion with no interest in survey results. Respondents interviewed by telephone also had a high level of interest (56% “very”). It is possible that web-based respondents would have also responded readily to the mail survey or telephone call, had they not first filled out the web survey. While response rates for internet-based questionnaires may be lower than mail-based surveys, when evaluated in a survey of American households, internet tools did not appear to exhibit item non-response bias (Hudson et al., 2004). In the context of our survey, the addition of an internet-based approach did not significantly increase the cost of our survey and had some advantages in ease of data processing. We speculate that internet-based administration can be an effective supplemental option to mailed questionnaires. Additional research is needed to determine if internet-based questionnaires are a suitable mode of administration when used as the only option for farmer populations, especially given potential issues related to internet coverage in rural areas and possible self-selection bias related to demographic variables such as age (Hudson et al., 2004).

The short survey length may also have contributed to the high response rate. Conversely, the length was also a limitation, constraining the information collected by the survey, including why respondents demonstrated interest in this topic area. In retrospect, we believe this issue is particularly interesting given that housing and bedding types was not identified as a research and education need in a previous survey of organic farmers in the northeastern US (Pereira et al., 2013). Additional research would be necessary to understand the true motivation behind the high response rate. For example, were the respondents motivated by challenges they are experiencing with their current housing and bedding systems? By perceived social trends or consumer demands related to confinement housing systems? And, is this farmer population considering alternative housing and bedding systems? As one farmer commented on the web-based survey, “I am very interested in the relationship between housing type, bedding type and pathogens . . . I hope there will be [a] more in depth survey at a later date.”

***Survey Results***

***Housing and Bedding Styles and Materials***. All 145 survey sample respondents provided information on the type of facility used, while one respondent did not report the type of bedding used. A single type of housing system was used by 123 (85%) of respondents. The most common housing type for lactating cows on farms using a single housing system was tiestall (*n* = 68, 46%, CI95 39-55%), which included 63 respondents (43%, CI95 36-53%) using only wood products for bedding, 4 respondents using wood and hay or straw, and 1 respondent who did not report the bedding material used (Figure 1). The next most frequent facility type on farms using a single housing systems was freestall (*n* = 43, 29%, CI95 21-38%), which included 21 farms (14%, CI95 10-21%) bedding with only wood products and 18 farms (12%, CI95 8-19%) bedding with only sand (Figure 1). Use of a bedded pack system was reported on 22 farms (15% CI95 10-22%). Of those using a bedded pack, nine (6%) farms reported using only a bedded pack housing system, and of these 6 respondents used wood products for bedding and 3 used hay or straw for bedding (Figure 1). Multiple housing systems for lactating cows were used on 22 (15%) of farms. Loose-housing with no stalls or cubicles (including bedded pack) was used solely or in combination with another housing type on 25 (17%, CI95 12-24%) farms. Among the 22 farms that reported using a bedded pack for lactating cows, 13 used this strategy in conjunction with another lactating cow housing type (“Bedded Pack Plus” Figure 2), including tiestall or freestall housing, and the bedding types on these farms included wood products only (*n* = 5), wood and hay or stray (*n* = 5), hay or straw (*n* = 2), and sand, wood products and hay or straw (*n* = 1). The remaining farms (14%) reported a mixed tiestall and freestall system (*n* = 9), freestalls using both sand and wood (*n* = 4), or a loose-housing system that was not described as a bedded pack and was bedded with wood products (*n* = 3).

There was a positive association between using more than one type of facility to house lactating cows and the number of lactating cows in respondent herds (*P* = 0.03). We had not expected that so many respondents would use more than one type of facility and more than one type of bedding material. Herds using bedded packs had the most variation in bedding and housing types. “Mixed” housing systems using bedded packs in combination with another style were common. As discussed above, to encourage a high response rate, questions were designed to be brief and targeted, which restricted the information provided in responses. For example, because it is always constructed in an open floor plan barn, we chose to include “bedded pack” as a housing style, rather than ask about loose-housing and then clarify if it was managed as a bedded pack. Furthermore, while respondents were able to select more than one bedding or housing type, there was an open component to this question where respondents could write a short response specifying which bedding was associated with which housing type. While this had the effect of shortening the survey, it may have introduced some potential measurement error. No respondent who selected multiple housing and bedding strategies was specific about which bedding was used in each housing type, highlighting a limitation of the current survey method and format. Future surveys could incorporate alternative methods (e.g., interview questionnaires) or questionnaire designs that allow respondents to provide more detailed information. Given the high response rate of the current survey, we have confidence in the estimates of the three most common housing and bedding types used on organic dairy farms in Vermont (tiestalls with wood products, freestalls with wood products or freestalls with sand).

