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Reducing use of antimicrobials — Experiences from an intervention study in organic dairy herds in Denmark

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ABSTRACT

With the aim of phasing out the use of antimicrobials 23 Danish organic dairy producers from the same organic dairy company participated in Stable School farmer groups from February 2004 to March 2005 in order to go through a common learning and development process towards their common goal. Data on production and herd health were evaluated from two years before to three years after the start of the Stable Schools. For comparison, data was collected from the remaining 35 herds delivering to the same dairy company, 118 organic dairy herds delivering to other dairies and 115 conventional herds. On average, the project herds were smaller with lower production and had half the incidence rate of mastitis treatment than the organic herds from other dairies before the start of the project. The incidence rate of mastitis treatments was reduced considerably from 20 treatments per 100 cow years to 10 treatments per 100 cow years after the project period. Somatic cell count (SCC) and scores for acute and chronic intramammary infections did not change significantly during the study period, and milk production increased at the same rate as in the other herd groups. The incidence rate of mastitis treatments or the reduction of the incidence rate could be related to the herd SCC or the prevalence of blind quarters. The incidence rates of locomotive disorders and reproductive disorders were lower in the project herds compared with herds from other dairies before the project start, and the differences increased during the project period though the reduction of the incidence rates in the project herds was not statistically significant. It is concluded that the farmers participating in the Stable Schools managed to reduce the use of antimicrobials in their herds also after the project period without apparent negative effects on production and udder and herd health.

1. Introduction

Maintaining and enhancing animal health and welfare of the individual animal and at the herd level is an important goal in organic farming (Verhoog et al., 2004). At the same time, chemical products affecting the natural balance among living organisms are prohibited in all areas of the organic farm. From an animal welfare point of view, however, no animal must suffer. Therefore, allopathic antimicrobials are allowed in the EU regulations for organic farming despite the fact that they are powerful cell toxins affecting both pathogenic and necessary bacteria, and they are as such regarded as unwanted products in organic terminology. The legislation encourages avoidance of allopathic antimicrobials in organic milk production if any alternative is available.

However, in the EU the consequence of using antimicrobials is only a doubling of the withdrawal time on milk and meat compared with conventional herds (CEC, 1999), which is in contrast to the US regulations defining any animal treated with

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antimicrobials or hormones as non-organic for the rest of its life (USDA, 2000). Consequently, the use of antimicrobials has a severe impact on the fate of the treated animal in organic herds in the US. Antimicrobials are therefore only rarely used in US organic herds (Pol and Ruegg, 2007; Zwald et al., 2004). In contrast to this, the impact of the organic legislation on the disease management strategies in Danish organic herds is not very large, and the difference compared with conventional herds is primarily related to the higher costs of follow up treatments by the veterinarian (Bennedsgaard et al., 2003). In Danish conventional dairy herds the farmer is allowed to treat individual cows with antimicrobials for up to 5 days if a veterinarian has diagnosed the disease and initiated the treatment. The right to do follow up treatments requires that the farmer has a health advisory service contract with the veterinarian. In organic herds only the veterinarian is allowed to handle antimicrobial treatments of the dairy cows. The dairies in Denmark handling organic milk also have special regulations of the use of antimicrobials compared to the EU regulation. At the time of the stable schools these special regulations included that the withdrawal time after treatment with antimicrobials was increased to three times of the period in the conventional herds. Antimicrobial dry cow treatments are only allowed in Denmark if the cow has been diagnosed with mastitis within 30 days before drying off or if a pathogen has been cultured in a milk sample within the same time period. This means that blanket dry cow therapy is not common in neither organic nor conventional herds in Denmark. A previous study showed that in Denmark only old organic herds had a significantly reduced incidence rate of veterinary treatments (Bennedsgaard et al., 2003), indicating that the focus on health improvements and the ability to fulfil this in daily practice follow a gradual mental conversion to the basic principles of organic livestock farming. In a recent interview study of Danish organic farmers, an explicit goal of reducing the use of antimicrobials was clearly linked to a fundamental improvement of animal health management according to the farmers (Vaarst et al., 2006).

The development project explicitly focused on dairy producers' effort to gradually phase out the use of antimicrobials in their herds. To reach this aim the farmers of the project were involved in farmer groups called Stable Schools. The concept of the Stable Schools in the project and the farmers' evaluation of it have been described in Vaarst et al. (2007). The aim of this article is to present and discuss the results of the one year participation in the Stable Schools by the 21 dairy herds. The results are measured by the development in veterinary disease treatments, SCCs, milk production and other indicators of dairy cattle health. These indicators were compared to data from other groups of dairy herds from two years before the project started to two years after the project ended.

2. Materials and methods

2.1. Study framework and design

The project was initiated as an action research project involving the Danish organization of organic farmers 'Organic Denmark', a private dairy company (at the start of the project owned by 46 organic milk producers in a cooperative society) and the Faculty of Agricultural Sciences. The aim of this project was to phase out the use of antimicrobial drugs ('antibiotics') from organic dairy herds through elimination of the need for disease treatment by minimizing the disease level in the herds and optimizing the selection criteria for treatment if necessary. At the time of the start of the project the involved dairy company was interested in investigating the possibilities of establishing a product line from herds with no use of antibiotics. One motivation was to be able to sell products on the US market. Farmers from 23 herds signed up to participate in the project. Since the use of antimicrobial drugs varies widely between herds and is related to different multifactorial diseases and farmer management strategies, many different approaches can also be made to improve the herd health situation. It was therefore decided that the main approach was to design individual farm and herd strategies through a participatory process using farmer groups for mutual advice and common learning. In accordance with the concept of Danish Stable Schools (Vaarst, 2007; Vaarst et al., 2007), which was developed in the project, the farmers participated in farmer groups each consisting of farmers from 5 to 6 farms and a facilitator from the project group meeting in turn on each of the participating farms to support each other in the development of strategies. The groups met monthly during a one year period. During the project period they would visit each farm twice with an interval of approximately 6 months. The results of the projects are consequently based on different farm-focused strategies, as opposed to testing one single strategy on all farms. The Stable Schools ran from February 2004 to March 2005 as part of the project. However, all herds continued in the Stable Schools for at least one year after the project period on their own initiative.

