Antibiotic Residue Prevention Methods, Farm Management, and Occurrence of Antibiotic Residues in Milk

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ABSTRACT
The objective of this study was to determine associations among the occurrence of antibiotic residues in bulk milk and various farm management practices. Ninety-four dairy farms were visited after antibiotic residues were detected in samples of their bulk milk (case farms) along with an equal number of residue-free farms (controls). Farmers completed questionnaires designed to elicit details of management practices used on farms and methods employed for prevention of antibiotic residues. Factors were initially examined unconditionally for statistical association with occurrence of residues; then multivariate associations were determined using multiple logistic regression. After adjusting for herd size in a logistic model, the risk of residues in milk was observed to increase in association with the frequent use of part-time labor in the milking of cows. The risk of residue occurrence was decreased in association with the use of milk residue test kits, when the farmer believed that increasing the dose of antibiotic required an increase in the withholding time of milk, and when tie stall and pipeline milking systems were used rather than milking parlors or tie stall and dumping station systems.

(Key words: antibiotic residues, prevention)

INTRODUCTION
Antibiotic residues are undesirable in milk products for a number of reasons. They can create a negative image of dairy products in the eyes of the public, there is some concern over possible deleterious effects of antibiotic residues on public health, and residues may be harmful to the manufacture of certain cultured milk products (1, 13, 19).

The dairy industry, along with government regulatory agencies, has been successful in reducing the prevalence of violative levels of antibiotic (including sulfonamide) residues (7). Nevertheless, violations still occur and some surveys report that trace levels are common (4, 6). Because antibiotic residues enter the milk supply at the farm level and milk producers themselves bear the final responsibility for selling residue-free milk, it is important that producers understand the factors that lead to antibiotic residues in milk and how these residues can be prevented.

Booth and Harding (3) conducted a survey of farms in the United Kingdom that had bulk milk antibiotic residue violations identified during government monitoring. Lactating cow intramammary antibiotic preparations were thought by inspectors to be responsible for the majority of residue occurrences, followed by dry cow intramammary, injectable, and intrauterine preparations. In that study, the three most common reasons for residue occurrences suggested by farmers were failure to withhold milk for the proper length of time, accidental transfer of milk from treated cows to bulk tanks, and prolonged excretion of drug from treated cows (3). Kaneene and Ahl (14) conducted a mail survey of Michigan farmers with positive and negative bulk milk antibiotic residue tests. Milk residues were associated with each of the following: increasing frequency of use of medicated feed, herd size, and numbers of hired persons. Farmers in the Michigan study thought that the most important management factors leading to drug residues were insufficient knowledge about drug withdrawal periods, errors due to hired help, insufficient records of treatment, and
identification of animals. McEwen et al. (22) conducted a mail survey of dairy farms in Ontario that were positive or negative for antibiotic residues. The use of part-time help for milking of cows, milking in a parlor system, and increased estimated frequency of intramammary antibiotic treatment on farms were among factors associated with residue occurrence. The design of these mail surveys, however, required that, in most cases, questionnaires were administered to study farmers weeks or months after residue violations had occurred. During this period, farmers may have changed drug handling practices and residue prevention methods or may not have recalled what practices they used up to the time of antibiotic residue violation. In this study, we had the opportunity to administer questionnaires to farmers as soon as they were notified of residue violation and before any management or residue prevention methods could be changed.

In this paper, we describe associations among the occurrence of antibiotic residues in the bulk milk of dairy farms, the use of residue prevention methods, and various farm management practices.

**MATERIALS AND METHODS**

**Milk Antibiotic Residue Detection**

Bulk milk samples from all dairy farms in the province of Ontario were tested twice monthly during the study period (December 1988 to October 1989) for the presence of antibiotic residues in milk as part of a government program of monitoring milk for safety and quality. Milk samples of approximately 35 ml were obtained aseptically from study farm bulk tanks at the time of milk pick-up by truckers, held at 4°C, and delivered to a central laboratory for testing within 48 h. Milk samples were initially screened for microbial inhibitory substances with the Brilliant Black Reductase Test (BR test, Laboratorium Enterotox, Krefeld, Germany) (10). Positive samples on screening were retested with a *Bacillus stearothermophilus* var. *calidolactis* disc assay (26) and were considered inhibitor-positive if a zone of inhibition at least as wide as that of a positive control disc containing .01 IU of penicillin was produced. For the purposes of this study, a farm was considered milk antibiotic residue-positive if milk was test-positive using the methods described.