Survey administration type was associated with housing/bedding system (chi-square = 21.68, *P* = 0.04). Producers using bedded pack and freestall wood systems were the most common users of the web-based survey (32% and 43% of each) relative to all other housing bedding types (average 12% among all categories). Correspondingly, producers using bedded pack or freestall wood systems responded with high level of interest (91% and 88% “very” or “sorta” interested, respectively). We speculate that these associations reflect interest level in the survey information due to either dissatisfaction with current housing and bedding systems or enthusiasm and interest in the survey information, i.e., evoked reciprocation influence (Groves, 1990). In contrast, producers using a freestall bedded with sand exhibited the greatest “nope” not interested and least “very” interested, and this group did not show a preference for survey administration types. This apparent lack of interest suggests this group of farmers are most satisfied with their current housing and bedding system and are not looking for additional information. These observations highlight the opportunity to develop studies to test hypotheses that mode of questionnaire administration, producer interest in topics related to cattle housing and producer satisfaction with current bedding systems influence survey response rate across the range management styles.

***Cattle Breeds***. We grouped breed types reported by respondents into four categories: 1) Holstein only 2) Jersey only 3) mixed Holstein and Jersey herds with crosses, or 4) mixed Jersey and Holstein herds with one or more additional breeds. Three respondents did not report the breed(s) of cattle on their farm and were excluded from analysis of breed associations with facility and bedding types. While breed distribution was similar across the housing and bedding type combination categories (Fisher’s exact test, *P* = 0.26), five of nine (55%) producers using only bedded pack style housing reported using Jerseys and Jersey crosses compared to the next highest proportion of Jersey herds among tiestall farms (*n* = 19, 30%) and freestall farms (*n* = 8, 22%) (Table 2).

***Frequency of Individual Cow Somatic Cell Count Testing***. Frequency of testing SCC for individual cows was reported by 142 respondents; three respondents did not report SCC testing frequency on their farm and were excluded from analysis of associations between SCC testing and facility or bedding types. Twelve farmers reported testing SCC for individual cows more than 12 times per year, 78 farmers reported SCC testing approximately monthly, 21 farmers reported SCC testing less than 6 times per year and 31 farmers reported never using SCC testing (Figure 2). In previous surveys, 69% of 35 organic dairy farms in Minnesota (Sorge et al., 2017) and 53% of 192 organic dairy farms in New York, Oregon and Wisconsin (Stiglbauer et al., 2013), reporting using DHIA services, although neither study appeared to explore how organic dairy farmers use DHIA testing data, frequency of SCC testing, or if SCC testing frequency was associated with other management practices. In this study, we found an association between housing type and SCC testing frequency (*P* = 0.02).  ~~In a logistic regression model with monthly SCC testing as an binary outcome variable and including the combined housing & bedding type as a predictor variable with 5 levels (tiestall wood, freestall sand, freestall wood, bedded-pack, or other),~~ producers using freestall sand facilities were less likely to test approximately monthly or greater compared to those using tiestalls with wood bedding (*P* = 0.01). Number of lactating cows (herd size) was not associated with any SCC testing frequency category (*P >* 0.54 in a univariable model, and *P* > 0.16 in the multivariable model that included housing type), and inclusion of both housing type and herd size did not improve the overall fit of the model compared to the model with only housing type. Hosmer-Lemeshow test of model fit provided no significant evidence to reject the null that the model fit the data. We note that 4 of the 9 bedded pack herds reported never SCC testing. The relatively small number of farmers in the bedded pack category compared to the size of the other categories (17 freestall sand, 20 freestall wood, 62 tiestall wood, and 34 other) creates a potential to falsely conclude there is no difference between this group and the others when a difference actually exists. Future studies testing associations between housing or bedding types that include bedded pack herds should account for the observation that use of this housing type appears to be relatively infrequent compared to use of other systems.

