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RESEARCH ARTICLE

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Qualitative and quantitative monitoring of antibiotics on dairy cattle farms in relation to animal welfare indicators

Giuliano Borriello[a], Giulia Cagnotti[a], Elena Avedano[a], Stefania Bergagna[b], Piero Iannello[c], Giorgia Di Muro[a], Sara Ferrini[a], Antonio D'Angelo[a] and Claudio Bellino[a]

[a]Dipartimento di Scienze Veterinarie, Università di Torino, Grugliasco, TO, Italy; [b]Istituto Zooprofilattico Sperimentale del Piemonte, Liguria e Valle d'Aosta, Laboratorio Benessere Animale, Torino, Italy; [c]Veterinario Libero Professionista, Piemonte, Italy

ABSTRACT

Antimicrobial resistance is a growing concern for the scientific community and the public, so many countries have stepped up monitoring to tackle it and promote correct antimicrobial use. The welfare assessment protocol for dairy cows used by the Italian National Reference Centre for Animal Welfare (CReNBA) recommends lowering the use of antibiotics, so this study assessed the effects of the introduction of the welfare score on antimicrobial use and animal welfare between 2015 and 2018. For this study, 23 dairy farms in northern Italy (Piedmont) were enrolled. Data on animal categories (calf, heifer and cow) and antimicrobial use were extrapolated from mandatory farm registers. The antimicrobial animal-defined daily dose (ADDD) and the ADDD per year (ADDD/year) were calculated. Each farm was evaluated with the CReNBA welfare assessment protocol for dairy cows. An increase was recorded for 2018 regarding the number of reared animals (especially adult cows) and in the welfare (2015: 71.44% ± 7.84% vs. 2018: 76.18% ± 6.40%; $p < 0.05$) and biosecurity score (2015: 44.42 ± 11.87 vs 2018: 60.49 ± 11.13; $p \leq 0.01$). The mean ADDD/y was lower for 2018 (3.04 ± 1.3 vs. 3.61 ± 1.5; $p = 0.01$), despite the extensive use of beta-lactams and cephalosporins. Most farms with high welfare scores showed a lower ADDD/y in both years. The correlation between higher levels of animal welfare and lower antimicrobial consumption suggests that drug use can be reduced improving animal well-being on the farm. Further reductions may be achieved by strengthening synergism between public health agencies and farm veterinarians.

HIGHLIGHTS

- The overall score improved in the year 2018
- Animal defined daily dose/year dose was lower after the introduction of the welfare evaluation method.
- The animal defined daily dose/year was reduced especially for the category 'cow'

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Introduction

Antimicrobial resistance is a growing concern for human and animal health alike since according to the WHO prevision (WHO 2014), it will be responsible for over 1 million human deaths per year as well as higher economic losses in farm production and increased zoonosis transmission by the year 2050. Resistance can be naturally acquired (Daeseleire et al. 2016), but the selective pressure caused by inappropriate antimicrobial use in recent years has accelerated the process (Prestinaci et al. 2015).

National monitoring programs in Europe have reported a correlation between the increase in antimicrobial resistance in human pathogens and the use of active substances in food-producing animals (EFSA/ECDC/EMA 2017). In response, mandatory or voluntary plans for the reduction of antimicrobial use have targeted the highest priority critically important antimicrobials (i.e. fluoroquinolones and third and fourth-generation cephalosporines) (EFSA/ECDC/EMA 2017). Guidelines for the responsible use of antimicrobials (Murphy et al. 2017) recommend that treatment should not be seen only as an economic problem but as a One-Health issue that impacts public health as shown by the data published for each European country (European Surveillance of Veterinary Antimicrobial

CONTACT Giuliano Borriello giuliano.borriello@unito.it

Use—ESVAC) (Bondt et al. 2013) in the annual reports of the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC) (Ferri et al. 2017). Since antimicrobial resistance is a worldwide issue, monitoring is operated also in non-European countries (McEwen and Fedorka-Cray 2002).

Antimicrobial consumption and its correct use on the farm is a key point of many monitoring plans for animal welfare and management.