2.2. Selection of herds

All 46 organic milk producers connected to a small Danish dairy company were approached regarding their interest in participating in the project. From the start 22 herds volunteered, and one additional farmer was allowed to join the project four months after initiation. During the project two herds went out of milk production.

Furthermore, 118 other organic dairy herds (producers of other dairy companies) and 115 conventional herds were included to evaluate the development over time. These herds had been randomly selected and had accepted to participate in other studies conducted by the research group. Furthermore, data from the 23 herds not participating in the project and another 12 herds joining the dairy company during the project period accepted to be included in the analysis. Data was continuously available from the central Danish Cattle Database. Data on culling, reproduction, milk yield, SCC and disease treatments were available at cow level. The data included information of the amount of antimicrobial drugs used each day for each disease treatment. The use of treatments by the farmer without allopathic antimicrobials was not registered in the database. The herd was visited by the same veterinarian in March 2004 and March 2005 to assess the clinical condition of a random sample of 50 cows per herd. In the data analysis the proportion of cows with blind quarters was evaluated. Blind quarters were defined as at least one quarter of the udder not being milked for the rest of the lactation. The reason for a quarter being blind could be inherited, a result of damage to the udder caused by mastitis or trauma or selective culling of a quarter due to high somatic cell count, low production or slow milking. Data on blind quarters were available from 52 of the herds in the group of other organic herds and 48 of the conventional herds based on a questionnaire filled in by the farmers in February 2007.

2.3. Data editing, variables and statistical analysis

Data were analyzed based on the 4 herd groups: Project herds (21 herds), other herds from the same dairy (35 herds), other organic herds (118 herds) and conventional herds (115 herds). Statistical difference was tested between herd groups within each year and for each of the years 2002 to 2006 within each herd group.

Herd size was calculated as cow-years including only animals that had calved. Longevity of cows was calculated as mean calving number at each test day and summarized as the average for each year. Involuntary culling was described by calculating the incidence rate of early culling defined as culling prior to 100 days in milk (DIM).

Production level was assessed by estimation of individual cow lactation curves using a 2-piece linear regression model with intercept (expected peak) at day 60 after calving. Cows with at least 1 milk record before day 60 and last test day later than day 180 were included in the analysis. Milk production was calculated as 305 days production of energy-corrected milk (ECM) (Sjaunja et al., 1990). Significance of differences between herd groups was calculated with a mixed linear model using the MIXED procedure in the SAS for Windows software package, version 9.13 (SAS Institute Inc.), with 305 days ECM production as outcome and Jersey breed, herd group and year within herd group as fixed effects and herd as random effect. The production of cows of the Jersey breed was multiplied by 1.11 before calculations based on data of the national average production of all Holstein Friesian and Jersey cows in Denmark from 1994 to 2005 (Danish Cattle Federation, 2007). This was done to be able to identify differences between breeds between the herd groups other than the general production potential. The same correction was used in an earlier study (Bennedsgaard et al., 2003).

Calculated bulk tank SCC was the product of individual SCC and milk yield divided by the sum of milk yield at test day. Individual SCC were used to estimate the number of cows with chronically elevated SCC and cows with a new acute rise in SCC according to Rasmussen et al. (2001). Tests of significance of differences in culling rate, culling rate before 100 DIM, mortality rate, calculated bulk tank SCC, bulk tank SCC, new acute rise in SCC and chronically elevated SCC were evaluated using the GLM procedure in SAS 9.13 (SAS Institute Inc.). Standard error of mean was calculated per herd group from the analysis of differences between years.

Disease treatments by the veterinarian and the medicine used were reported to the Danish Cattle Database by the veterinarian. In general, all veterinary treatments of infectious diseases included use of allopathic antimicrobials and were regarded as antimicrobial treatment in the data analysis. Treatments within 10 days of last treatment were excluded because they were regarded as follow up treatment of the same disease case. Incidence rate of mastitis treatment as registered in the Danish Cattle Database was calculated per 100 cow years. Dry cow treatment was defined as udder treatments after day 270 DIM whether registered as clinical mastitis or treatment at drying off and treatments prior to day 270 DIM if registered as dry cow treatment by the veterinarian. The treatments counted as dry cow treatments were also included in the incidence rate of mastitis treatment. Because of skewness of the data statistical significance was tested with a negative binomial distribution using the GENMOD procedure in SAS 9.13 (SAS Institute Inc.) with herd group or year within group as explanatory variables. The Jersey breed had no influence on neither mastitis nor dry cow mastitis and was consequently not included in the analysis. Veterinary treatment of locomotive disorders with antimicrobials, veterinary treatment of metabolic diseases and veterinary treatments of other diseases normally treated with antimicrobials were calculated as treatments per 100 cow years. Treatments of locomotive disorders were mostly hock infections and foul-in-the-foot (interdigital necrobacillosis) whereas digital dermatitis and sole ulcers were often treated without antimicrobials by the hoof trimmer and therefore in general were not registered in the Danish Cattle Database. Treatment of other diseases normally treated with antimicrobials included pneumonia, diarrhea, displaced abomasum and miscellaneous infections. Veterinary treatments of reproductive disorders normally treated with antimicrobials (including retained placenta and metritis) were calculated as treatments per 100 calvings. Veterinary treatment of milk fever was calculated as cows treated per 100 calvings of cows in second lactation or older. Because of skewness of the data for reproductive disorders, locomotive disorders, metabolic diseases, milk fever and other diseases treated with antimicrobials caused by a relatively high number or herds with no or very few treatments, statistical significance was tested with a negative binomial distribution using the GENMOD procedure in SAS 9.13 (SAS Institute Inc.) with herd group or year within group and Jersey breed as explanatory variables. Jersey breed was only significant in the model for milk fever. Standard errors of means were calculated in the model. Descriptive characteristics of each of the 23 project herds originally included in the project can be found in Vaarst et al. (2007).

