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Survey on the disposal of waste milk containing antimicrobial residues on Swiss dairy farms

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ABSTRACT

Feeding waste milk containing antimicrobial residues (WMA) to calves has been associated with increased antimicrobial resistance in calves' commensal bacterial flora. The objectives of this study were (1) to document practices related to the disposal of WMA on Swiss dairy farms and (2) to evaluate the association between farm characteristics and the feeding of WMA to calves. A web-based questionnaire on practices surrounding waste milk disposal was completed by 1,625 dairy producers (10.9% of solicited producers). Logistic regression models were built to evaluate the association between herd characteristics and the practice of feeding WMA. Waste milk produced during and up to the first milking after completion of antimicrobial treatment or during the withdrawal period was fed to at least some of the calves on 47.3% of respondents' farms. Farms in organic production had lower odds of feeding WMA to calves than nonorganic farms [odds ratio (OR) 0.59]. Farms located in the eastern region of Switzerland, as opposed to those in the western region, had increased odds of feeding WMA to calves (OR 2.01). A yearly average bulk tank somatic cell count ≥150,000 cells/mL was associated with increased odds of feeding WMA to calves compared with the reference category of <100,000 cells/mL (OR 1.62). An average cow-level annual milk production ≥8,500 L was associated with increased odds of feeding WMA to calves compared with farms in the interquartile range with a production of 6,500 to 8,499 L (OR 1.24). Further research is warranted to investigate dairy farmers' motivations affecting this practice, and to quantitatively define calves' exposure to antimicrobial residues and the resulting antimicrobial resistance in calves' commensal flora on these farms.

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INTRODUCTION

Antimicrobial resistance (**AMR**) is a major concern in human and veterinary medicine. In recent years, the feeding of nonsalable or waste milk containing antimicrobial residues (**WMA**) to calves has come under scrutiny. This practice has been associated with increased AMR in calves' commensal microbial flora (Duse et al., 2015; Maynou et al., 2017; Foutz et al., 2018; Jarrige et al., 2020), in addition to affecting gastrointestinal and respiratory microbiomes (Deng et al., 2017; Maynou et al., 2019; Zhang et al., 2019) and calves' health (Klein-Jöbstl et al., 2015; Zou et al., 2017; Calderón-Amor and Gallo, 2020). The feeding of WMA to calves is common in both Europe and America, with prevalence estimates of 33% to 87% of study farms (USDA, 2007; Vasseur et al., 2010; Brunton et al., 2012; Duse et al., 2013; Staněk et al., 2014; Klein-Jöbstl et al., 2015; Calderón-Amor and Gallo, 2020). In a previous study in Austria, WMA was more often fed to calves on farms of more than 20 cows (Klein-Jöbstl et al., 2015), whereas in Sweden the proportion of farms feeding WMA to calves varied by geographic region, and this practice was more common on farms in nonorganic production and in tiestall housing (Duse et al., 2013). Furthermore, difficulties with disposal have been reported as one of the reasons for feeding WMA to calves (Brunton et al., 2012). When not fed to calves, WMA is often disposed of with manure, where antimicrobial residues could contribute to the persistence of antibiotic resistance genes and their dispersal in the environment (Jechalke et al., 2014; Ricci et al., 2017).

Calves' exposure to antimicrobial residues through the feeding of WMA may vary between farms and between countries, as may the consequences of exposure, with regard to involved drugs, their concentrations, the frequency and duration of WMA feeding, and the subpopulations of calves exposed (Brunton et al., 2012;

Duse et al., 2013). In the United States, where WMA from multiple cows is generally pooled on large dairies, detectable concentrations of at least one antimicrobial drug were found in 60 to 82% of collected WMA samples (Pereira et al., 2014; Tempini et al., 2018). However, in small-scale farms, the number of cows at risk of being treated with antimicrobial drugs on any given day is lower; therefore, WMA might not be produced every day and may originate from a single or very few cows at a time. Accordingly, the level of calves' exposure to residues in WMA could be speculated to be lower on small farms, but has not been investigated.

Swiss dairy farms are typically smaller than the farms from previous reports on the feeding of WMA to calves, with an average herd size of 22 adult cows in 2018 (Gerber et al., 2020). Moreover, fattening veal calves on site, rather than selling them, is common on Swiss dairy farms (Lava et al., 2016). Veal calves may include predominantly male calves (72–74.4%) as well as excess female calves, and may be of dairy breeds (31.1–44%), beef breeds or crossbred (39–39.8%), or dual-purpose breeds (17–29%; Lava et al., 2016; Becker et al., 2020). Therefore, calves that are potentially exposed to residues in WMA on Swiss dairy farms are replacement heifers and calves intended for veal production, which may include young calves before they are sold (at around 4 wk of age) for veal production as well as calves that remain or are purchased to be fattened on the farm. Another important feature of Switzerland with regard to the production of WMA is the fact that sales of intramammary antimicrobials are higher in Switzerland (3.4 mg/population correction unit) compared with the mean of European countries (0.6 mg/population correction unit; EMA, 2020). Due to the absence of a practical and safe alternative for disposal of WMA, feeding WMA to calves still is a legally accepted practice in Switzerland (BLV, 2020). However, the prevalence of this practice on Swiss dairy farms is unknown. The objectives of this study were (1) to document practices related to the disposal of WMA on Swiss dairy farms and (2) to evaluate the association between farm characteristics and the feeding of WMA to calves.