Animal welfare, previously defined by the Brambell report (Brambell 1965), in Italy is guaranteed by regulations that define the minimum mandatory standards for the protection of animals (Italian Parliament 2001; European Council 2004; 2009) and other regulations regarding specific species (Italian Parliament 2011). Indicators to objectively assess welfare level are (Rushen et al. 2011) conventionally divided into two groups: indicators of farm facilities and indicators of animal well-being (animal-based measure) (Spigarelli et al. 2020). The Italian National Reference Centre for Animal Welfare (CReNBA) developed a checklist for free-stall or tie-in dairy farms aimed to assess and improve animal welfare, a matter of growing concern for the consumer, management and lower the use of antibiotics. This score evaluates the welfare, biosecurity and risk management of each farm, so a high overall score is positive feedback for the farmer who is encouraged to maintain good management level and a more rational use of antimicrobials.

With this premise in mind, we conducted this study to assess the effects of the introduction of the CReNBA score on antimicrobial use and animal welfare between 2015 and 2018 in intensive dairy farms.

Material and methods

Farm recruitment

For the purpose of this study, 23 intensive dairy farms in northern Italy (Piedmont), with a complete and reliable record documenting antimicrobial consumption were routinary assessed by a team of experts. All the farms were scheduled for a first welfare assessment in 2015 and a subsequent check on the year 2018.

The farmers agreed to provide information about pharmacological treatment and the productive status of their farms. All the procedures performed to obtain data regarding the animals, milk production, antimicrobial consumption, welfare and biosecurity were conducted in accordance with current animal welfare regulation (Directive 98/58/EC and Italian Decree Law 146/2001)

Animal data

The number of animals reared between 2015 and 2018 was obtained from the farm's management records. For each farm animals were categorised age-wise (Saini et al. 2012; González Pereyra et al. 2015) according to the system used by Society of Veterinarians operating in the livestock sector (SIVAR) online software

1. Cow: age >2 years
2. Heifer: age 2 months to 2 years
3. Calf: age ≤ 2 months

The data were also used for calculating the antimicrobial consumption.

Antimicrobial consumption

Data on antimicrobial use from 2015 to 2018 were extracted from the mandatory farms' treatment records (Italian Parliament 2006) or prescription drug invoices. The total amount of antimicrobials used was determined, as was the animal-defined daily dose (ADDD), defined as the amount of active principle (mg) that should be administered per each kg of live weight for each day of treatment, according to the summary of the characteristic of the product in Italy (SPC) (Jensen et al. 2004).

The ADDD for long-acting drugs was obtained by dividing the recommended dosage by the number of days in treatment after one application of the drug (long-acting factor). Long-acting factors were gleaned from the literature or from the product insert issued by the pharmaceutical company (Pardon et al. 2012; Dedonder et al. 2016; Lava et al. 2016).

We extrapolated from the ADDD the total consumption of antimicrobials per year (ADDD/y), which is considered a risk index: it indicates the risk that a given animal in a population will be treated during one year. This measure was obtained with SIVAR online software (https://ddd.veterinariodifiducia.it/Logon). The ADDD/y was calculated:

$$ADDD/y = \frac{Total\ amount\ of\ drug\ administered\ (mg)/ADDD}{mean\ of\ animals\ reared\ during\ the\ year\ *estimated\ average\ weight\ (kg)}$$

The equation was applied to each animal category (cow, heifer, calf) for each farm. Since the productive cycle is shorter for male dairy calves than for female, a shorter period was considered for antimicrobial consumption.

Antimicrobial use was quantified according to the chemical composition of the drug's active principles (European Medicines Agency 2015).

Welfare and biosecurity assessment

All data on welfare and biosecurity assessment were collected from the reports for 2015 and 2018. The reports were carried out by certified staff and by the authors according to the CReNBA welfare assessment protocol for dairy cows (https://www.classyfarm.it/wp-content/uploads/sites/4/2021/01/Manuale-Benessere-e-Biosicurezza-Autocontrollo-BOVINA-DA-LATTE_Classyfarm_REV019-22_01_2021_compressed.pdf). Briefly, several items were examined for loose-housing and tie-housing systems divided in five areas (Area A – Farm management and personnel; Area B – Housing; Area C – Animal-based measures, Area D – Biosecurity, Area E – Risk and alarm systems) (Table 1). Most checklist items are evaluated on either a trichotomous (unacceptable, acceptable, optimal) or a dichotomous scale (unacceptable, acceptable); each item concurs differently on the total score for each area based on its importance. Scores are then entered into an algorithm to obtain a score for the general condition of a farm (0 to 100%). Scores for individual farms can be compared against national data in the three CReNBA categories:

1. Insufficient: farms with a final score in the 33rd percentile
2. Good: farms with a final score between the 33rd and the 66th percentile
3. Excellent: farms with a final score > the 66th percentile

Statistical analysis

Statistical analysis was performed using R software, version 4.0.0 (https://cran.r-project.org). Normality was assessed with the Shapiro-Wilk test. Mean, standard deviation, median, and range are reported for numerical variables. The difference between numerical variables was assessed with Student's *t*-test, the Wilcoxon Rank-Sum test and the ANOVA test. Statistical significance was set at $p \leq 0.05$.