While our estimate of individual cow SCC testing frequency appears to be similar to the frequency of DHIA testing reported previously (Stiglbauer et al., 2013; Sorge et al., 2017), the accuracy of our results may have been restricted and possibly underestimated due to the wording of our survey question. For example, when asking about individual cow SCC testing, we provided an acronym, DHIA (Dairy Herd Improvement Association), commonly associated with a regular testing service that can include individual cow milk SCC measurement by flow cytometry because we were specifically interested in this form of SCC testing. We expect farmers interpreted this to mean we were asking about subscription to a regular testing service that includes SCC testing. For example, one producer reported never performing individual cow SCC tests but then noted in a comment that the California Mastitis Test (CMT) was used for testing individual cows on their farm suggesting this farmer recognized the difference in these different mastitis screening tests. Routine CMT or cow-side SCC testing has been reported to be used more frequently than DHIA testing on organic dairy herds in other US states, although DHIA use was defined as full service including milk quality, breeding, production calving and herd inventory information (Stiglbauer et al., 2013). Further research is needed to quantify mastitis screening practices in this target population.

***Number of lactating cows****.* One respondent did not report the number of lactating cattle on their farm and was excluded from analysis of herd size associations with facility and bedding types.The median lactating cow herd size among the remaining 144 respondents was 59.5 cows (range 2-400, mean 71, standard deviation (SD) 4.5, CI95 62 – 80 cows; Figure 5). The number of lactating cows reported by respondents is in the range reported by other surveys of US organic dairy farms (Sorge, 2016). The number of cows varied between housing bedding types in this study population (*P* < 0.01) while past surveys of US organic dairy farms did not appear to explore this association (Stiglbauer et al., 2013; Sorge et al., 2017). Producers reporting using freestall systems bedded with sand and wood or using both freestalls and tiestalls housed more cows than tiestall herds (*P* < 0.05 in post hoc pairwise comparisons). When extreme outliers were removed from the categories freestall with sand, freestall and tiestall, freestall with wood and bedded pack plus the confidence in these associations was improved (*P* < 0.01). Despite these differences, many producers using freestall barns had a herd size that was similar to all other housing strategies (Figure 3). Other studies investigated herd size, facility age, or facility type on organic dairy farms but not within the same survey. For example, Sorge et al. (2016) reported a 10-year mean change in herd size of 5.7 cows (range -11 to +30), but did not report on associated changes in facility types, while Stiglbauer et al. (2013) reported the mean age of housing (36.5 years) but did not report changes in herd size or facility types for US organic farms. Future surveys might collect more detailed data on farms that use multiple housing and bedding types, and trends in facility types and herd size for organic dairy farms.

***Years of Dairy Farming Experience****.* Years of experience could be perceived as a variable in studies measuring the impact of management. Years of dairy farm management experience was reported by 126 respondents; however, 144 respondents reported years of organic dairy farm management experience. Respondents’ overall years of dairy experience varied among all housing/bedding categories *(P =* 0.20) (Figure 4). The years of organic dairy farm experience had a narrower range than length of the total dairy experience, we suspect because many producers transitioned to organic from conventional dairy management. While organic experience mostly did not differ between housing/bedding strategy, producers using a tiestall without a wood-based bedding (“Tiestall other bedding”) worked more years in organic dairy production than producers managing herds in freestall sand facilities (*P* = 0.04). This difference was not found for overall experience (Figure 6), perhaps suggesting that producers in this source population using freestall sand facilities were the most recent to transition to organic dairy production.