3. Results

3.1. Herd data

Data on herd characteristics such as size, average calving number, estimated 305-day milk production, culling rate and mortality are shown in Table 1. The proportion of herds with primarily Jersey cows was 38% in the project herds and 51% in the other herds from the same dairy compared to 9 and 8% in the other organic herds and the conventional herds. The project herds were smaller than the herds in the other groups throughout the study period. The herd size increased in all herd groups, though the increase was only significant in the 2 large groups. The average calving number was higher in the organic herds compared with the conventional herds throughout the study period. No changes were seen in the study period. The difference in average calving number in the 2 groups of herds from the dairy of the project herds was not

Table 1
Herd characteristics: herd size, average calving number, milk production level, culling rate and mortality in the 4 herd groups from 2002 to 2006.

Variable	Herd group	No. herds	2002	2003	2004	2005	2006	SEM
Herd size Cow years	Project	21	73^{b}	73^{b}	75^{b}	78^{b}	80^{b}	8
	Other same dairy	35	95^{a}	100^{a}	101^{a}	108^{a}	112^{a}	7
	Other organic	118	99^{a,1}	103^{a,1,2}	104^{a,1,2}	109^{a,2}	116^{a,3}	3
	Conventional	115	91^{a,1}	96^{a,1}	100^{a,1,2}	111^{a,2}	117^{a,3}	5
Average calving no.	Project	21	2.5^{a}	2.6^{a}	2.5^{a}	2.5^{a}	2.4^{a}	0.07
	Other same dairy	35	2.6^{a}	2.6^{a}	2.6^{a}	2.5^{a}	2.5^{a}	0.06
	Other organic	118	2.4^{a}	2.4^{a}	2.4^{a}	2.3^{a}	2.3^{a}	0.03
	Conventional	115	2.2^{b}	2.2^{b}	2.1^{b}	2.1^{b}	2.2^{b}	0.02
Estimated 305 days milk production	Project	21	6940^{c,1}	7344^{b,1,2}	7531^{c,2}	7533^{c,2}	7578^{c,2}	172
	Other same dairy	35	7296^{b,c,1}	7607^{b,1,2}	7720^{b,c,1,2}	7799^{b,c,2}	7838^{b,c,2}	160
Kg ECM	Other organic	118	7486^{b,1}	7746^{b,2}	7951^{b,2,3}	8066^{b,3}	8085^{b,3}	77
	Conventional	115	8546^{a,1}	8821^{a,2}	8934^{a,2,3}	8981^{a,2,3}	9061^{a,3}	83
Culling rate Cows/100 cow years	Project	21	31^{b}	37^{b}	37^{a,b}	31^{c}	37^{a,b}	2
	Other same dairy	35	31^{b,2}	38^{b,1}	39^{a,b,1}	33^{b,c,2}	35^{a,b,1,2}	2
	Other organic	118	35^{b,2}	39^{b,1}	36^{b,2}	37^{b,1,2}	35^{b,2}	1
	Conventional	115	40^{a,2}	45^{a,1}	42^{a,2}	40^{a,2}	39^{a,2}	1
Mortality rate, Cows/100 cow years	Project	21	3.3^{a,b,1,2}	3.7^{a,b,1}	3.8^{a,b,1}	1.8^{b,3}	2.1^{c,2,3}	0.5
	Other same dairy	35	3.9^{a,b}	3.9^{a,b}	4.6^{a,b}	3.5^{a}	3.5^{b,c}	0.6
	Other organic	118	3.2^{b,2}	3.6^{b,1,2}	3.4^{b,1,2}	3.9^{a,1}	3.7^{b,1,2}	0.2
	Conventional	115	4.1^{a,2}	4.6^{a,1,2}	5.3^{a,1}	4.5^{a,1,2}	4.9^{a,1,2}	0.3

^{a,b,c} Different letters indicate significant differences ($P<0.05$) between groups.
^{1,2,3} Different numbers indicate significant differences ($P<0.05$) between years.

significantly different from the other organic herds when taking the larger proportion of Jersey cows into consideration.

The milk production in the project herds was significantly lower than the production in the group of other organic herds in all years except 2003 after correction for Jersey breed, but not different from the herds from the same dairy. The changes in milk production in the project herds were not significant from before (2003) to after the project initiation, although the changes were similar to those in the other herd groups.

The culling rate was lower in the project herds and the other herds from the same dairy in all years except 2004 compared with the conventional herds (Table 1). No systematic development with regard to the culling rate seemed to exist in the project herds. The cow mortality in the project herds was lower in 2005 and 2006 compared with 2003, but if compared with 2002 the decrease was only significant in 2005. No decrease in mortality was seen in the groups of other organic herds or conventional herds. Except in 2005 the mortality was higher in the conventional herds than in the group of other organic herds. No differences in early culling prior to 100 DIM were seen, either between herd groups or between years; therefore the data are not included in the table.

In all years the SCC in the project herds was lower than in the other herds from the same dairy and the other organic herds, although the difference was only significant in 2002 (Table 2). In the other organic herds as well as the conventional herds, the SCC decreased until 2005. In the project herds the SCC on test days as well as in the bulk tank increased from 2002 to 2003 (not significantly). Both the calculated SCC and the bulk tank SCC in the project herds remained at a fairly stable level in 2004 and 2005.

Table 2
Udder health indicators: average somatic cell count on test days and bulk tank somatic cell count of milk delivered to the dairy, acutely elevated and chronically elevated SCC scores in the 4 herd groups from 2002 to 2006.