Results

Farm data

In every farm, calves were reared in individual boxes until 28th day post calving and fed twice a day until 28th day, when the animals were moved to a roofed common paddock of $\sim$ 50 m^2. Calves were gradually weaned at the age of 2 months, water was always provided ad libitum. Heifers and adult cows were housed in free-stall pens with at least 10 m^2 per animal between bedding, feeding and loafing areas. Each animal was provided with $\sim$0.9 m of feeding space and linear space for water provision was >10cm/cow. Total Mixed ration specific for the productive phase was administered twice a day. Table 2 presents the number of animals reared on the 23 farms. The mean number of animals was slightly higher in 2018 (330 ± 176.68 vs. 299.74 ± 147.46), with 14/23 farms reporting an increase of more than 5%, whereas 2 farms reported a decrease of more than 10%. No differences in milk production were recorded between the year 2015 (28.57 ± 5.10) and 2018 (28.28 ± 5.33).

The difference in the number of animals reared between 2015 and 2018 by animal category (cow; heifer; calf) is reported (Table 3). The number of cows was lower in 2018 than in 2015 for 3/23 farms. The decrease in the number of heifer and calf was >5% in 7/23 and 4/23 farms, respectively. As reported in Figure 1, a significant increase ($p \leq 0.05$) was detected in the overall welfare score (2015: 71.43 ± 7.86 vs.2018: 76.19 ± 6.40) and for each area (A: 77.65 ± 0.16 vs 82.71 ± 7.52–B: 65.25 ± 10.30 vs. 70.42 ± 8.62–C: 71.52 ± 9.41 vs. 76.13 ± 8.89) between 2015 and 2018. Moreover, also for the Biosecurity category an improvement was detected during the 2018 assessment (44.42 ± 11.87 vs 60.49 ± 11.13).

The ADDD/y (± SD) was significantly lower in 2018 compared to 2015 (3.04 ± 1.3 vs. 3.61 ± 1.5; $p = 0.01$). An increase between 0.75 and 38.4% in ADDD/y between 2015 and 2018 was observed for 8/23 farms, whereas the decrease for the remaining 15/23) farms was higher (6.3–63.1%) (Table 4).

The median ADDD/y for cows was lower ($p \leq 0.05$).in 2018 (3.50, range: 1.10–9.03) compared to 2015 (4.97, range 1.42–7.21) ($p \leq 0.05$). The median ADDD/y for heifers was 0 in both 2015 (range 0–3.42) and 2018 (range 0–5.36), whereas the median ADDD/y for calves was higher in 2018 than in 2015 (11.73, range 0–54.83 vs. 9.82, range 2.50–120.51) even though the difference was not statistically significant.

Table 5 presents the data on active drug principle; there was a significant reduction in the use of polymixins ($p \leq 0.05$), macrolides ($p = 0.01$) and sulphonamides ($p \leq 0.05$) in the year 2018 compared to the year 2015.

Welfare and biosecurity assessment

The mean (± SD) animal welfare score was higher in 2018 compared to 2015 (76.18% ± 6.40% vs.

Table 1. CReNBA checklist for on-farm assessment of dairy cow welfare.