MATERIALS AND METHODS

Methods

A questionnaire was developed to collect information from Swiss dairy producers on their practices surrounding WMA disposal (available on repository, Bernier Gosselin et al., 2021). The 42-question questionnaire included a section on general farm characteristics (n = 13 questions), a section on practices surrounding production and disposal of WMA from cows treated with antimicrobial drugs during lactation (n = 19), and a section on practices surrounding the use of colostrum and transition milk from cows treated with antimicrobial intramammary therapy at dry-off (n = 10). Transition milk was defined as nonsalable milk produced by a cow in the days after calving but after the initial milking of colostrum. In the section on waste milk disposal, colostrum and transition milk were considered as containing a negligible amount of antimicrobial residues (Ricci et al., 2017). Some of the questions were dependent on previous individual answers or a combination of previous answers, such as questions relating to specific practices on farms where WMA is fed to calves. Most questions (n = 27) were single- or multiple-answer questions, some of which included an option that allowed the respondents to specify their personal answer (e.g., "other," antimicrobial drug). Due to veal production, the categories of calves receiving WMA were based on purpose (veal vs. replacement) rather than sex. Eleven questions could be answered with a numerical value. For a set of questions related to WMA production (e.g., volume, number of cows or days), the respondents were asked to provide an estimate of the monthly average from the previous 3 mo. For one question on WMA disposal practices, respondents were asked to rank the methods used on their farm, from the most to the least commonly used methods, and to leave out the methods they do not use. The following choices were provided: disposed of in the manure pit, eliminated with wastewater, eliminated on the ground outside (e.g., on a meadow), fed to calves, fed to other farm animal species, fed to other non-production animal species, and other method. Additionally, in the second and third sections, the respondents were given the opportunity to provide comments regarding their practices in free-text answer fields. Answers to 12 questions were mandatory to submit the completed questionnaire, because they contained essential information for the survey (Bernier Gosselin et al., 2021), but the remaining questions could be left unanswered.

The questionnaire was first developed in English, then translated to German and French, and the latter 2 versions were compared to one another to confirm equivalence of the questions and answer options. The questionnaire was then transferred into its web-based form (LimeSurvey, version 2.6.7; limesurvey.org). The questionnaire was pretested by 5 producers (4 in German and 1 in French) and revised accordingly. An invitation to participate in the survey was sent once electronically by Swiss breeding associations (Swissherdbook, Holstein Switzerland, Braunvieh Schweiz)

to all their German- and French-speaking members for whom they had an e-mail address on record. The invitations were sent in German (n = 11,394), in French (n = 1,841), or in both languages (n = 1,733), for a total of 14,968 members. The questionnaire remained open from November 9 to December 6, 2020.

Statistical Analyses

Responses to the questionnaire were exported from the survey software and analyzed using R version 4.0.3 (R Foundation for Statistical Computing) and SAS Studio 3.8 (SAS Institute Inc.). Continuous numerical variables were inspected for outliers and unrealistic values. Descriptive statistics of categorical data were conducted as the proportion of respondents selecting an answer among the number of respondents who answered the question. Cantons (federal states) were regrouped according to 7 regions (FSO, 2021), then further grouped into 3 regions as follows: east (Ostschweiz, Ticino), central (Nordwestschweiz, Zentralschweiz, Zurich), and west (Mittelland, Genferseeregion). Continuous variables were summarized as mean ± standard deviation when normally distributed, and as median, first and third quartiles, and range when not normally distributed. The associations between fattening of veal calves, pooling of WMA, and calf category being fed WMA were evaluated using chi-squared tests.

Multivariable logistic regression models were built to evaluate the association between WMA feeding and herd characteristics. Based on descriptive statistics, approximately half of the respondents who feed WMA to calves only feed WMA produced during the withdrawal period, which may result in different levels of calves' exposure to antimicrobial residues than feeding WMA during treatment of the cow. Therefore, 2 separate logistic regression models were built, with the outcome variables being (1) feeding WMA produced during and up to the first milking after completion of treatment (parenteral, intramammary, or both), and (2) overall feeding of WMA with potential residues (which included WMA produced either during treatment or during the withdrawal period, for parenteral, intramammary, or both), respectively. Production type was dichotomized as organic and nonorganic (i.e., "organic" not being selected among production labels). Average bulk tank somatic cell count (**BTSCC**) was categorized as <100,000 cells/mL (median), 100,000 to 149,999 cells/mL, and ≥150,000 cells/mL. Average cow annual milk yield was categorized as <6,500 L, 6,500 to 8,499 L (interquartile range), and ≥8,500 L. For each model, independent variables were screened ($P < 0.05$) for inclusion based on unconditional analyses, and correlations between independent variables were evaluated. Variables were selected for the final model by stepwise backward elimination, using the Akaike information criterion. Because many of the independent variables were associated, removed variables were then reintroduced one by one in the model, and the effect on the estimates of the remaining variables was evaluated. Any confounding variable (>20% variation in other variables' estimates) was kept in the model.