Variable	Group	No. herds	2002	2003	2004	2005	2006	SEM
Calculated somatic cell count × 1000 cells per ml	Project	21	238^{c}	257	263	252	271	16
	Other same dairy	35	287^{a,b}	274	280	279	289	13
	Other organic	118	299^{a,1}	282^{1,2}	276^{2}	269^{2}	283^{1,2}	8
	Conventional	115	274^{b,c,1}	265^{1,2}	263^{1,2}	252^{2}	267^{1,2}	7
Bulk tank somatic cell count × 1000 cells per ml	Project	21	226	249	233	231	251	16
	Other same dairy	35	259^{1}	254^{1,2}	237^{1,2}	231^{2}	248^{1,2}	10
	Other organic	118	252^{1}	240^{1,2}	228^{2}	224^{3}	242^{1,2}	6
	Conventional	115	238^{1}	236^{1}	225^{1,2}	218^{2}	234^{1}	6
New acute SCC score % of cows at risk at each test day	Project	21	5^{c}	6^{b}	7^{b}	7	7	0.8
	Other same dairy	35	7^{a,b,c}	7^{b}	8^{a,b}	8	8	0.6
	Other organic	118	7^{b}	8^{b}	7^{b}	7	8	0.3
	Conventional	115	8^{a}	9^{a}	9^{a}	8	8	0.4
High chronic SCC score % of cows at each test day	Project	21	10^{b}	12^{b,c}	13^{a,c}	15^{a,b}	15^{a,b}	1.9
	Other same dairy	35	16^{a}	16^{a}	17^{a,b}	18^{a}	19^{a}	1.6
	Other organic	118	14^{a}	14^{b}	13^{c}	13^{b}	14^{b}	0.5
	Conventional	115	15^{a}	15^{a,b,c}	15^{a,b}	15^{b}	15^{b}	0.8

^{a,b,c} Different letters indicate significant differences ($P<0.05$) between groups.
^{1,2,3} Different numbers indicate significant differences ($P<0.05$) between years.

In 2002 (1 year before the start of the project), the project herds had a significantly lower prevalence of cows with new acute SCC scores and high chronic scores on test days compared with the group of other organic herds. These differences were neither significant in 2003, nor in the years after the project start. Both the percentage of cows with new acute chronic scores and chronic scores showed an increasing tendency in the project group during the study period, but was still at a level lower or equal to the groups used for comparison in 2006.

The incidence rate of mastitis treatments was significantly lower in the 2 groups of herds from the dairy of the project herds than in the other groups in 2002 (Table 3). From 2003 the incidence rate in the project herds was significantly lower than in all other herd groups. From 2003 to 2005 the incidence rate of treatments was reduced to 50% of the level before the project initiation and was about 5 times lower than the incidence rate in the conventional herds. The other herds from the same dairy had a similarly low mastitis treatment incidence rate, being significantly lower than the group of other organic herds in 2002, 2005 and 2006. The decrease in the incidence rate of mastitis treatments was also seen in the group of other organic herds with a significant decrease from 2003 to 2005. The incidence rate was highest in the conventional herds with a minor non-significant decrease from 2004 onwards. In both groups of herds from the dairy of the project herds the incidence rate of dry cow treatments was reduced to about 50% after the project start. In the project herds the full reduction could be observed between 2003 and 2004, but in the other herds from the same dairy it took place from 2004 onwards. In the other organic herds a minor decrease was also seen from 2004 onwards.

Except in 2003 the incidence rate of treatment of locomotive disorders was lower in the organic herd groups compared with the conventional herds (3). The incidence rate in the project herds was lower than in the group of other organic herds except in 2004. The incidence rate in the project group was significantly lower in 2005 compared with 2004. In 2005 and 2006 the incidence rate was lower in the project herds compared with all other herd groups.

Veterinary treatments of reproductive disorders treated with antimicrobials were mainly retained placenta and metritis and decreased from 2003 to 2006 in the project herds (Table 3). The incidence rate was lower than in the group of other organic herds and conventional herds in all years, and in 2006 it was also lower than in the other herds from the same dairy. The conventional herds had the highest incidence rate in all years. The incidence rate of other antimicrobial treatments did not change during the study period. The incidence rate was lower in the organic herds compared with the conventional herds

Table 3
Incidence rate of veterinary treatments with antimicrobials of mastitis treatment, mastitis treatment of dry cows, locomotive disorders, reproductive disorders and other disorders and veterinary treatment of metabolic disorders and milk fever in the 4 herd groups from 2002 to 2006.