**Study Farm Selection**

Field staff with the Dairy Inspection Branch of the Ontario Ministry of Agriculture and Food, who were located throughout the province, were notified the same day that a bulk milk sample from a farm in their area was antibiotic residue test-positive. Visits to these antibiotic residue-positive farms (case farms) were made by the field persons as soon after notification by the laboratory as possible, usu-
TABLE 2. Farmer-estimated frequency of antibiotic treatment of cows, by route of administration, on case and control farms.

<table>
<thead>
<tr>
<th>Route of antibiotic administration</th>
<th>Case farms (n = 94)</th>
<th>Control farms (n = 94)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intramammary</td>
<td>2.01</td>
<td>1.28</td>
<td>*</td>
</tr>
<tr>
<td>Intramuscular or intravenous Oral</td>
<td>1.09</td>
<td>.84</td>
<td></td>
</tr>
<tr>
<td>Oral</td>
<td>.14</td>
<td>.11</td>
<td></td>
</tr>
<tr>
<td>Intraterine</td>
<td>.58</td>
<td>.70</td>
<td></td>
</tr>
</tbody>
</table>

*P ≤ .05.

ally the same day. Thus, case farms were visited 2 to 3 d after the test-positive milk sample was obtained. During the visits, field persons administered questionnaires to farmers (copy available on request). The questionnaires were designed to obtain information about selected farm management factors (Table 1), antibiotic treatment practices (Table 2), and residue prevention methods (Table 3). These were selected because the authors thought they might explain why some farms are at greater risk than others of antibiotic residues in bulk milk, based on reports in the literature and knowledge of antimicrobial use on farms. In addition, there were questions on the source of feed (farm grown, purchase, or combination) for lactating cows and on the source of antibiotics used (veterinary or nonveterinary source). Farmers were also asked if they treated cows only under the advice of a veterinarian, or as they themselves thought necessary, or not at all. They were also asked to describe details of antibiotic treatment administered to lactating cows in the 5 d before the test-positive milk sample was obtained, including the antibiotic used, route of administration, dose, number of treatments, and person administering treatments.

It was not possible to administer the questionnaires in "blind" fashion; farmers were advised of the antibiotic residue violation just before being asked to complete the questionnaires. Shortly after visiting a case farm, the same field person administered the questionnaire to another dairy farmer living in the same geographical area whose farm had consistently tested negative for antibiotic residues in milk (control farm). It was not possible to match

TABLE 3. Milk antibiotic residue prevention methods employed on case and control dairy farms.

<table>
<thead>
<tr>
<th>Residue prevention method</th>
<th>Percentage of farms using method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case farms (n = 94)</td>
</tr>
<tr>
<td>Mark treated cows</td>
<td>71.28</td>
</tr>
<tr>
<td>Use separate equipment to milk treated cows</td>
<td>41.43</td>
</tr>
<tr>
<td>Withhold milk from all quarters of treated cows</td>
<td>99.85</td>
</tr>
<tr>
<td>Have used antibiotic test kit</td>
<td>8.60</td>
</tr>
<tr>
<td>Keep record of antibiotic treatments</td>
<td>47.87</td>
</tr>
<tr>
<td>Thought doubling of dose requires increased milk withholding time</td>
<td>37.23</td>
</tr>
</tbody>
</table>

*P ≤ .05.

case and control farms on the day of bulk milk testing for antibiotic residues. Milk samples from control farmers were tested for antibiotic residues less than 2 wk before questionnaire administration. Control farmers were asked to provide details of antibiotic treatments administered to lactating cows in the 5 d preceding questionnaire administration. Because pairs of case and control farms were not matched on day of antibiotic residue testing, these groups were not compared with respect to factors pertaining to treatment of individual cows with antibiotics. The questionnaire data were used, however, to describe numbers of cows treated, routes of administration used, frequency of "extra-label" antibiotic use, and use of combinations of antibiotic products on farms. Extra-label drug use has been defined as the use of antibiotics in a fashion that is different than that recommended on the drug product label (24). The drug label recommendations typically include information on the appropriate dose, frequency of antibiotic administration, and indication of approval for use in lactating cows. Questionnaires were also used to determine if the same person who treated cows with antibiotics also milked treated cows.