Area A: Farm management and personnel	
1	Number of stockpersons
2	Experience and training of stockpersons
3	Animal grouping strategy
4	Inspection of animals
5	Type of handling
6	Milking parlour access and exit
7	Feeding strategy
8	Use of concentrate feeds (daily dose)
9	Water provision
10, 11, 12	Cleanliness of water points (lactating cows, dry cows, heifers)
13, 14, 15	Cleanliness of floors in walking areas (lactating cows, dry cows, heifers)
16, 17, 18	Bedding material management (lactating cows, dry cows, heifers)
19	Use and management of calving pens
20	Foot inspection and foot bathing
21	Hygiene of milking parlour or milking robot
22	Milking routine
23	Biosecurity measures
Area B – Housing	
24	Housing of animals >6 months of age
25, 26, 27	Space availability in the lying area (lactating cows, dry cows, heifers)
28	Calving pen presence and size
29	Design of the lying area
30, 31, 32	Type of bedding material (lactating cows, dry cows, heifers)
33, 34, 35	Type of floor in walking areas (lactating cows, dry cows, heifers)
36, 37, 38	Available space at feed bunk (lactating cows, dry cows, heifers)
39	Feeding place dimensions and accessibility
40, 41, 42	Functioning and number of water points (lactating cows, dry cows, heifers)
43	Bedding material for new-born calves (<2 weeks of age) in single pens
44	Space for calves up to 8 weeks of age (in single pens)
45	Possibility for calves to see and touch each other (in single pens)
46	Space for calves in group pens
47	Facilities for sick animals
48	Waiting room and milking parlour design
49	Milking machine or milking robot maintenance
50	Temperature, humidity and ventilation
51	Gas (NH3, H2S, CO2) concentration
52	Artificial lighting
Area C–Animal-based measures	
53, 54, 55	Avoidance distance test (lactating cows, dry cows, heifers)
56, 57, 58	Body condition score (lactating cows, dry cows, heifers)
59, 60, 61	Cleanliness of flank, upper leg, lower leg and udder (lactating cows, dry cows, heifers)
62, 63, 64	Integument alterations (lactating cows, dry cows, heifers)
65	Lameness (lactating cows, dry cows)
66	Bulk tank milk somatic cell count
67	Number of antibiotic treatments for clinical mastitis in 1 year
68	Annual mortality rate of adult cows (cows died on farm, euthanized or emergency slaughtered)
69	Annual mortality rate of calves 2–30 days old
70	Mutilations (disbudding, dehorning, tail docking)
Area D: Biosecurity	
71	Rodent and insect control
72	Other animal species on the farm
73	General precautions at entry of stranger
74	Management of entrance of regular visitors
75	Disinfecting vehicles at entrance to the farm
76	Possibility of contact between outside vehicles and farm animals
77	Collecting animal carcases
78	Loading live animals
79	Purchasing and/or moving animals outside the farm
80	Quarantine
81	Mastitis control and prevention
82	Control and prevention of major infectious diseases
83	Health condition pertaining to Infectious Bovine Rhinotracheitis (IBR)
84	Health condition pertaining to Paratubercolosis
85	Control and analysis of water source
Area E: Risk and alarm systems	
86	Water sources
87	Noise
88	Ventilation system alarm
89	Fire alarm
90	Backup power generator

Table 2. Number of animals reared between 2015 and 2018 and percentage of change.

	No. of animals (2015)	No. of animals (2018)	Δ no. of animals	Δ %
Mean (± SD)	299.74 (± 147.47)	330.00 (± 176.68)	30.26 (± 39.13)	0.09 (± 0.11)

No. of animals (2015): number of animals reared in 2015; no. of animals (2018): number of animals reared in 2018; Δ no of animals: difference in number of animals reared between 2015 and 2018; Δ %: percentage of change in the number of animals between 2015 and 2018.

Table 3. Number and differences in the number of cows, heifers and calves (2015–2018).

	Cows (2015)	Cows (2018)	Heifers (2015)	Heifers (2018)	Calves (2015)	Calves (2018)	Δ Cows	Δ Heifers	Δ Calves
Mean (± SD)	124.00 (±64.14)	138.61 (± 71.37)	88.61 (± 43.67)	97.04 (± 56.08)	87.09 (± 45.04)	94.35 (± 55.89)	14.61 (± 16.65)	8.43 (± 24.01)	7.26 (± 16.40)

Δ cows: differences between the cows reared in 2015 and 2018. Δ heifers: differences between the heifers reared in 2015 and 2018. Δ calves: differences between the calves reared in 2015 and 2018.