Variable	Group	No. herds	2002	2003	2004	2005	2006
Mastitis treatment	Project	21	$22\pm6^{b,1}$	$20\pm5^{c,1}$	$13\pm3^{c,1,2}$	$10\pm3^{d,2}$	$10\pm3^{d,2}$
	Other same dairy	35	$34\pm5^{b,1}$	$35\pm6^{b,1}$	$34\pm6^{b,1}$	$26\pm4^{c,1,2}$	$21\pm3^{c,2}$
Treatments/100 cow years[1]	Other organic	118	$47\pm3^{a,1}$	$46\pm3^{b,1}$	$43\pm3^{b,1,2}$	$36\pm3^{b,2,3}$	$35\pm2^{b,3}$
	Conventional	115	56 ± 4^{a}	59 ± 4^{a}	59 ± 4^{a}	53 ± 3^{a}	52 ± 3^{a}
Mastitis treatment of dry cows	Project	21	$9\pm2^{b,1}$	$6\pm2^{c,1,2}$	$3\pm1^{c,2}$	$3\pm1^{c,2}$	$3\pm1^{c,2}$
	Other same dairy	35	$12\pm2^{a,b,1}$	$12\pm2^{b,1}$	$12\pm3^{b,1}$	$8\pm2^{b,1,2}$	$5\pm1^{c,2}$
Treatments/100 cow years[2]	Other organic	118	$14\pm1^{a,1}$	$13\pm1^{b,1}$	$13\pm1^{b,1}$	$9\pm1^{b,2}$	$8\pm1^{b,2}$
	Conventional	115	17 ± 2^{a}	20 ± 2^{a}	22 ± 2^{a}	20 ± 2^{a}	18 ± 2^{a}
Locomotive disorders	Project	21	$4.3\pm1.2^{b,1,2}$	$4.0\pm1.1^{b,1,2}$	$5.0\pm1.4^{b,1}$	$2.0\pm0.6^{c,2}$	$3.5\pm1.0^{c,1,2}$
Treatments/100 cow years	Other same dairy	35	4.3 ± 0.9^{b}	$6.4\pm1.3^{a,b}$	5.3 ± 1.1^{b}	5.7 ± 1.2^{b}	6.7 ± 1.3^{b}
	Other organic	118	6.0 ± 0.5^{b}	6.4 ± 0.5^{a}	7.1 ± 0.6^{b}	6.6 ± 0.6^{b}	6.8 ± 0.6^{b}
	Conventional	115	$8.0\pm0.7^{a,1,2}$	$7.5\pm0.7^{a,2}$	$9.9\pm0.8^{a,1}$	$8.9\pm0.8^{a,1,2}$	$9.5\pm0.8^{a,1,2}$
Reproductive disorders treated with AB	Project	21	$4.7\pm1.0^{c,1,2}$	$5.9\pm1.2^{c,1}$	$4.6\pm1.0^{c,1,2}$	$4.1\pm0.9^{c,1,2}$	$3.0\pm0.7^{d,2}$
	Other same dairy	35	$6.0\pm0.9^{c,1,2}$	$5.8\pm0.9^{c,1,2}$	$5.9\pm1.0^{c,1,2}$	$4.1\pm0.7^{c,2}$	$6.3\pm1.0^{c,1}$
Treatments/100 cow years	Other organic	118	9.6 ± 0.7^{b}	9.6 ± 0.7^{b}	10.5 ± 0.7^{b}	10.1 ± 0.7^{b}	9.7 ± 0.7^{b}
	Conventional	115	16.6 ± 1.1^{a}	16.8 ± 1.1^{a}	19.4 ± 1.2^{a}	19.1 ± 1.2^{a}	18.7 ± 1.2^{a}
Other antimicrobial treatments	Project	21	0.5 ± 0.2^{b}	0.7 ± 0.3	1.0 ± 0.3^{b}	0.5 ± 0.2^{c}	0.9 ± 0.3^{b}
	Other same dairy	35	0.9 ± 0.2^{b}	1.2 ± 0.3	1.0 ± 0.2^{b}	0.7 ± 0.2^{c}	0.8 ± 0.2^{b}
Treatments/100 cow years	Other organic	118	1.2 ± 0.2^{b}	1.6 ± 0.2	1.2 ± 0.2^{b}	1.4 ± 0.2^{b}	1.2 ± 0.1^{b}
	Conventional	115	2.1 ± 0.2^{a}	1.6 ± 0.2	2.0 ± 0.2^{a}	2.0 ± 0.2^{a}	2.3 ± 0.3^{a}
Ketosis and other metabolic diseases	Project	21	4.0 ± 1.0^{b}	3.5 ± 0.7^{b}	3.7 ± 0.3^{b}	2.6 ± 1.1^{b}	2.6 ± 1^{b}
	Other same dairy	35	2.3 ± 0.5^{b}	2.8 ± 0.4^{b}	3.1 ± 1.0^{b}	2.9 ± 0.8^{b}	2.6 ± 0.8^{b}
Treatments/100 cow years	Other organic	118	3.3 ± 0.3^{b}	3.4 ± 0.5^{b}	3.7 ± 0.6^{b}	3.3 ± 0.5^{b}	3.0 ± 0.4^{b}
	Conventional	115	7.8 ± 0.7^{a}	7.1 ± 0.5^{a}	8.0 ± 0.6^{a}	7.8 ± 0.5^{a}	6.8 ± 0.4^{a}
Milk fever	Project	21	$10.3\pm1.7^{a,b}$	11.6 ± 1.9^{a}	13.1 ± 2.0^{a}	$10.9\pm1.7^{a,b}$	10.3 ± 1.7^{a}
	Other same dairy	35	$9.3\pm1.4^{a,b}$	10.6 ± 1.6^{a}	11.7 ± 1.7^{a}	$10.9\pm1.5^{a,b}$	10.8 ± 1.6^{a}
Treated cows/100 calvings[3]	Other organic	118	$8.5\pm0.8^{a,2}$	$10.1\pm1.0^{a,1}$	$9.8\pm0.9^{a,1,2}$	$8.9\pm0.8^{a,1,2}$	$8.6\pm0.8^{a,2}$
	Conventional	115	6.3 ± 0.8^{b}	6.2 ± 0.8^{b}	6.6 ± 0.8^{b}	6.3 ± 0.8^{b}	5.8 ± 0.7^{b}

[1] All udder treatments of lactating and dry cows.
[2] All treatments of udder infections after day 270 DIM and treatments registered as dry cow treatments.
[3] Only calvings in second lactation or older included in analysis.
± Indicates standard error for analysis of differences between years within group.
[a,b,c] Different letters indicate significant differences ($P<0.05$) between groups,
[1,2,3] Different numbers indicate significant differences ($P<0.05$) between years.

except in 2003. In all years the herds from the dairy of the project herds tended to have fewer treatments than the other organic herds, but the difference was only significant in 2005.

The incidences of metabolic diseases and milk fever these herds did not change significantly during the study period in any herd group (Table 3). In all years the incidence rate of metabolic diseases was highest in the conventional herds. The incidence risk of milk fever treatments was lower in the conventional herds, and the difference was significant in most years despite correction for the high number of Jersey cows in the herds from the dairy of the project herds.