RESULTS

Herd Characteristics

Of 14,968 dairy producers to whom an invitation to complete the survey was sent, 1,625 (10.9%) completed the survey. The survey was completed in German by 1,346 (82.8%) producers and in French by 279 (17.2%) producers. In proportion of the total number of dairy producers in each canton (FSO, 2020), the participation rate by canton ranged between 1.5% and 7.4%, with the exceptions of Ticino (0.5%) and Geneva (10%). After exclusion of Ticino (predominantly Italian-speaking), the participation rate differed by region ($P < 0.01$) with 4.6%, 5.7%, and 6.3% for the eastern, central, and western regions, respectively. Similarly, the participation rate by agricultural zone (determined based on climate, communication routes, and topography) ranged between 5% and 7.3%. In proportion of the number of farms in conventional and organic productions, the participation rate was 4.5% and 8.0%, respectively. The distribution of respondents' farms for various herd characteristics are presented in Tables 1 and 2.

Production of WMA

The median number of adult cows was 26 (first to third quartiles 18–39; range 1–200, n = 1,608), and the median number of cows per month producing WMA was 1 (first to third quartiles 0.5–2; range 0–22; n = 1,597). The median number of liters of WMA produced per month was 150 (first to third quartiles 50–250; range 0–5,000; n = 1,147). The median number of days per month during which such milk was produced was 5 (first to third quartiles 1–10; range 0–30; n = 1,583).

Disposal of Waste Milk

The proportion of producers who reported managing WMA differently than other types of waste milk (without residues) was 66.8% (1,044/1,562). When asked to rank the methods they use for the disposal of WMA (rank 1 = most commonly used method), the median

Table 1. Distribution of geographic and management characteristics of 1,625 Swiss dairy farms from which a completed questionnaire was submitted

Herd characteristics (number of responses)	Number (%)	95% CI
Region[1] (n = 1,421)		
East	268 (18.9)	16.8–20.9
Central	416 (29.3)	26.9–31.6
West	737 (51.9)	49.3–54.5
Agricultural zone[2] (n = 1,619)		
Midland	572 (35.3)	33.0–37.7
Pre-alpine hills	282 (17.4)	15.6–19.3
Mountain I	277 (17.1)	15.3–18.9
Mountain II	288 (17.8)	15.9–19.7
Mountain III	137 (8.5)	7.1–9.8
Mountain IV	63 (3.9)	2.9–4.8
Production type[3] (n = 1,625)		
Conventional	975 (60.0)	57.6–62.4
Organic	263 (16.2)	14.4–18.0
Sustainability and animal welfare label	637 (39.2)	36.8–41.6
Other labels	29 (2.8)	1.1–2.4
Predominant cow breed (n = 1,617)		
Braunvieh	519 (32.1)	29.8–34.4
Swiss Fleckvieh[4]	433 (26.8)	24.6–28.9
Holstein	430 (26.6)	24.4–28.7
Simmental	122 (7.5)	6.3–8.8
Montbéliarde	46 (2.8)	2.0–6.7
Jersey	14 (0.9)	0.4–1.3
Other breeds, crossbreeds, and mixed herds	53 (3.3)	2.4–4.1
Housing type (n = 1,625)		
Tiestall	761 (46.8)	44.4–49.3
Freestall	847 (52.1)	49.7–54.6
Other (mixed)	17 (1.1)	0.6–1.5
Milking system (n = 1,625)		
Parlor	658 (40.5)	38.1–42.9
Pipeline	616 (37.9)	35.5–40.3
Bucket	218 (13.4)	11.8–15.1
Robot	106 (6.5)	5.3–7.7
Other	27 (1.7)	1.0–2.3
Veal calves fattened on the farm (n = 1,625)		
No	1,048 (64.5)	62.2–66.8
Yes	577 (35.5)	33.2–37.8

[1]East: Ostschweiz, Ticino; central: Nordwestschweiz, Zentralschweiz, Zurich; west: Mittelland, Genferseeregion (FSO, 2021).

[2]Determined based on climate, communication routes, and topography; Ordonnance sur le cadastre de la production agricole et la délimitation de zones, Dec. 7, 1998, 912.1, www.fedlex.admin.ch/eli/cc/1999/46/fr; https://map.geo.admin.ch/?lang=en&topic=ech&bgLayer=ch.swisstopo.pixelkarte-farbe&layers=ch.swisstopo.zeitreihen,ch.bfs.gebaeude_wohnungs_register,ch.bav.haltestellen-oev,ch.swisstopo.swisstlm3d-wanderwege,ch.astra.wanderland-sperrungen_umleitungen,ch.blw.landwirtschaftliche-zonengrenzen&layers_opacity=1,1,1,0.8,0.8,0.75&layers_visibility=false,false,false,false,false,true&layers_timestamp=18641231,,,,,&catalogNodes=687,755.

[3]More than one response was possible.