***Future Housing Trends and Research Priorities for Organic Dairy Farms****.* In the United States, producers of organic ruminant livestock must provide year-round access to the outdoors. Farmers may provide temporary confinement or shelter for animals because of inclement weather, and animal health, safety and well-being, among other reasons. Shelter or housing for US organic dairy cattle must be designed to allow for: “(i) Natural maintenance, comfort behaviors, and opportunity to exercise; (ii) Temperature level, ventilation, and air circulation suitable to the species; and (iii) Reduction of potential for livestock injury” (USDA, 2020). In our review of the literature, we find research on shelter or housing for US organic dairy farms is limited. We propose continued research on the impact of housing and bedding on organic dairy cattle productivity and well-being, including animal health (e.g., lameness and mastitis) would inform best practices regionally and nationally, especially for regions where indoor winter housing facilities and bedding materials may be used for five to six months of the year. Our survey improves knowledge of lactating cow housing and bedding types used on organic dairy farms in our region and identifies some key issues for further study. In particular, given the relatively high frequency of tiestall housing facilities in this sample, research is needed on how organic dairy producers perceive and are responding to changing consumer demands related to confinement housing.

Better knowledge of the distribution and types of housing and bedding used on organic dairy farms is necessary to identify representative samples for research studies. Research on the relationship between housing types and animal behavior, health, and well-being and environmental impacts is important to help direct the future of housing for dairy cattle and could help inform consumer acceptance of common cattle husbandry systems. For example, a picture-based approach used to assess the public acceptance of common indoor housing systems in Germany found that the acceptance of loose-housing (freestall barns) was relatively low (17% or less) and paddock or pasture access increased public acceptance (Kühl et al., 2019). Notably, their study did not include an assessment of consumer acceptance of either confinement tiestall barns with pasture access during good weather (i.e., the most common scenario among respondents in our sample population of organic dairy farms) or loose-housing bedded pack systems with pasture access during good weather (Leso et al., 2020).

Bedded pack, compost bedded pack, or loose-housing systems, are designed for cow comfort and may offer a number of advantages over other housing systems (Astiz et al., 2014; Leso et al., 2020). Fewer foot and leg injuries are cited in loose-housing bedded pack or compost bedded pack systems compared to freestall barns (Burgstaller et al., 2016; Lobeck et al., 2011). There are reports of decreased incidence of mastitis for dairy cows housed on compost bedded pack (Astiz et al., 2014). Although Black et al., (2014) suggested mastitis causing bacterial genera are found in high concentrations in composted bedded pack systems, udder health and hygiene in these systems is comparable to sand-bedded freestalls (Eckelkamp et al. 2016). Bedded pack compost material is a highly suitable soil amendment which can increase soil organic matter and fertility (Leso et al., 2020). Despite these potential benefits, our survey results indicate the adoption of compost bedded packs for lactating cows on organic dairy farms in Vermont is relatively limited. One recent study found improved hygiene and udder health for cows housed outdoors on straw bedded packs compared to cows housed indoors on compost bedded pack during three winters in Minnesota (Sjostrom et al., 2019). In our survey, no farms reported “outwintering” lactating cows on outdoor bedded packs. We suggest that understanding the potential benefits of and barriers to transitioning organic dairy farms from tiestall confinement facilities to alternative housing is a critical research need for the organic dairy industry in our region, nationally and perhaps globally.

**CONCLUSIONS**

Our survey found that tiestall barns bedded with wood products are the dominant winter housing system for lactating organic dairy cattle in Vermont. We identified a diversity of housing systems including a number of farms using mixed housing and bedding styles in organic dairy production in Vermont. A relatively small number of organic farmers reported using bedded packs in open housing systems for lactating cows. We conclude that developing a simple survey on a useful topic and timing the survey for the potential availability of the target population can result in a high response. Future research in this area should leverage this interest to foster key relationships with organic producers to build a more robust research and extension program supporting housing and facilities management. The approach presented here might be adapted in other regions to survey farmers in organic dairy production.