3.2. Changes in the project herds

Changes in the incidence rate of mastitis treatment in the 21 project herds from 2003 to 2006 are illustrated in Fig. 1.

The herds are numbered according to the mastitis treatment incidence rate in 2003 before the start of the project. As can be seen from Fig. 1, the changes over the 4-year period varied widely between herds. In a few herds (4, 6, 9, 10) the incidence rate was higher in 2005 and 2006 than in 2003, but still at a level below 20 treatments/100 cow years. Only 1 herd (no. 21) was above the average level of the other organic herds in 2006.

In Fig. 2 the calculated SCC for all herds in 2003 and 2006 is shown together with the change in the incidence rate of veterinary mastitis treatment with antimicrobials. The herds are numbered as in Fig. 1. No association could be found between the level of veterinary mastitis treatments or reduction in treatment with the herd SCC.

The number of cows in the project herds with at least 1 blind quarter is illustrated in Fig. 3; the prevalence of cows with at least 1 blind quarter increased from 8.4% in March 2004 to 10.1% in March 2005 (not statistically significant). The prevalence increased in 14 herds and decreased in 5 herds. By way of comparison it may be mentioned that in February 2007 the prevalence of cows with blind quarters was 8.4% in 52 herds in the group of other organic herds and 9.0% in 48 herds in the group of conventional herds.

4. Discussion

4.1. Differences in herd characteristics and disease treatment

The herd sizes of the 2 large groups of organic and conventional herds were comparable with the national average at 120 and 106 in 2006 (Danish Cattle Federation, 2007), indicating that these herds were representative of Danish dairy herds. The herds from the project dairy had more jersey cows than the herds in the two comparison groups. This difference was expected as the dairy involved was the only Danish dairy marketing specific products based on Jersey milk. The jersey breed was included in the statistical analysis but only showed significant differences for average calving numbers, milk fever treatments and milk production. No significant difference in antibiotic treatments was found between herds of different breeds within the herd groups. This indicates that the differences in disease treatments between the herds from the project dairy and the other herd groups were not primarily a result of the larger proportion of dairy herds.

The difference in average calving numbers between organic and conventional herds is in accordance with earlier findings of Bennedsgaard (2003).

The decreasing trend in SCC in the two large herd groups may be related to a new lower penalty limit at 200,000 cells/ml in the bulk tank milk and higher penalties for SCC above 400,000 cells/ml. This trend was broken in 2006, probably due to a remarkably hot summer.

An important difference in incidence rate of mastitis treatments between the conventional and organic herds can be found in the incidence rate of treatments at the time of drying off and in the dry period. In 2006 the incidence rate of dry cow treatments in all organic herd groups was less than half the level in the conventional herds. This may indicate that treatment at drying off in the conventional herds is more related to treatment of non-clinical infections or even preventive treatment despite the requirement of a bacteriological or clinical diagnosis in the Danish regulations.

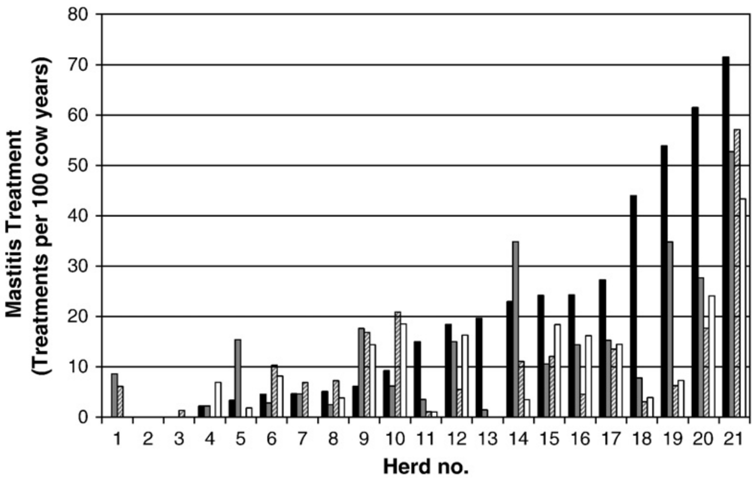

Fig. 1. Incidence rate of veterinary mastitis treatments in 21 organic dairy herds before and after the project initiation in March 2004. Herd number is based on the ranking in incidence rate in 2003. (2003 (black), 2004 (grey), 2005 (crossed) and 2006 (white)).

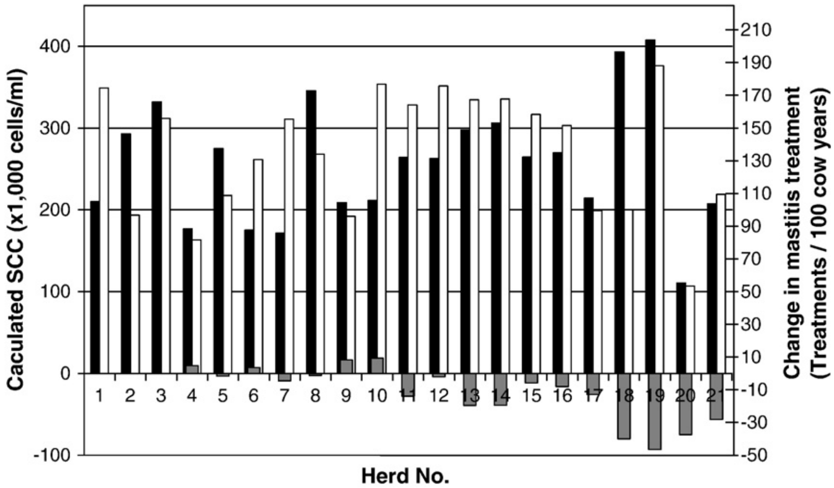

Fig. 2. Calculated bulk tank somatic cell count from 2003 (black bars) and 2006 (white bars). Calculated from monthly or bimonthly test day results. Grey bars indicate changes in incidence rate of mastitis treatment from 2003 to 2006 (see Fig. 1).