[4]Crossbreeds of Simmental and Red Holstein.

number of methods that were ranked was 2 (first to third quartiles 1–2; range 1–7; n = 1,476). The distribution of the disposal methods among the first 3 ranks is presented in Table 3. The method most commonly ranked first was the manure pit (61.1%; 902/1,476), followed by feeding to calves (18.2%; 268/1,476). When a second rank was assigned (n = 998), the methods most commonly ranked second were feeding to calves (49.2%; 491/998) and the manure pit (26.4%; 263/998). The 3 most common ranking patterns were the manure pit as rank 1 and feeding to calves as rank 2 (27.6%; 408/1,476), the manure pit as only disposal method (23.6%; 349/1,476), and feeding to calves as rank 1 and the manure pit as rank 2 (11.9%; 175/1,476). The median rank was 1 for the manure pit (n = 1,239), 2 for feeding to calves (n = 895), wastewater (n = 306), and spread outside (e.g., on a meadow; n = 273), 3 for feeding to other farm animal species (n = 189), and 4 for feeding to other non-production animal species (n = 140) and for other method (n = 161). Among "other"

Table 2. Herd characteristics of 1,625 Swiss dairy farmers who completed the survey[1]

Herd characteristics (number of responses)	All farms			Farms where WMA is fed to calves			Farms where WMA is not fed to calves		
	Median	Q1–Q3	Range	Median	Q1–Q3	Range	Median	Q1–Q3	Range
Number of adult cows (n = 1,608)	26	18–39	1–200	28	20–42	1–200	24	16–35	2–130
Average cow annual milk yield (n = 1,567)	7,500	6,500–8,500	3,500–13,000	7,800	7,000–8,500	3,500–13,000	7,200	6,288–8,200	4,000–12,000
Average bulk tank SCC ($\times 10^3$ cells/mL; n = 1,484)	100	80–120	45–300	100	80–130	45–300	95	76–120	45–300
Number of years managing the farm (n = 1,528)	17	8–26	1–47	15.5	7–25.25	1–45	18	8–26	1–47

[1]WMA = waste milk containing antimicrobial residues. Q1–Q3 = first and third quartiles.

methods that were specified by the respondents, the manure pile was most commonly cited (n = 13). Among these producers, the manure pile was ranked 1 (n = 10), 2 (n = 2), or 7 (n = 1). Five of them also ranked (in the second or third rank) elimination in the manure pit as a disposal method; therefore, these responses were not included in the category "manure pit" but were left in the category "others."

Feeding of Waste Milk with Antimicrobial Residues to Calves

The feeding of different types of waste milk to calves among all producers is presented in Table 4. Overall, 47.3% (769/1,625; 95% CI 44.9–49.8%) of the respondents selected at least one of the answers corresponding to types of waste milk that potentially contained antimicrobial residues (Table 4). The different practices for this subset of producers are presented in Table 5. Although in these farms the median number of days on which WMA is produced was 5, the median number of days on which such milk is fed to calves was 4 (first to third quartiles 2–5; range 0–30; n = 729). The proportion of respondents who fed WMA to calves, including WMA produced during antimicrobial treatment up to the first milking after completion of treatment (parenteral, intramammary, or both), was 24.5% (95% CI 22.4–26.6%), whereas 22.8% (95% CI 20.8–24.9%) of respondents only fed WMA produced during the withdrawal period (parenteral, intramammary, or both). The group age of calves fed WMA was only calves older than a given age on 73.3% farms (564/769; median 14 d; first to third quartiles 10–30), all calves on 19.9% farms (153/769), and only calves younger than a given age on 11.8% farms (91/769; median 100 d; first to third quartiles 30–120). In addition to calves' age and category (replacement heifers, calves destined to veal production), various factors such as volume of WMA produced and availability of other types of waste milk without antimicrobial residues influenced the producers' decision to feed WMA to calves (Table 5). The producers who selected the criterion "specific antimicrobial drug received by the cow" were asked to specify their answer, and critically important antimicrobial drugs was the most common answer. Likewise, the producers who selected the criterion "specific (suspected) bacteria for which a cow was treated" were asked to specify their answer, and 45 producers cited at least one bacterial species, including *Staphylococcus aureus* (n = 38), *Streptococcus uberis* (n = 8), (unspecified) *Staphylococcus* spp. (n = 3), *Escherichia coli* (n = 2), and *Trueperella pyogenes* (n = 1). In addition to the choices of potential influential factors provided in the questionnaire, other factors cited by the farmers

Table 3. Distribution (number with column percentage in parentheses) of the first 3 ranks attributed to disposal methods for waste milk containing antimicrobial residues

Method	Rank 1 (n = 1,476)	Rank 2 (n = 998)	Rank 3 (n = 316)
Manure pit	902 (61.1)	263 (26.4)	60 (19.0)
Fed to calves	268 (18.2)	491 (49.2)	103 (32.6)
Wastewater	150 (10.2)	75 (7.5)	24 (7.6)
Spread outside	105 (7.1)	67 (6.7)	41 (13.0)
Fed to other farm animal species	13 (0.9)	54 (5.4)	42 (13.3)
Fed to other nonproduction animal species	4 (0.3)	30 (3.0)	26 (8.2)
Other method	34 (2.3)	18 (1.8)	20 (6.3)

included the time elapsed after treatment (e.g., 2–5 d into the withdrawal period), the administration route (intramammary), and time until slaughter when WMA was fed to veal calves. Additionally, many producers commented upon WMA valorization (avoiding feed waste, economic reasons).