Data Analysis

Data were entered into microcomputer files (dBASE III Plus, Ashton-Tate, Torrance, CA) and checked for validity of entry. Initially, unconditional associations ($P < .05$) between the occurrence of residues in milk (dependent variable: case-control status) and farm-level factors of interest were determined. For binary variables, comparisons between case and control farms were made with the chi-square or Fisher’s exact test (28). Significant differences ($P < .05$) between cases and controls for multiple level categorical variables were determined with the Duncan’s multiple range test, and, in the case of continuous variables, comparisons between groups were made with Student’s $t$ tests (28).

Variables unconditionally associated with antibiotic residue occurrence ($P < .05$) were offered for entry into a multiple logistic regression model, using stepwise selection, with bulk milk antibiotic residue occurrence (i.e., case or control) as the dependent variable (16). The number of milking cows for each herd was forced into the model to control for the possible confounding effect of herd size. Interaction terms were constructed from main effect variables and tested for significance. Otherwise, variables were allowed to remain in the model if statistically significant ($P < .05$). The fit of the model was determined by an analysis of deviance (21). The final logistic regression model was the following:

$$\text{Logit } Pr(AR = 1 | X) = \alpha_m + \sum_{i=1}^{5} \beta_i X_i$$

where $Pr(AR = 1 | X)$, the dependent variable, is the probability of antibiotic residues in bulk milk ($AR = 1$), given independent variables $X_i$; $\alpha_m$, the log odds for antibiotic residues in bulk milk, all $X_i = 0$; $\beta_i = \text{change in the log odds for a unit increase in } X_i$; $X_1$, the binary effect of tie stall with pipeline milking system on dairy farm, coded as 0 for yes and 1 for no responses; $X_2$, the binary effect of farmer belief that doubling of drug dose required increase in milk withholding time, coded as 0 for no and 1 for yes; $X_3$, the binary effect of frequent use of part-time labor on farms for milking, coded as 0 for yes and 1 for no; $X_4$, the binary effect of having used on-farm test kit for antibiotic residues at some time, coded as 0 for no and 1 for yes, respectively; $X_5$, the continuous effect of number of milking cows in the herd. Statistical analyses were conducted on a microcomputer with SAS (SAS Institute Inc., Box 8000, Cary, NC) and Statistix 3.1 (Statistix, PO Box 130204, St. Paul, MN) software.

RESULTS

Questionnaires were administered to 94 case and an equal number of control farms. Farm management practices compared on case and control farms are shown in Table 1. Case farmers were significantly ($P < .05$) more likely to make frequent use of part-time employees for the milking of cows, but control farmers used part-time help less frequently or not at all. Postmilking teat dips were used on significantly more control than case farms. Questionnaires were more fre-
Quently milking parlor or tie stall and dumping station. Significant differences were not observed between the proportions of case and control farms that used medicated feed for any species of farm animal, that purchased milk cows in the preceding month, or that differed in the mean number of milking cows per herd. No significant differences between cases and controls were observed with respect to the brand of milking equipment, the type of teat dip, or in the proportion of farms where more than one person participated in milking. No differences were noted in the proportions of case and control farms that fell into three categories of feed preparation: those that grew all of their own feed, those that grew most feed but purchased some supplements, and those that purchased most of their feed supplies.

Table 2 presents farmer-estimated numbers of cows treated with antibiotics per month by various routes of administration for each of case and control farms. Significant differences between groups of farms were observed only in the case of intramammary antibiotics; case and control farmers estimated that, on average, 2.01 and 1.28 cows, respectively, were treated per month. Although not significant \( P < .05 \), the estimated frequencies of administration of injectable (intramuscular or intravenous) and oral antibiotics were also higher on case farms. The estimated frequency of intrauterine antibiotics was higher, but not significantly, on control farms. Farmers were asked if they treated cows with antibiotics as they thought necessary, only under the advice of a veterinarian, or not at all. All farmers reported using antibiotics, although some said they did not use antibiotics by certain routes of administration. No significant differences between groups were observed in the proportions of farmers that treated cows only under the advice of a veterinarian and those that treated as they felt necessary. Significantly more case than control farmers denied using injectable (intramuscular or intravenous) and dry cow intramammary antibiotics. Nearly all farmers in both groups used intramammary antibiotics in lactating cows, as they felt necessary, without the advice of a veterinarian.

Fifty-one percent of farmers indicated that they purchased all antibiotics from their veterinarian, 4% purchased all from a cooperative or feed store, and 45% preferred to purchase from a combination of these sources. No significant differences between cases and controls with respect to these sources of antibiotics were detected.