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Tables

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Table 1. Frequency (%, within column) of participant interest level in the project results, stratified by the questionnaire administration method used by respondents | | | | | |
| Self-reported interest level |  | | | | |
| Mail 1 | Mail 2 | Phone | Web | Total |
| Did not Respond | 7 (9.3) | 1 (3.9) | 0 (0) | 3 (11.5) | 11 (7.6) |
| Nope | 9 (12.0) | 6 (23.1) | 4 (22.2) | 0 (0) | 19 (13.1) |
| Not Really | 11 (14.7) | 3 (11.5) | 1 (5.6) | 2 (7.7) | 17 (11.7) |
| Sorta | 24 (32.0) | 13 (50.0) | 3 (16.6) | 6 (23.1) | 46 (31.7) |
| Very | 24 (32.0) | 3 (11.5) | 10 (55.6) | 15 (57.7) | 52 (35.9) |
| Total | 75 | 26 | 18 | 26 | 145 |

Table 2. Reported frequency (%, within column) of breed in use by respondent dairy farms among housing and bedding styles. Three farms, one from each of bedding styles Freestall Sand, Freestall Wood, and Tiestall Wood did not indicate breed and are not included here (*n* = 142). Only breeds that were used on more than one farm were specified in the table; breeds used on a single farms were included as “other”.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | Housing Bedding Style | | | | | | | | | | | | | |
|  | | | Bedded Pack | | Bedded Pack Plus | | Freestall & Tiestall | | Freestall | | Loose Housing | | Tiestall | | Total | |
| Ayrhire, Holstein, Jersey, cross | | | 1 (11.1) | | 0 (0) | | 0 (0) | | 1 (2.4) | | 0 (0) | | 3 (4.4) | | 5 (3.5) | |
| Ayrshire, Jersey | | | 0 (0) | | 0 (0) | | 0 (0) | | 0 (0) | | 0 (0) | | 3 (4.4) | | 3 (2.1) | |
| Holstein | | | 0 (0) | | 4 (30.8) | | 3 (33.3) | | 13 (31.7) | | 0 (0) | | 16 (23.5) | | 36 (25.2) | |
| Holstein cross | | | 0 (0) | | 1 (7.7) | | 0 (0) | | 2 (4.9) | | 0 (0) | | 0 (0) | | 3 (2.1) | |
| Holstein, Jersey | | | 1 (11.1) | | 1 (7.7) | | 0 (0) | | 0 (0) | | 0 (0) | | 2 (2.9) | | 4 (2.8) | |
| Holstein, Jersey, cross | | | 1 (11.1) | | 4 (30.8) | | 2 (22.2) | | 11 (26.8) | | 0 (0) | | 14 (20.6) | | 32 (22.4) | |
| Jersey | | | 4 (44.4) | | 0 (0) | | 0 (0) | | 6 (14.6) | | 0 (0) | | 19 (27.9) | | 29 (20.3) | |
| Jersey cross | | | 1 (11.1) | | 0 (0) | | 0 (0) | | 2 (4.9) | | 0 (0) | | 2 (2.9) | | 5 (3.5) | |
| Mixed | | | 0 (0) | | 1 (7.7) | | 2 (22.2) | | 1 (2.4) | | 0 (0) | | 5 (8.8) | | 9 (7) | |
| Other | | | 1 (11.1) | | 2 (15.4) | | 2 (22.2) | | 5 (12.2) | | 3 (100) | | 3 (4.4) | | 16 (11.2) | |
| Total | | | 9 | | 13 | | 9 | | 41 | | 3 | | 67 | | 142 | |

Figure captions

Figure 1. Number of farms within each housing strategy stratified by type of bedding material used. Each stacked bar represents a different housing strategy and pattern within bar represents the frequency of bedding material used within each strategy. Producers that reported using a bedded pack barn in combination with another housing type are grouped together (“Bedded Pack Plus”).

Figure 2. Somatic cell counts (SCC) of individual cows in each housing/bedding strategy. Each stacked bar represents a different combination of housing strategy and bedding material. Pattern within bar represents frequency of SCC determinations on individual cows (*n* = 145).

Figure 3. Number of cows varies among housing/bedding types. Illustrated is a box plot with the center line as median (*n* =145). Points represent individual farm herd size.

Figure 4. Distribution of management experience in each housing/bedding strategy. Illustrated is a box plot with a median center line for years of a) organic dairy experience, and b) total dairy experience (*n* = 145).