Associations Between Herd Characteristics and WMA Feeding Practices

Herd characteristics associated with the feeding of WMA to calves in the unconditional analyses included production type, region, agricultural zone, housing type, milking system, herd size category, average yearly cow milk yield category, average BTSCC category, and volume of WMA produced monthly (all $P < 0.01$). Feeding WMA to calves was not significantly associated with whether the questionnaire was completed in German or French ($P = 0.17$), the number of previous years of farm management ($P = 0.11$), or whether veal calves were fattened on the farm ($P = 0.80$). Housing type and milking system were not included in the logistic regression models due to their association with herd size category (both $P < 0.01$). Volume of WMA produced was not included, due to a large number of missing data. All other variables associated with WMA feeding were included. In the model with feeding WMA produced during and up to the first milking after completion of treatment as the outcome variable, production type, region, and BTSCC remained significant in the final model, and average yearly cow milk yield category was kept as a confounding variable for BTSCC (Table 6). In the model with feeding any WMA (during treatment and withdrawal period) as the outcome variable, production type, region, BTSCC, and average yearly cow milk yield category remained significant in the final model (Table 7). In both models, WMA was more likely to be fed to calves on farms located in eastern cantons than in western cantons. An average BTSCC ≥150,000 cells/mL was significantly associated with increased odds of WMA feeding compared with the category <100,000 cells/mL. Additionally, in the model with feeding any WMA, herds in the lower average yearly cow milk yield category were less likely to feed WMA, and herds in the higher average yearly cow milk yield category were more likely to feed WMA, compared with the category of average yearly cow milk yield between 6,500 and 8,499 L.

Regarding associations between management practices, fattening veal calves on the farm was associated with calf category being fed WMA ($P < 0.01$). Among farms where veal calves were fattened, the proportions

Table 4. Number and proportion of respondents (n = 1,625) using different types of waste milk to feed calves (more than one response was possible)

Types of waste milk fed to calves	Number (%)
Without antimicrobial residues	
Transition milk[1]	1,461 (89.9)
High SCC milk	1,294 (79.6)
Grossly abnormal milk	669 (41.2)
Milk produced after non-antimicrobial treatment	833 (51.3)
With antimicrobial residues	
During and up to the first milking after treatment—parenteral	382 (23.5)
During and up to the first milking after treatment—intramammary	154 (9.5)
Withdrawal period—parenteral	616 (37.9)
Withdrawal period—intramammary	579 (35.6)

[1]Transition milk was defined as nonsalable milk produced by a cow in the days after calving but after the initial milking of colostrum.

Table 5. Waste milk feeding practices and influential factors thereof, among producers who feed waste milk containing antimicrobial residues (WMA) to calves (n = 769)

Practice (number of responses)	Number (%)
Average percentage of WMA produced daily used as feed (n = 709)	
<25%	405 (57.1)
25%–50%	134 (18.9)
50%–75%	65 (9.2)
>75%	105 (14.8)
Pooling of milk from multiple treated cows (n = 769)	
Never (single cow only)	351 (45.6)
Milk from up to 2 treated cows	337 (43.8)
Milk from ≥3 treated cows	81 (10.5)
Calf category fed WMA (n = 769)	
All calves	419 (54.5)
Calves intended for veal production only	245 (31.9)
Replacement heifers only	105 (13.7)
Group age of calves fed WMA[1] (n = 769)	
Only calves older than a given age[2]	564 (73.3)
All calves	153 (19.9)
Only calves younger than a given age[3]	91 (11.8)
Other factors affect feeding of WMA[1] (n = 751)	
Availability of waste milk without antimicrobial residues	343 (45.7)
Volume of WMA	333 (44.3)
Milk price	207 (27.6)
Specific antimicrobial drug received by the cow	72 (9.6)
Specific (suspected) bacteria	57 (7.6)
None of the above	124 (16.5)
Other factors	53 (7.1)
Time interval after milking at which WMA is fed (n = 754)	
≤15 min	484 (64.2)
15 min–6 h	224 (29.7)
6 h–12 h	31 (4.1)
>12 h	15 (2.0)
Conservation of WMA when fed >15 min after milking (n = 270)	
Room temperature	207 (76.7)
Acidified	28 (10.4)
Refrigerated	17 (6.3)
Pasteurized	1 (0.4)
Other method[4]	28 (10.3)

[1]More than one answer possible.

[2]Median 14 d; first to third quartiles 10–30.

[3]Median 100 d; first to third quartiles 30–120.

[4]Comments included the milk being cooled down (e.g., 10–12°C) or kept warm in a tank or automatic feeder.

Table 6. Logistic regression model on the probability of using waste milk with antimicrobial residues produced during and up to the first milking after completion of treatment as calf feed, as a function of production type, region, average bulk tank SCC category, and adjusting for cow-level annual milk yield category, based on survey responses from 1,256 producers

Effect	Estimate	SE	Estimate *P*-value	Odds ratio	Odds ratio 95% CI
Intercept	−1.16	0.10	<0.01	—	—
Production type			0.01		
Organic	−0.27	0.11	0.01	0.58	0.38–0.89
Nonorganic	Referent	—	—	Referent	—
Region			0.02		
East	0.27	0.11	0.01	1.63	1.16–2.28
Central	−0.05	0.10	0.62	1.19	0.87–1.61
West	Referent	—	—	Referent	—
Bulk tank SCC (cells/mL)			0.02		
100,000–149,999	−0.03	0.09	0.78	1.24	0.93–1.67
≥150,000	0.27	0.11	0.01	1.67	1.17–2.38
<100,000	Referent	—	—	Referent	—
Average cow milk yield (L)			0.10		
<6,500	−0.25	0.13	0.06	0.75	0.51–1.12
≥8,500	0.22	0.11	0.04	1.21	0.90–1.61
6,500–8,499	Referent	—	—	Referent	—

of farms on which WMA was fed to all calves, only to female calves, or only to calves intended for veal production were 42.4%, 11.6%, and 46.0%, respectively, whereas these proportions were 61.3%, 14.8%, and 23.9% on farms without veal calf fattening. Pooling of WMA was associated with fattening veal calves ($P < 0.01$) and with calf category being fed WMA ($P = 0.02$). Waste milk was pooled in a higher proportion of farms among those that fed WMA to all calves than among farms that only feed WMA to replacement heifers or to calves intended for veal production.

