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Exploring milk shipment data for their potential for disease monitoring and for assessing resilience in dairy farms

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ABSTRACT

The use of routinely recorded data for research purposes and disease surveillance is an attractive proposition. However, this requires that the validity and reliability of the data be evaluated for the purpose for which they are to be used. This manuscript reports an evaluation of milk shipment data for evaluating their usefulness in disease monitoring and the resilience of organic and conventional dairy herds in Sweden. A large number of inconsistencies were observed in the data, necessitating substantial efforts to "clean" the data. Given that the selection of rules used in the cleaning process was subjective in nature, a sensitivity analysis was carried out to determine if different cleaning routines produced substantially different results. Despite the cleaning efforts we observed far more large residuals at the shipment level than expected. Thus, it was concluded that the data were too "noisy" to be used for identification of short term impacts on milk production.

Resilience was evaluated by examining the residual variance in milk shipped per cow per day under the assumption that herds with high resilience would have lower residual variance. The effects on residual variance of organic status or whether or not the herd used an automatic milking system were evaluated in models in which the residual variance was stratified or not by these factors. We did not find consistent evidence to suggest that organic herds had higher resilience than conventional herds, but this could be partly due to using residual variance as the measure indicating resilience.

1. Introduction

Milk recording data are a common source of information when it comes to measuring milk production, milk composition and udder health in dairy production. Milk recording is based on individual cow measurements taken, usually, monthly. An alternative, potential source of information on milk production and milk composition is the milk shipment data, which has the benefit of being recorded frequently, i.e. at each bulk tank milk shipment, usually every one or two days. Milk shipment data are, however, aggregated on a herd level and have therefore less detail. Because most serious diseases afflicting dairy cattle affect milk production (Wüthrich et al., 2016; Cumming et al., 2005; Charfeddine and Pérez-Cabal, 2017; Toftaker et al., 2017), these regularly collected milk production data have potential for use in research and for disease surveillance through monitoring of fluctuations in production. Milk shipment data have previously been used for research purposes (Toftaker et al., 2017), but a thorough evaluation of the usefulness of the data source still is needed.

The concept of resilience in ecological systems was first described by the Canadian ecologist Holling (1973) and describes the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. In modern literature, resilience is defined as the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks (Folke, 2006). Elgersma et al., 2018;Döring et al. (2014) suggest that there are different definitions of resilience but distinguish three steps that all covered in almost all definitions: disturbance, response and outcome. In dairy production resilience can be defined as the capacity to cope with disease and other production disturbances, a concept akin to general adaption (Elgersma et al., 2018;Döring et al., 2014; Elgersma et al., 2018). Health, as stated by the IFOAM principles of organic agriculture, is the wholeness and integrity of living systems. It is not simply the absence of illness, but the maintenance of physical, mental, social and ecological well-being. Immunity, resilience and

*Abbreviations:*AMS, automated milking system

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regeneration are key characteristics of health (IFOAM, 2018). Organic philosophy implies that natural behaviour, optimal feed and low stress levels are disease preventing factors and that they also lead to better resilience. Thus, it can be hypothesised that organic dairy herds would have less severe, or shorter duration of infections or other diseases/disturbances.

However, the concept of resilience in organic dairy production is challenging to assess and at least one previous attempt has been carried out. Elgersma et al. (2018) used variability of milk production in individual cows as an indicator of resilience. If milk shipment data can be shown to be a reliable means for disease surveillance, we hypothesize that they can be used to assess resilience by monitoring the variability in the routine bulk tank milk shipment volumes.

The first objective of this study was to explore the challenges and possibilities of using milk shipment data as a source of information for disease outbreak surveillance. A secondary objective was to use shipment data to assess the potential difference in resilience in organic versus non-organic dairy production.