Figures

Andrews 1

Diagram

Description automatically generated

Andrews 2

Diagram, engineering drawing

Description automatically generated

Andrews 3

Diagram

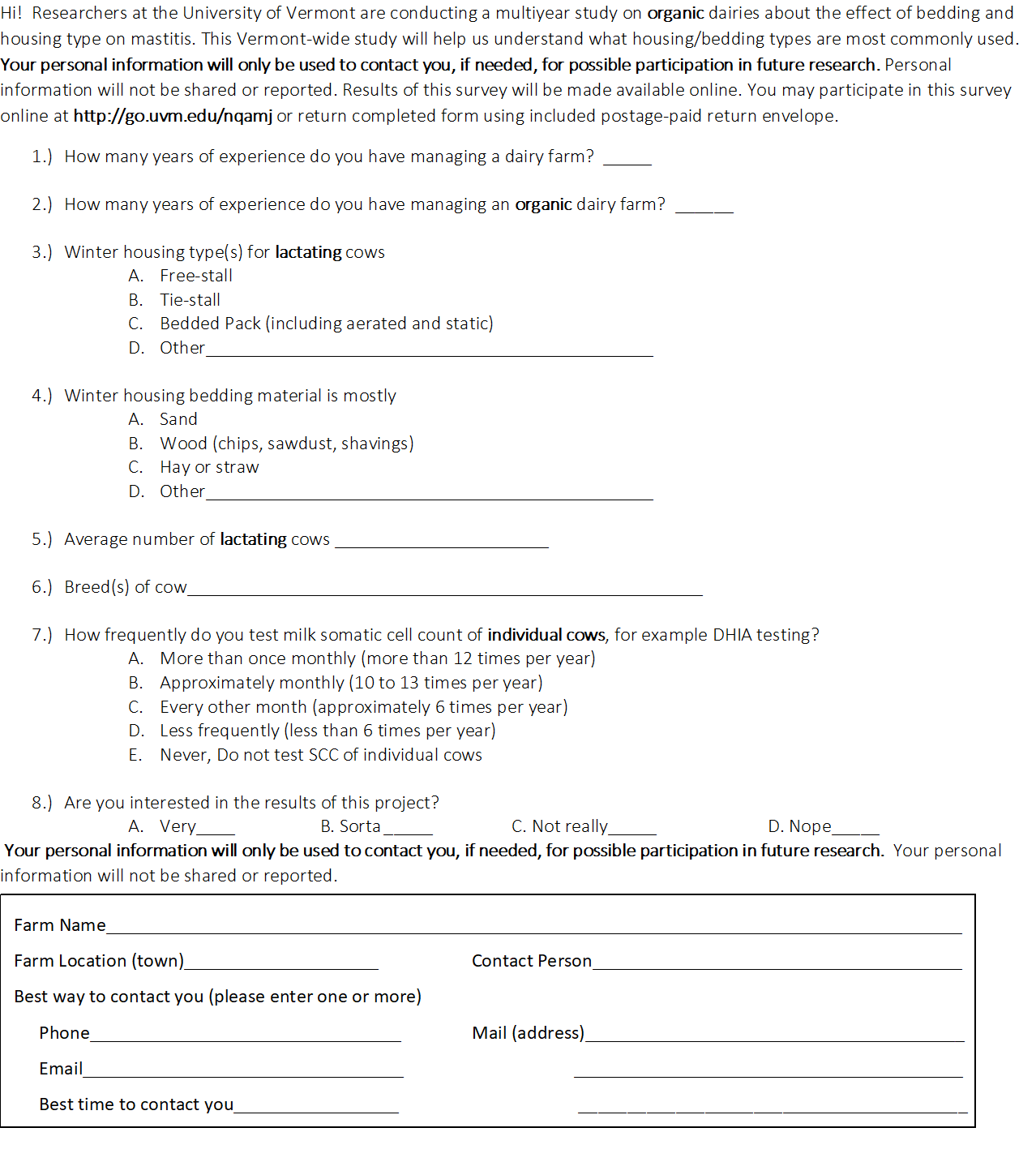
Description automatically generated

Andrews 4Diagram, engineering drawing

Description automatically generated

Supplemental materials

S1. Questionnaire



S2. Press Release