Farmers reported treatment of lactating cows with antibiotics on 73 out of 94 case farms in the 5 d before the antibiotic residue-positive milk sample was collected and from 29 out of 94 control farms in the 5 d before questionnaire administration. An average of \( 0.78 \pm 1.03 \) cows were treated on the 102 farms (73 case and 29 control) during this period. Of the farms reporting antibiotic treatments and sufficient treatment information, intramammary antibiotics were administered on 77.2%, combinations of drug products were used on 14.7%, antibiotics were administered in extra-label fashion on 48.1%, and the person who administered the antibiotic treatments was always the person who milked treated cows on 77.9% of farms.

Proportions of case and control farms using various routes of antibiotic residue prevention methods at the time of questionnaire administration are shown in Table 3. Significantly more control farms used separate equipment for milking treated cows (59.57%) than case farms (41.43%), and the latter tended to use the same equipment for all cows and attempted to divert the milk from treated cows from the tank. Significantly more control than case farmers had used an antibiotic residue test kit on their farm. Some of the farmers had their own kit, and others used kits owned by veterinarians, government offices, dairies, and cooperatives. Although not significant \( P > .05 \), more control farmers reported marking treated cows in some way, and more case farmers reported withholding milk from all quarters of treated cows and reported keeping records of antibiotic treatments. Similarly, there were no differences between groups in the type of records kept: record book, computer, blackboard, calendar, or other. When asked how milk withholding times would be affected by hypothetically doubling the treatment dose, significantly more control than case farmers felt that withholding times would be increased (Table 3).

Farmers were asked their opinion of the importance of antibiotic residues in milk. No significant differences between case and control groups of farms were observed. Approximately 96% of farmers thought that antibiotic residues...
residues were of public health significance, 98% thought that residues could interfere with the manufacture of cultured milk products, and 97% thought that antibiotic residues were significant because of the effect they had on public opinion.

The factors significantly associated \( (P < .05) \) with occurrence of antibiotic residues in milk in the final logistic regression model are presented in Table 4. The risk of antibiotic residue occurrence was increased in association with the frequent use of part-time labor in the milking of cows and was decreased in association with the use of tie stall and pipeline rather than parlor or tie stall and dumping station milking systems. Risk was also reduced with the use of test kits for residues and when farmers thought that hypothetically doubling the dose of antibiotic administered would require an increase in the withholding time of milk. No interaction terms were significant in the model. An assessment of the deviance of the model indicated that a relatively poor fit \( (P = .0504) \) with the data was achieved, indicating that the model should not be used for predictive purposes.

**DISCUSSION**

We used logistic regression analysis in this study to measure covariance among a number of potential risk factors for antibiotic residues in milk. After adjusting for the possible confounding effect of herd size, the frequent use of part-time labor in the milking of cows was associated with increased risk of residue occurrence in the regression model. Similar findings were observed in a mail survey conducted by McEwen et al. (22). Part-time farm workers may be less aware of the necessity of withholding milk from antibiotic-treated cows, or there may be a failure of communication in identifying treated cows when these people are employed. Kaneene and Ahl (14) found that among dairy farmers surveyed by mail in Michigan antibiotic residues in milk were associated with an increase in the numbers of people working on farms; however, we did not find this to be the case in this or in a previous mail survey (22). We asked farmers in this study about recent antibiotic treatments and compared the names of the people who administered the treatments with those who milked treated cows and found that on 77.9% of farms the same person performed these two tasks. When people who administer antibiotics to cows are different from those people who milk cows, there is opportunity for failure of communication with respect to the need to withhold milk.

In the regression model, risk of milk antibiotic residues was reduced with tie stall and pipeline milking systems compared with milking parlors or tie stalls with dumping stations. Milking parlors were also associated with residue occurrence in a mail survey of dairy farms in Ontario (22). Perhaps it is more difficult to identify treated cows in these systems or more difficult to use separate equipment to milk treated cows. It is not clear why tie stall with dumping station systems would also be associated with milk residues.
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Farmers who thought that hypothetically doubling the dose of antibiotics administered necessitates a longer milk withholding time had a reduced risk of milk residues. This supports the view that knowledge of antibiotic residues has some importance to their avoidance in milk. Kaneene and Ahl (14) found that dairy farmers in Michigan thought that more education on residue avoidance was required. In another study of Michigan dairy farmers, Marteniuk et al. (20) reported that among cows treated during a monitoring program, compliance with recommended slaughter withdrawal times for antibiotics was 96%, indicating that some farmers, albeit a small number, may not have been aware of drug withdrawal times. Van Dresser and Wilcke (29) have reported that among farmers investigated because of drug residues in meat animals, over 50% were unaware of the proper withholding time.