2. Materials and methods

2.1. Study population

This study was based on a data from a research project with focus on monitoring outbreaks with Bovine Respiratory Syncytial Virus and Bovine Corona Virus in organic and conventional dairy herds in Sweden (Wolff et al., 2015). The sampling frame was all dairy herds with an average herd size of at least 50 cows and enrolled in the Swedish Official Milk Recording Scheme. Geographically, all Swedish counties except for the most southern (Skåne) were included. Skåne was excluded because it was known that there are very few Bovine Respiratory Syncytial Virus or Bovine Corona Virus negative herds in that region. Organic herds were defined as herds with KRAV-certified dairy production (www.krav.se). KRAV is the major Swedish certification body for organic production. In Sweden all farms have grazing systems according to legal requirements. The main Swedish breeds are Swedish Red and Swedish Holstein, where the yearly average milk yield in 2017 was 9156 kg and 10,274 kg, respectively (Veldhuis et al., 2016;Växa Sverige, 2018). All dairy companies have individual rules on bulk milk somatic cell counts for premium payments and for rejection of deliverance of milk. A simple random sample of 400 conventional and all eligible organic herds (n = 244) were sent a written invitation to the study in May 2011. The number of invited herds was based on previous experiences of about 30% willingness among Swedish dairy farmers to participate in similar observational studies. In total, 69 (17%) and 75 (31%) farmers with conventional and organic herds, respectively, agreed to participate in the project. However, only 93 herds (54 organic and 39 conventional) had all of the required milk shipment and milk size data and were included in the analyses. In 27 out of 93 herds the milking system changed from conventional milking systems to AMS during the study period.

2.2. Data sources

Both milk shipment and herd size data were available for the period of 1 Apr 2012 to 26 Nov 2015 and these were the data used in the analyses. The shipment data were obtained from the Swedish central milk shipping register, but were collected in two different ways. Firstly, herd-level data were collected from farmers, through their system interface, and secondly, from the central register itself. The central register only saves shipment data for the past three years. Data collected from farmers through their system interfaces stretch further back in time compared to the data retrieved directly from the central register, as interface collection was executed at an earlier point in time. Despite two different collection methods, all shipment data derived from the same source and all variables are the same.

Test day records (approximately monthly) of herd size for the period of 1 July 2010 to 26 November 2015 had been obtained from the Swedish Official Milk Recording Scheme. In order to estimate the number of cows milked on each milk shipment date, linear interpolation of the number cows milking on the previous and subsequent test dates was used. Total milk shipped was converted to milk per cow per day based on the length of the interval between shipments and the estimated number of cows milking.

A herd management data file was obtained from the Swedish Official Milk Recording Scheme. This file included production system, meaning whether the herd was organic or conventional (non-organic), and whether or not it had AMS. If the herd switched AMS category during the study period, the date of transition was noted and the herd's AMS status determined for each shipping date. Region of the country (1 = south, 2 = central, 3 = north), breed of the herd (1 = > 80% Swedish Red, 2 = > 80% Swedish Holstein, 3 = mix Red and Holstein, 4 = other breeds/mix or not recorded) were recorded.

2.3. Data compilation, cleaning and new variable calculations

A number of steps were taken during compilation and amalgamation of the data. These are described in Table 1.

It was clear that there were quite a few large changes in the amount of milk shipped that could not possibly be explained by changes in actual milk production in the herd. In order to remove these "artifacts" a set of rules were created to identify records that had changes in milk shipment volume that were unlikely to have come from a real change in production. These rules were:

Suspect rule 1 - Identify observations where shipping interval changed length (e.g. 2 days to 1 day).

Suspect rule 2 - Identify observations where the total Kg of milk shipped per day changed by more than 20% in small herds (< 50 cow herds), 15% in medium herds (50–99 cow herds) and 10% in large herds (> = 100 cow herds)

Table 1
Steps in preparation of data set cln20.

Data compilation steps	# of herds	# of observations
Initial milk shipment data file	137	95858
Remove exact duplicate records (n = 3243)	137	92615
Combine multiple shipments within one day into a single daily total (5393 combined into 2615 records)	137	89837
Drop duplicate records on consecutive days (n = 164)	137	89673
Drop all milk shipment data after 26 November 2015 (n = 9257) and (38) herds (n = 20,760) with no herd size information	99	59656
Merge with herd managment file and drop (5) herds (n = 646) with no management information	94	59010
Data cleaning steps		
Identify observations meeting supect rule #1 (n = 886)		
Identify observations meeting supect rule #2 (n = 2226)		
Identify observations meeting supect rule #3 (n = 2806)		
Drop observations flagged by any of the preceding three rules plus two shipments on either side (n = 7240)	94	51770
Drop one herd subsequently identified as having seasonal calving (n = 627)	93	51143