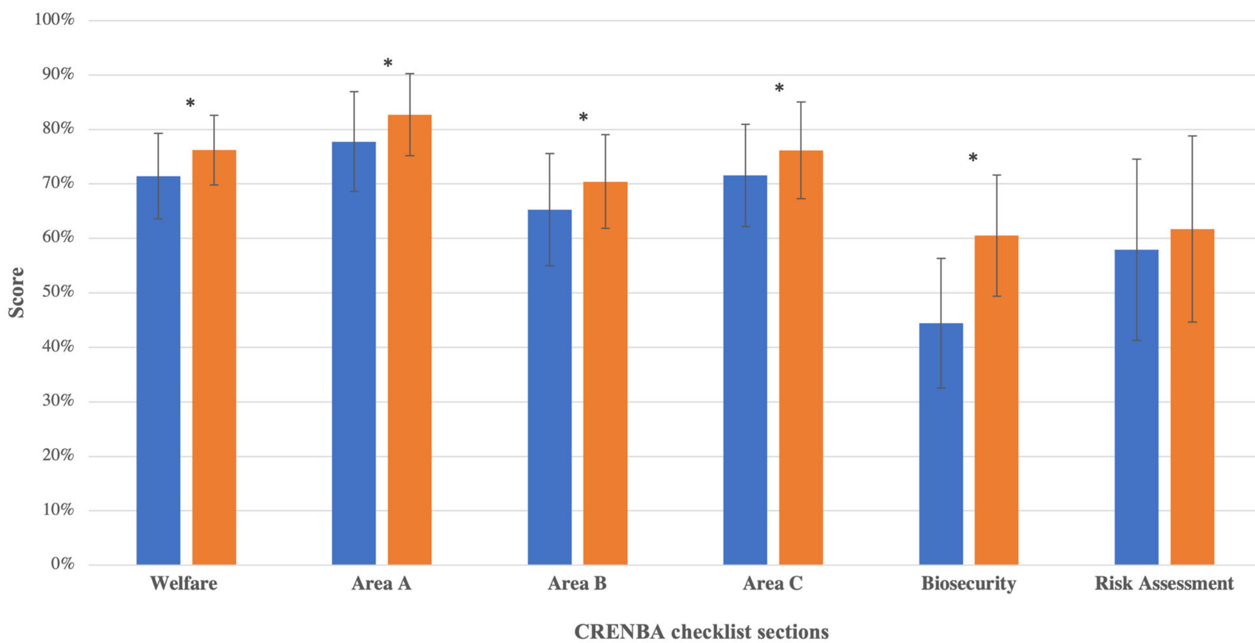

Figure 1. CRENBA Score assessed in the years 2015 and 2018 (*$p \leq 0.05$); Area A: management; Area B: housing; Area C: Animal base measure and the animal-based measure.

Table 4. Antimicrobial consumption (2015 vs. 2018).

	ADDD/y (2015)	ADDD/y (2018)	Δ ADDD/y	Δ ADDD/y %
Mean (± SD)	3.62 (±1.51)	3.05 (±1.31)	−0.57 (±1.04)	−13.0% (±24.5%)

ADDD/y (2015): ADDD/y for 2015; ADDD/y (2018): ADDD/y for 2018; Δ ADDD/y: difference in ADDD/y between 2015 and 2018; Δ ADDD/y %: percentage of change between 2015 and 2018.
ADDD: animal defined daily dose.

71.44% ± 7.84%; $p < 0.05$); a lower welfare score was noted for 5/23 farms, with a decrease between 1% and 6%. Most farms (18/23) allocated between the 2nd tertial of the maximum score in 2015, whereas slightly more farms (21/23) fell between the 66% and the 100% percentile in 2018 (Figure 2). Three farms (nos. 7, 9, 20) improved their animal welfare score from good to excellent, whereas the score for two (nos. 1, 8) decreased. The data arranged by CReNBA classification for the tertials (Figure 2) show that most of the farms located in the second tertial (good) increased their score to the third tertial (excellent).

Regarding the CReNBA checklist section 'biosecurity' and 'risk and alarm systems', the mean (± SD) for biosecurity in 2015 and 2018 was 43.83 (± 13) and 60.49 (± 11.12), respectively ($p < 0.05$). The median (range) for risk and alarm systems was 61.91 (range 7.97–84.58) in 2015 and 61.49 (range 34.16–100) in 2018.

Association between antimicrobial consumption and animal welfare

Animal welfare scores for all farms were above 50% for both 2015 (range 52.51–85.79%) and 2018 (range 61.9–86.76%). For this analysis, only the intervals between the second and the third quartile (50–70%) and between the third and the maximum score (75–100%) were taken. The number of farms with a score greater than 75% increase in score went from 8 in 2015 to 14 in 2018. This improvement was related to the difference in antimicrobial consumption. The farms with a welfare score lower than 75% had a higher median (range) ADDD/y than those with lower scores in both 2015 (3.84, 1.10–7.28 vs. 2.70, 1.38–4.77) and 2018 (3.46, 1.13–5.11 vs. 3.46, 1.13–5.11).