4.2. Strategies practiced in the herds in order to reduce antibiotic use

The concept of the project was to reduce or phase out the need for antimicrobial treatments through herd health and welfare promotion and avoid unnecessary use of antimicrobials. This is reflected in the results since the common goal for all participating herds seems to have been fulfilled in as many individual ways as there were participating farms. Many of the improvements focused on enhanced access to fresh air, ventilation and hygiene and quality of the floors in the housing system. As mastitis was the most common disease problem in most herds, milking and improved hygiene were also much in focus in many herds. The strategies were generally characterized by the fact that they were basic management routines being implemented in ways that fit with the priorities of the farmers on each specific farm, and they committed themselves to and articulated the need for a method of implementing the improvements themselves in the Stable Schools. The changes in the herds and the farmers' reflections are discussed in Vaarst et al. (2007).

4.3. Patterns of reducing antibiotic use

Even before the project period the use of veterinary treatments in the project herds was significantly lower than in the organic and conventional herds which are included for comparison. However, it is remarkable that the other herds within the same dairy company also had a significantly lower use of veterinary antimicrobial treatments related both to mastitis and other diseases, although only the project herds were characterized by a decrease in antimicrobial usage during the project period (2004). Despite the differences in mastitis treatment only minor differences were seen in the indicators of udder health based on individual cow SCC. The study indicates that the use of antimicrobials for mastitis treatments reflects the priorities and choices of the farmer rather than the actual udder health status of the herd. This

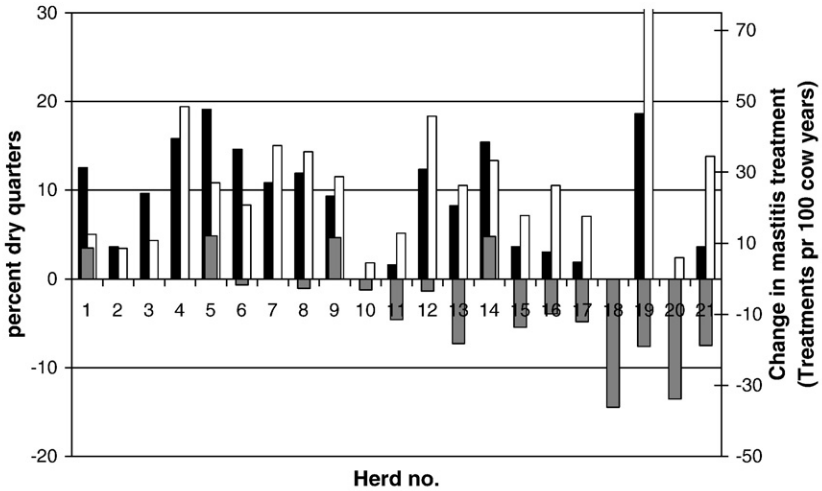

Fig. 3. Blind quarters recorded in the project herds at the start of the project in March 2004 (black bars) and 1 year later (white bars). Grey bars indicate changes in incidence rate of mastitis treatment from 2003 to 2004 (see Fig. 1).

was revealed through an in-depth-interview study with the farmers who perceived that they went through a development process in the Stable Schools that stimulated them to herd and farm-specific improvements (Vaarst et al., 2007). The strategies chosen by each farmer were based on farmer commitment and identified farm-specific methods of improvements, which were commonly developed among the farmers in the Stable Schools. The farmers were going through an empowering development process, enabling and stimulating them to take decisions and improve their own life situations based on an analysis of the herd and farm situation (Vaarst, 2007). In a recent Norwegian study it was concluded that the difference in incidence rate of veterinary treatment between organic and conventional herds was related to differences in attitudes towards treatment (Valle et al., 2007). Based on the results of this study, the authors suggest a similar conclusion and that profound change can be introduced over a short period of time when the farmers are motivated. The 2 groups of herds from the dairy of the project herds have a lower milk production compared with the other organic herds. Bennedsgaard et al. (2003) also found a lower milk production in the old organic herds which also had a lower incidence rate of mastitis treatments. Based on these studies, any direct impact of the lower milk production on mastitis cannot be assessed, nor can it be assessed whether the milk production level is related to the farmers' choice of a particular treatment strategy. However, in the project herds the farmers were able to reduce the incidence rate of mastitis treatments to about half the level before the project started despite an increase in production that was comparable to the other herd groups. This was in accordance with an earlier study of farmers trying to reduce the use of antimicrobials on their own (Vaarst et al., 2006). In that study the farmers indicated that they changed their opinion on which cases of udder infection would benefit from antimicrobial treatment. All the organic herds in the study converted to organic farming before 2001. The project herds had been managed organically for a longer period than the other organic herd groups, with 71% of the herds having converted before 1996 compared with 45% in the group of other herds from the same dairy and 42% in the group of other organic herds. The decrease in the incidence rate of mastitis treatments in all groups of organic herds in the study may be a result of the herds making a long-term mental conversion to organic farming including a change in the threshold for antimicrobial treatment. The decrease might have been strengthened by the debate of the early results of the Stable School project which received much attention in the agricultural press in early 2005 and 2006. The farmers from the dairy of the project herds meet several times a year to discuss different subjects. The results of the first year of the project were also discussed at these meetings and may explain the large reduction in mastitis treatment in the herds not participating in the Stable Schools from 2004 to 2006. Because of this the data from 2005 and 2006 cannot be seen as true controls since we do not know if the incidence rate of mastitis treatment would have changed in the other organic herds without the public discussions of the Stable School project.