Management of Cows Receiving Dry-Off Antimicrobial Therapy

Practices related to the management at calving of the colostrum and milk of cows that had been treated with intramammary antimicrobial dry-off therapy are presented in Table 8. In addition to the most common tools used by the producers to guide their decision for selective antimicrobial dry-off therapy, criteria commonly cited in the "other" category included the cow's milk yield, age, and dry period duration; season and alpine pasture; and veterinarians' recommendation and participation in selective therapy programs. On most farms (63.5%; 977/1,539), cows that received antimicrobial dry-off therapy were identified differently at calving from cows that did not. Furthermore, most producers reported storing frozen colostrum (77.8%), of whom a majority did not store colostrum from cows that had received antimicrobial dry-off therapy (64%; 809/1,264). Among the producers who fed colostrum or transition milk, or both, from treated cows, 21.4% (305/1,427) reported that the first colostrum meal fed to the calf could be a mix of colostrum from more than one treated cow. When fed to calves older than 24 h of age, colostrum or transition milk could be a mix from 2 (36.8%; 411/1,118) or 3 and more (8.9%; 100/1,118) treated cows.

DISCUSSION

The primary objective of this study was to estimate the prevalence of practices related to the disposal of WMA among Swiss dairy farms, with the practice of feeding WMA to calves being of special interest. The most common disposal method was by discarding WMA in the manure pit, followed by feeding it to calves. Other methods were selected by a smaller number of producers and were typically less commonly used on their farm (i.e., attributed a higher ranking number). When the respondents were asked to rank the methods they use for the disposal of WMA, 60.6% (895/1,476) of respondents ranked "feeding to calves," meaning that they use this method. However, when asked whether they use different types of waste milk (some with residues and others without) to feed calves, both the absolute number and the proportion of respondents who fed at least one of the waste milk types containing antimicrobial residues were lower (47.3%; 769/1,625). The explanation for this discrepancy is unknown. It is possible that some producers attributed a rank to feeding to calves (e.g., least frequently used disposal method) but considered this to occur so infrequently that they did not select WMA in the counterpart question. Nevertheless, these prevalence estimates are similar to those reported from the United States (30–57%), Canada (47.7%), the United Kingdom (41.2%), and the

Table 7. Logistic regression model on the probability of using waste milk with antimicrobial residues (produced during treatment or the withdrawal period or both) as calf feed, as a function of production type, region, average bulk tank SCC category, and average cow annual milk yield category, based on survey responses from 1,256 producers

Effect	Estimate	SE	Estimate *P*-value	Odds ratio	Odds ratio 95% CI
Intercept	−0.08	0.09	0.37	—	—
Production type			<0.01		
Organic	−0.27	0.09	<0.01	0.59	0.42–0.82
Nonorganic	Referent	—	—	Referent	—
Region			<0.01		
East	0.36	0.10	<0.01	2.01	1.47–2.76
Central	−0.03	0.09	0.74	1.36	1.04–1.77
West	Referent	—	—	Referent	—
Bulk tank SCC (cells/mL)			<0.01		
100,000–149,999	0.07	0.08	0.39	1.42	1.10–1.83
≥150,000	0.21	0.10	0.05	1.62	1.17–2.26
<100,000	Referent	—	—	Referent	—
Average cow milk yield (L)			<0.01		
<6,500	−0.38	0.11	<0.01	0.63	0.46–0.87
≥8,500	0.30	0.09	<0.01	1.24	0.95–1.62
6,500–8,499	Referent	—	—	Referent	—

Czech Republic (64.7%; Raymond et al., 2006; USDA, 2007; Vasseur et al., 2010; Staněk et al., 2014; Higham et al., 2018). More than one disposal method was generally used, which could be explained by the fact that less than 50% of the volume of WMA produced daily is used to feed calves in most farms where WMA is fed to calves, likely due to small herd sizes and thus the small number of calves present on these farms at any given time. Alternatively, this reflects the fact that, on many farms, WMA is disposed of in different ways according to criteria based on the nature of the milk (e.g., time after treatment, administration route of antimicrobials) or the characteristics of the calves to be fed (e.g., age or purpose). Discarding WMA from the first milking after treatment was done by 48% (371/769) of respondents feeding WMA, compared with 30% in a previous study (Brunton et al., 2012). Similar to other studies (Brunton et al., 2012; Duse et al., 2013; Klein-Jöbstl et al., 2015; Higham et al., 2018), WMA feeding differed based on calves' sex or purpose and age, although the median minimum age of 14 d was lower than the 4 wk reported in a previous study (Duse et al., 2013). Veal calves were fattened in a significant proportion of farms (35.5%). When asking which category of calves were fed WMA, one of the provided choices was "calves intended for veal production," without distinction being made between young calves to be sold for veal production and calves being fattened on site. Because virtually all farms may have young bull calves for at least a short period (before they are sold for veal production), all respondents had the possibility to select this answer. Nevertheless, feeding WMA to this category of calves was associated with the fattening of calves on the farm. Although calves intended for veal production may be perceived on most farms as less important than heifer calves, they represent an additional source of income for farms where they are fattened. To the authors' knowledge, the effect of WMA feeding to calves beyond the "usual" weaning age of 7 to 12 wk on the fecal shedding of antimicrobial-resistant bacteria by calves has not been evaluated. Some producers mentioned time until slaughter as a criterion influencing the feeding of WMA to calves. Nonetheless, this practice raises a concern for human exposure to antimicrobial residues and antimicrobial-resistant bacteria in veal meat (Di Labio et al., 2007; Jarrige et al., 2020).