Table 5. Median animal-defined daily dose/y by antimicrobial class.

Antimicrobial category	2015 Median (Range)	2018 Median (Range
Aminoglycosides	0.38 (0–1.25)	0.33 (0–1.16)
Penicillins	1.28 (0.07–2.90)	1 (0.21–3.79)
First and second generation cephalosporines	0.14 (0–0.56)	0.08 (0–0.71)
Third and fourth generation cephalosporines	0.51 (0–1.12)	0.34 (0–1.95)
Quinolones	0.17 (0–1.20)	0.14 (0–1.18)
Phenicols	0 (0–0.15)	0 (0–0.20)
Polymixins	0[b] (0–1.80)	0[b] (0–0.12)
Lincosamides	0.02 (0–0.72)	0.02 (0–0.42)
Macrolides	0.13[a] (0–0.64)	0.01[a] (0–3.34)
Rifaximin	0 (0–0.23)	0 (0–0.42)
Sulphonamides	0.1[b] (0–1.72)	0.01[b] (0–0.60)
Tetracyclines	0.22 (0–2.31)	0.15) (0–1.03

[a]$p = 0.01$; [b]$p < 0.05$.

Concerning the welfare scores categorised as good, a further quartile interval was obtained from the minimum and maximum (52.51–86.76%) and highlights the difference in good and excellent welfare scores. Comparison revealed differences between the interval for 2015 (Q1 52.51–67.36%; Q2 67.37–71.35%; Q3 71.36–77.56%; Q4 77.57–85.79%) and for 2018 (Q1 61.92–72%; Q2 72.01–77.90%; Q3 77.91–80.44%; Q4 80.45–86.76%). There was no statistical difference between the mean ADDD/y for the two years; however, a downward trend was noted for all quartiles except Q2 (Table 6).

Discussion

To our best knowledge, few studies to date have investigated the relationship between antimicrobial consumption and CReNBA checklist items for on-farm assessment of dairy cow welfare. Our data show an increase in the number of reared animals (especially adult cows) on

Figure 2. Percentage of welfare by tertial. Blue dots: farms with welfare score higher than 66% in both years. Red dots: farms with welfare score lower than 66% for at least one year.

Table 6. Animal-defined daily dose (ADDD)/y (2015 vs. 2018) for each quartile.

	Q1	Q2	Q3	Q4
ADDD/Y 2015	3.40 (± 1.70)	3.38 (± 1.85)	3.64 (± 1.23)	3.28 (± 1.64)
ADDD/Y 2018	2.91 (± 1.78)	4.03 (± 0.60)	2.60 (± 1.03)	2.57 (± 1.21)

Q1: first quartile; Q2: second quartile; Q3: third quartile; Q4: fourth quartile; ADDD/Y 2015: animal defined daily dose for 2015; ADDD/Y 2018: animal defined daily dose for 2018.

most of the farms (83%) in 2018. This increase was also followed by a significant improvement in the year 2018 on the overall welfare score and all its subsections: management (Area A), housing (Area B) and the animal-based measure (Area C). So, the potential negative effects of higher number of animals were mitigated by an improvement of the structures and some issues, such as overcrowding, have been avoided. However considering that animals are periodically moved to different pens according to the productive cycle, multiple inspections during the year are needed to perform reliable assessment and prevention of overcrowding (Bach et al. 2008).

Milk production by animal did not vary probably because the scores obtained were good or excellent in both years. This result is probably a combined outcome of all the components of the score, not the welfare alone since von Keyserlingk et al. (2009) reported that a high production level alone is not necessarily an indicator of good animal condition and that other parameters also need to be considered (e.g. culling rate, mastitis rate).