In many cases of mastitis, especially mastitis caused by *E. coli* and *Staphylococcus aureus*, the effect of treatment with antibiotics is very limited (Owens et al., 1997; Pyorala and Pyorala, 1998). A group of Danish mastitis experts concluded that the use of antibiotics for mastitis could be reduced by 40% on an average Danish dairy herd by critically evaluating the effect of antibiotic treatment before each treatment (Aarestrup et al, 2004). These studies indicate that a large proportion of the differences between the organic and the conventional herds and the changes in the incidence rate of treatment could be explained by different criteria for treatment. The focused discussions of differences in mastitis treatment and handling of cows with elevated SCC in the individual herds in the Stable Schools may have inspired the farmers to change their treatment criteria resulting in some of the large reduction in mastitis treatment.

4.4. Blinding quarters as a strategy for reducing SCC

The strategy of drying off quarters with high SCC may have helped reducing the SCC measured. Only very few herd managers record blind quarters in the central Danish Cattle Database although the possibility exists. This information has therefore been collected at a later time, which makes a direct association difficult to estimate. However, the prevalence of blind quarters seemed similar both in the conventional herds, the other organic herds, as well as in the project herds before the project started, despite a significantly lower incidence rate of mastitis treatments in the project herds in 2003 and 2004. The attitude to blinding quarters as a strategy for eliminating problems of chronic mastitis has changed over the last decade (Vaarst et al., 2001, 2002, 2006). Previously, farmers related the presence of cows with blind quarters in the herds to ‘poor udder health management’. Now a more pragmatic view on drying off quarters prevails, namely as a relevant way of avoiding the use of antimicrobials, including the increased risk of creating antimicrobial resistance and delivering milk of lower quality maybe even containing antimicrobial residuals. The farmers' attitude has changed, which is also demonstrated in this project. Vaarst et al. (2006) showed a large variation in the farmers' attitude towards blinding of quarters as a treatment strategy, which we can confirm in our study, where the range was between 0 and 30%. Further, the large variation in the prevalence of blind quarters between the project farmers may reflect both different mastitis control strategies and different incidences of clinical and/or chronic mastitis.

4.5. Other diseases

Only minor changes in the use of antimicrobials for treatment of diseases other than mastitis were seen. The incidence rate of treatments of reproductive disorders was already low compared with the conventional herds. Bennedsgaard et al. (2003) showed a decrease in both the treatment of retained placenta and ketosis over 1 to 2 years after conversion to organic production. The difference between organic and conventional herds may be a combination of differences in feeding and production level and differences in treatment threshold. Only when comparing 2003 with 2005 the reduction in the incidence rate of treatments of reproductive disorders in the project herds was significant. Compared with the development in the other herd groups the reduction was large enough to make the incidence rate significantly lower than all other herd groups in 2006. In contrast to the incidence rate of mastitis treatments no indication at all of reduction was seen in the other herd groups for reproductive disorders. The same development was seen for the locomotive disorders. The increase in treatment of locomotive disorders in 2004 was caused by a high incidence rate of foul-in-the-foot in a small number of herds often caused by problems with the quality of the paths from the stable to the pasture, which was a much discussed topic among the farmers in the Stable Schools.

The incidence risk of milk fever requiring veterinary treatment seems to be higher in the organic herds in general, despite the same access to products for preventive treatment of milk fever. Only veterinarians are allowed to perform intravenous calcium treatment in Danish herds, so the number may reflect that oral treatments with calcium products were not sufficient or not used. The Stable Schools did not seem to have any effect on the incidence risk. Though the high proportion of Jersey cows in the herds from the project dairy explains the difference between these herds and other organic herds, it would be expected that the special focus on herd health and prevention of disease could have improved the prevention strategies for milk fever in the project herds.

4.6. Differences between diseases

The large reduction in the incidence rate of mastitis treatments and smaller reductions for other disease groups may indicate that the use of antimicrobials for mastitis treatment was easier to reduce than the use of antimicrobials for other diseases. In the study by Vaarst et al. (2006) several farmers indicated that they changed their perception of the individual sick animal from being an accident to being a result of bad management or wrong decisions. Compared with most other diseases, udder infections are often diagnosed as subclinical or mild clinical cases, which may even vary in severity from day to day. The mild character of many udder infections places the farmers in a situation where the decision to use antimicrobials is more a decision of choosing to improve milk production and decrease the bulk tank SCC than to treat a sick and suffering animal (Vaarst et al., 2002). Furthermore, most farmers have much knowledge about different strategies to control udder infections besides treating individual animals. For diseases like retained placenta, metritis or foul-in-the-foot the decision to treat is more often a decision to stop the suffering of a cow, and the strategies for prevention may include basic changes in feeding or the housing system that are not always possible. The very low and decreasing cow mortality in the project herds indicates that the farmers did not withhold treatment for life threatening diseases as part of their effort to reduce the use of antimicrobials, and the unchanged culling rate and average calving number indicate that the reduction was achieved without compromising the longevity of the dairy cows.

5. Conclusion

The development in the project herds with an explicit shared goal of phasing out antimicrobials was characterized by a drop in antimicrobial use by approximately 50% over a 1-year period and by maintaining of the low incidence rate to the end of the study period. The non-significant increase in the frequency of cows with blind quarters in the project herds during the first project year indicates that some farmers introduced or more intensely used a strategy where chronically infected quarters were blinded. But this change was too small to explain the large reduction in mastitis treatments. We could not detect an association between the use of antimicrobials and the development in SCC at herd level at all.

After the initiation of the project a decrease in the incidence rate of mastitis treatments was seen in both the other herds from the same dairy and the other organic herds. The potential influence from the public attention to the project has not been further investigated.

The Stable Schools in the project herds seem to have caused long-term changes in the use of antimicrobials in the herds in accordance with the primary goal of the project. The Stable School concept has been implemented in other dairy herds in Denmark since the project ended. The results of these initiatives are still not analyzed.

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