Use of antibiotic test kits was also associated with reduced risk of residues in the regression model. These kits can be used to test milk from individual cows or bulk milk samples. We did not ask farmers to name the test kits employed, but a variety of products are available, employing a range of methodologies and spectra of antibiotic sensitivities (27). It has been proposed that the kits can be used in a variety of ways: to test milk from all treated cows at the end of the withholding time, or more selectively, for cows treated with large doses of antibiotic, dry cows calving early after dry cow treatment, or for testing of bulk milk where accidental contamination with milk from a treated cow is suspected (12). Our findings demonstrate that the use of antibiotic test kits is associated with reduced risk of milk residue occurrence under field conditions.

In the multiple logistic regression model, the number of milking cows per herd was included to control for possible confounding effects that this factor may have on the relationships between other factors and residue occurrence. Although the number of cows milked was not significantly different on case and control farms, other epidemiological studies of antibiotic residues in milk have observed this to be the case (14, 22). Although statistically insignificant, case farms had more milking cows on average than control farms in the present study. Kaneene and Ahl (14) and McEwen et al. (22) found significant associations between residue occurrence and herd size; thus, it was thought necessary to adjust for this factor in the regression analysis. Herd size is likely to be related to the frequency of antibiotic administration to cows, although in another survey conducted in Ontario, McEwen et al. (22) observed that adjustment for herd size did not negate the association between residue occurrence and estimated frequency of antibiotic treatment. Kaneene and Ahl (14) concluded that larger herds would have more employees, and, hence, more opportunity for errors in communication and accidental transfer of milk from treated cows. Again, we found no difference in the numbers of people milking cows on case and control farms.

Medicated feed use was not significantly related to milk residue occurrence in this study or in a previous mail survey of a different population of dairy farms in Ontario (22). In Canada, feeds medicated with antibiotics are not licensed for use in lactating cows, although the potential exists for accidental contamination of milk cow feed with medicated feed intended for calves, swine, or some other type of farm animal. Apparently in this study group, the potential for this type of accident did not significantly contribute to the occurrence of residues in milk. This finding is in contrast to that of Kaneene and Ahl (14), who reported that increasing use of medicated feed was associated with residue occurrence. In the latter study, medicated feed use was more common on study farms than we observed. This finding, or perhaps regional differences in medicated feed regulation, could account for the different observations between these studies.

Lactating or dry cows may be purchased without knowledge of antibiotic treatment, and it has been suggested that milk from these cows can be a source of residues (2, 3). In this study, purchase of milk cows into herds in the month preceding questionnaire administration was not associated with residue occurrence. We did not ask farmers, however, if they considered or took special precautions with regard to the possibility of residues in the milk of newly purchased cows.

Estimated frequency of treatment of lactating cows with intramammary antibiotics was significantly higher on case than control farms in simple association, but not when all variables were considered together in the regres-
sion analysis. This type of antibiotic is especially likely to lead to milk residue problems because of the high concentrations of antibiotic injected directly into the mammary gland and because treatment for mastitis is common on dairy farms. Meek et al. (23) found that the rate of clinical mastitis per animal-year was the highest among all diseases of dairy cows recorded on 110 randomly selected dairy farms in Ontario. McEwen et al. (22) also found that residue occurrence in milk was associated with an increase in the estimated frequency of treatment of lactating cows with intramammary antibiotics, indicating that dairy farmers need to take extra care when treating lactating cows in this manner. Most dairy farmers in this study used intramammary antibiotics as they felt necessary, without the direct guidance of a veterinarian.

Use of teat dip was also unconditionally associated with reduced risk of antibiotic residues. This practice reduces mastitis in dairy herds (17), and, perhaps in that way, use of teat dip may reduce the need to treat animals and, therefore, the probability of antibiotic residues occurring in milk.