The frequency of calves' exposure to residues in WMA seemed to be relatively low, with a median of 4 d per month and 75% of the farmers feeding WMA to calves ≤10 d per month (third quartile). Previous surveys have not reported on the frequency of WMA feeding. Brunton et al. (2012) reported that the proportion of waste milk in the liquid diet varied widely between farms, from less than 25% to more than 75%, although it cannot be determined from that study whether this represented the frequency or the proportion of daily vol-

Table 8. Practices related to antimicrobial dry-off therapy and use of colostrum (first milk after calving) and transition milk (nonsalable milk produced during the days following calving but after the first milking of colostrum) from cows having received such therapy

Practice (number of responses)	Number (%)
Proportion of cows receiving intramammary antimicrobial therapy at dry-off (n = 1,625)	
<25%	819 (50.4)
25–50%	335 (20.6)
50–75%	180 (11.1)
>75%	162 (10.0)
100%	129 (7.9)
Criteria used to guide selective dry-off antimicrobial therapy[1] (n = 1,480)	
Milk bacteriological culture	392 (26.5)
Multiplex PCR test in commercial laboratory	232 (15.7)
California mastitis test	593 (40.1)
Milk SCC	1,142 (77.2)
History of mastitis	753 (50.9)
Use of colostrum from a cow treated at dry-off for the calf's first colostrum meal (n = 1,553)	
Always	1,266 (81.5)
Sometimes	161 (10.4)
Never	126 (8.1)
Use of colostrum from a cow treated at dry-off as feed for calves >24 h of age (n = 1,556)	
Always	283 (18.2)
Sometimes	582 (37.4)
Never	691 (44.4)
Use of transition milk from a cow treated at dry-off as feed for calves >24 h of age (n = 1,515)	
Always	608 (40.1)
Sometimes	495 (32.7)
Never	412 (27.2)

[1]More than one answer possible.

ume (e.g., high frequency of diluted WMA). It should be kept in mind that even if the estimated frequency of exposure on Swiss dairy farms appeared low, it is unknown whether it is sufficiently low to avoid AMR selection. In an experimental study, even discontinuous exposure to antimicrobials in milk resulted in increased AMR in calves' fecal flora (Langford et al., 2003). In the present study, actual frequency of calves' exposure to WMA was not measured, nor were drugs and concentrations of antimicrobial residues. The longitudinal feeding of (pooled) WMA has been associated with increased AMR in calves' commensal microbial flora (Aust et al., 2013; Brunton et al., 2014; Maynou et al., 2017; Foutz et al., 2018; Jarrige et al., 2020). Some practices, such as discarding WMA from the first day (or days) after completion of treatment, might reduce the concentration of antimicrobial residues in WMA to which the calves are exposed. Duse et al. (2015) detected no difference in AMR prevalence between the practice of feeding WMA produced during treatment and the withdrawal period compared with feeding WMA produced during the withdrawal period only. Further research is needed to better characterize calves' exposure to residues on small farms, the resulting AMR in calves' commensal gut flora, and the extent to which specific practices may be effective at preventing AMR selection.

In the present study, geographical region and production type were associated with WMA feeding, similar to findings in a previous report from Sweden (Duse et al., 2013). The regional difference could be explained by intrinsic factors (e.g., habits or economic motivations) that were not explored in this study, or by recommendations conveyed by local veterinarians or authorities (Duse et al., 2013). Waste milk feeding was found to be more common in larger herds (>20 cows) in a previous study from Austria (Klein-Jöbstl et al., 2015) but not in another from Sweden (Duse et al., 2013). In the present study, herd size was associated with WMA feeding in the unconditional analyses but was no longer significant in the models after accounting for other variables (such as milk production). Among other herd characteristics investigated, average BTSCC category was also significant in the final models. In previous studies on Swiss dairy farms, antimicrobial treatments related to udder health represented the highest proportion of treatment incidence in cows (Menéndez González et al., 2010), and yield-corrected BTSCC was positively associated with incidence of intramammary treatment (Nägele et al., 2019). Therefore, BTSCC could represent a proxy for herd udder health, as well as antimicrobial use, and consequently the incidence and monthly volume of WMA produced. A higher average production level of the cows was associated with increased odds of feeding WMA, which could also be associated with a higher volume of WMA produced when a cow is treated with an antimicrobial drug that has a milk withdrawal period. When producers were asked which factors influenced their decision to feed WMA to calves, volume of WMA was identified by 44.3% of respondents as an influential factor. An intention to valorize WMA was mentioned by many producers, which was also a common reason for feeding WMA in a previous study (Brunton et al., 2012). On the other hand, the present study revealed differential practices, for instance related to calves' age or to pathogens or antimicrobial drugs that might be present in WMA, suggesting that producers might have concerns other than economic loss. Further investigation of the diversity of perceptions and motivations that may play a role in WMA disposal practices, as well as other intrinsic factors associated with WMA feeding in general, is warranted.