The mean ADDD/y between 2015 and 2018 (3.61 ± 1.5–3.04 ± 1.3; $p \leq 0.01$, respectively) was lower than reported in previous studies, even though these differences could be due to different antimicrobial and welfare assessment protocols (Pol and Ruegg 2007; Trevisi et al. 2014) . Kuipers et al. (2016) reported a mean ADDD/y of 5.86 over an 8-year period, whereas Pol and Ruegg (2007) reported a higher mean ADDD/y (5.43) over a 5-year period for dry therapy and intramammary drugs (3.58) and over a 2-year period for antimicrobial therapy for different use. Finally, Mazza et al. (Mazza et al. 2021) reported a mean ADDD/y of 4.8 ADDD/biomass, for cows, heifers and calves grouped together. The differences in the number of farms, animal weight and animal categories in these studies (Pol and Ruegg 2007; Kuipers et al. 2016) highlight the need for standardisation of study design between different countries. Despite some standardisation attempts have been made, comparison between studies can still be difficult and many evaluated parameters could differ between the scores. The decrease in ADDD/y between 2015 and 2018 we observed is in accordance with Kuipers et al. (2016); this suggests that regulating the use of antimicrobials is effective in reducing consumption, though more work still needs to be done.

The most frequently used antimicrobial class was penicillin, probably because of the extensive use of beta-lactams in mastitis treatment and prevention (Zwald et al. 2004; Sawant et al. 2005; Pol and Ruegg 2007), whereas there was a reduction in polymyxin, macrolides and sulphonamides in the year 2018. The use of polymyxin and macrolides is discouraged due to their importance in human medicine, so this reduction could be due to the increasing attention by the veterinary practitioner on this topic, whereas the decrease of ADDD/y for sulphonamides could be attributed to a subjective decision of the farm vet. The use of cephalosporines too is discouraged in farm animals due to their importance in human medicine, but no reduction was detected. Even if their use was little compared with penicillin in our study, this lack of reduction could be due the short withdrawal time of most third and fourth-generation cephalosporin (Brunton et al. 2012), causing concern since they are classified as critically important antimicrobials (CIAs). Therefore, their use should be discouraged unless necessary to prevent a decrease in antimicrobial susceptibility (Stevens et al. 2019; McDougall et al. 2021).

Animal welfare besides antimicrobial drugs holds crucial importance for animal health and public opinion. This parameter can be quantified by different methods and should be assessed by evaluation and audit (Rushen et al. 2011). The farms in the current study had a CReNBA score higher than the first tertial (33%) and did not present serious inadequacies. These results are shared by previous studies that used either the same or a different evaluation system (Trevisi et al. 2014; Molina et al. 2019), which indicates that animal welfare is increasingly recognised as an important parameter in many parts of the world. The increase in animal welfare and biosecurity between 2015 and 2018 was probably motivated in part by consumer demand (Rushen et al. 2011) and in part by the famer's knowledge that high welfare and biosecurity standards are key to better productivity (Trevisi et al. 2014; Molina et al. 2019; Bugueiro et al. 2021). Previous studies suggested a correlation between high welfare indicators and lower incidence of podal, respiratory and mammary disease (von Keyserlingk et al. 2009; Molina et al. 2019; Bugueiro et al. 2021). In brief, higher management standards may be linked to lower antimicrobial consumption.

In our study, grouping the farms by quartiles of the CReNBA score showed a higher ADDD/y for the farms with a score lower than 50–70% than the farms with a higher score (70–100%) for both 2015 and 2018. Thus, farms with higher levels of welfare showed lower antimicrobial consumption. When we divided the study population according to relative animal welfare score, we observed no linear and constant decrease in antibiotic consumption from the lowest to the highest score. Nonetheless, the mean ADDD/y for the farms in the inferior quartiles was higher than that for the farms in the higher quartiles for both years probably because the farms had good baseline animal welfare scores. Differences in antimicrobial consumption may be better compared between farms with greater differences in CReNBA scores.

Conclusion

Our study findings provide additional evidence for the relationship between improved animal welfare and biosecurity values of the CReNBA score and lower antimicrobial consumption. Even though more studies are needed to confirm our results, compliance with new regulations and improvement in farm's welfare and biosecurity may have had a pivotal effect. However, to further reduce microbial use, synergies between public health agencies and farm veterinarians are essential to decide treatment/prevention and to educate farmers in the correct use of antimicrobials.

Ethical approval

All the owners were previously informed regarding all the procedures performed and gave written consent to use the animals. All the procedures performed to obtain the data were conducted in accordance with current animal welfare regulation (Directive 98/58/EC and Italian Decree Law 146/2001)

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Claudio Bellino http://orcid.org/0000-0002-8845-4394

Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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