Only 73 of 94, or 78%, of case farms actually reported treating lactating cows in the 5 d before the antibiotic residue-positive milk sample was collected. This was unexpected because all of these were test-positive for antibiotic residues. Perhaps on some farms, animals treated more than 5 d before the positive milk sample was collected were responsible for the positive test. Alternatively, when a milk residue violation occurred, these farmers were subject to a substantial financial penalty, and perhaps embarrassment, and some may have attempted to deny responsibility by reporting that no animals were treated. This is supported by the observation that significantly more case than control farms reported the policy of never using injectable or dry cow intramammary antibiotics, and, although not significant, more case than control farmers said they never used intramammary antibiotics. Kaneene and Willeberg (15) have examined the problem of recall bias and retrospective studies of residue occurrence, and McEwen et al. (22) reported that when mail questionnaires were administered to farmers some weeks or months after milk residue detection, unexpected results with respect to the use of certain residue control practices were detected. In the present study, farmers were questioned very soon after residues were detected in milk (case farmers). Thus, there would not have been time to alter management practices or residue prevention methods as a direct consequence of the test result itself.

If, however, we are to believe that some case farmers did indeed not treat lactating cows with antibiotics, then either the residues entered the milk by some other route, or the test results were not accurate. Apparently false positive results have been reported for antibiotic residue tests based on microbiological assays (5, 18). Carlsson and Björck (5) have shown experimentally that milk from mastitic cows will produce false positive results on a B. stearothermophilus var. calidolactis tube diffusion assay similar to the test used for screening purposes in this study. Other than through the milk of intentionally treated lactating cows, antibiotic residues could conceivably have entered the milk through dry cows newly entering the milking herd (11), recently purchased milking cows treated before sale, or through the accidental use of medicated feed. An insufficient number of antibiotic-treated dry cows were reported to have begun lactation and entered the study herds in the 5 d before questionnaire administration to allow comparison between case and control herds with respect to this factor. More case than control farms reported purchase of lactating cows in the month preceding the questionnaire, but this was not statistically significant. Similarly, there was no significant difference in the proportions of case and control farms that used medicated feed.

During the 5 d before collection of violative milk samples on case farms and 5 d before questionnaire administration on control farms, lactating cows on 48.1% of study farms were treated with antibiotics in extra-label fashion. During the same period, cows were treated with more than one antibiotic product on 14.7% of farms. We did not compare case and control farms for these factors because these groups of farms were not matched on day of antibiotic residue test; nevertheless, our findings suggest that some farmers could profit from more knowledge of antibiotic use, misuse, and the occurrence of residues. Farmers should be made aware that label withholding
time recommendations do not apply to extra-label treatments and that concurrent use of more than one antibiotic product may also influence milk withholding times, and, thus, farmers should be advised to take precautions. Ideally, these precautions may include stopping the practices of extra-label antibiotic use and administration of more than one antibiotic product at the same time. If this type of treatment is necessary in the best interests of an animal, then the guidance of a veterinarian would be indicated (7, 25). Additional precautions include using a residue test kit sensitive to the appropriate drug or drugs, extending the milk withholding time following treatment, or both.

With respect to residue prevention methods other than the use of antibiotic residue detection kits, the practice of using separate equipment for milking treated cows was unconditionally associated with reduced risk of milk residues. This has been observed previously (22), and as has been suggested by others (9). Using separate equipment is likely to be more reliable than attempting to divert milk from the tank while using the same equipment for untreated and treated cows alike.

As expected, nearly all farmers knew that milk should be withheld from all quarters of treated cows because residues can be found in the untreated quarters (8). Booth (2) reported that in 1981, 8% of antibiotic residue occurrences in milk in the United Kingdom were thought by farmers to be due to failure to withhold milk from all quarters of treated cows. In a later survey (3), this proportion had decreased to 2.5% in 1984 to 1985, presumably as a result of education. Similarly, the practice of marking treated cows was exercised on most farms in this study, and no differences between cases and controls were observed.

Over 95% of all farmers in this study thought that antibiotic residues in milk were important for public health considerations, interference with production of cultured milk products, and public perception of milk products. Although we found no differences in these opinions between case and control farms, Kaneene and Ahl (14) reported that farmers on milk residue-positive farms were less likely than those on negative farms to think residues important to public health.

Antibiotic residues in milk are an undesirable consequence of treating milk cows with these drugs. Certain precautions, such as the use of residue test kits, using separate milking equipment, taking special care when part-time employees must be used, and increasing farmer knowledge of drug residues, can decrease the likelihood of residues occurring.

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MILK ANTIBIOTIC RESIDUES AND PREVENTION