A majority (92.1%) of producers practiced selective dry cow therapy, which represents a significant improvement compared with data from a previous report in which a majority (55.5%) of Swiss farms practiced blanket dry cow therapy (Gordon et al., 2012). This selective therapy approach resulted in less than 25% of the cows receiving therapy at dry-off on most of the farms. This is consistent with the reported decrease in sales of antimicrobial dry-off products since 2010 (FOPH and FSVO, 2020), partly attributable to legislation restricting veterinary prescription of antimicrobial drugs for prophylactic use, introduced in 2016 (Verordnung über die Tierarzneimittel, 2016). However, some criteria cited in the "other" category were not in line with this legislation, such as "season" or "alpine pasture," which, although not always specified by the respondents, is presumed to be associated with increased use of antimicrobial dry-off therapy. Similar to a previous study (Duse et al., 2013), the proportion of farms feeding the colostrum from cows treated with antimicrobials at dry-off to newborn calves was high, consistent with known benefits of colostrum feeding for calves' health (Godden et al., 2019). This proportion was lower for the feeding of transition milk from treated cows to older calves. Although a part of treated cows might present detectable concentrations of antimicrobial residues in colostrum, the risk of calves' exposure to residues through colostrum feeding is further mitigated by a low proportion of treated cows (Ricci et al., 2017).

One of the limitations to this study is the low response rate of 10.9%, which might be explained by the sensitive nature of the topic of antimicrobial residues in milk. It is possible that some producers who regularly use antimicrobials felt uncomfortable completing the

survey, whereas others who use little or no antimicrobials did not complete the survey because they felt that it did not apply to their farm. Several producers who completed the survey wrote comments that reflected the latter possibility. Both situations might also have created a selection bias. Participation in the survey may have been driven by a higher concern regarding antimicrobial use and resistance, which possibly has a higher prevalence among producers who use little or no antimicrobials. Higher participation rate of farmers in organic production compared with conventional production (8.0% vs. 4.5%) might suggest a positive bias, resulting in an underestimation of WMA feeding prevalence in the overall population of dairy farms. Conversely, the lower participation rate of producers from the eastern region (4.6% vs. 5.7% and 6.3% in the central and western regions, respectively) might reflect different management practices or levels of concern with this topic. However, the relevance of this bias for the overall and modeling results is difficult to predict, especially as the attribution of the farms to 3 regions was based primarily on geographic location, which may be associated with various other parameters such as herd size or management practices. Additional potential sources of bias include membership in a breeding association as a prerequisite for participation, and the use of electronic invitation and online questionnaire, although the latter is not believed to be a significant source of bias even in rural areas nowadays. The effect of selection bias based on language was believed by the authors to be minimal, as only 0.9% of Swiss dairy producers are located in Ticino, whereas the distribution of German- and French-speaking respondents (82.8% and 17.2%, respectively) was similar to the distribution of language-specific e-mail invitations sent (86.1% and 13.9%, respectively). Second, a recall bias may have affected responses relating to WMA production (number of cows, number of days, and volume) as well as BTSCC. We cannot exclude the possibility that some of the questions and response items may have been misunderstood or unable to capture the full spectrum of possible situations or practices on the farms, resulting, for instance, in responses in the "other" category. Finally, as already mentioned, some producers fed WMA produced only after several days (e.g., 2–5 d or more) of the withdrawal period. Under the Swiss organic label, antimicrobial use is restricted, and producers are required to double the withdrawal period and to feed preferably maternal, unaltered (non-medicated, non-mastitic) milk to calves (BioSuisse, 2021). Therefore, they are only allowed to feed WMA produced during the second half of the withdrawal period to calves. Based on the classification used in the analyses, these herds would be classified as feeding WMA, although there might no longer be residues in WMA used on these farms, resulting in a misclassification bias. Organic farms were probably more likely to be affected by this bias. To minimize the effect of this bias, 2 models were built, and production type was significantly associated with the practice of feeding WMA or not in both models. Therefore, the authors believe that this bias has not significantly affected the conclusions.

Finally, although management practices may differ between regions within countries, some of the results of this study might be generalizable to small-scale dairy production systems from other countries. For instance, in farms of similar size, the number of calves to feed can be expected to be similar. However, the frequency of WMA production (and feeding to calves) is also influenced by antimicrobial use practices. Sales of intramammary antimicrobials are higher in Switzerland than in other European countries (EMA, 2020). Therefore, frequency of WMA production and feeding to calves may be lower on small farms from other European countries, unless their use of systemic antimicrobials in lactating cows is higher.

In conclusion, in respondents' farms, WMA was most commonly disposed of in the manure pit. The prevalence of feeding WMA to calves on Swiss dairy farms was estimated to be 47.3%, although this estimate decreased to 24.5% when considering only WMA produced during treatment and up to the first milking after completion of antimicrobial treatment. Furthermore, the incidence of the feeding of WMA to calves was low, with a median of 4 d per month. Herd characteristics affecting this practice included production type, region, average BTSCC, and average milk yield per cow. Further research is needed to evaluate intrinsic factors and perceptions associated with this practice and with the intention to adopt alternative disposal practices.

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