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Decision tree analysis to evaluate dry cow strategies under UK conditions

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Economic decisions on animal health strategies address the cost-benefit aspect along with animal welfare and public health concerns. Decision tree analysis at an individual cow level highlighted that there is little economic difference between the use of either dry cow antibiotic or an internal teat sealant in preventing a new intramammary infection in a cow free of infection in all quarters of the mammary gland at drying off. However, a potential net loss of over £20 per cow might occur if the uninfected cow was left untreated. The only economically viable option, for a cow with one or more quarters infected at drying off, is antibiotic treatment, although a loss might still be incurred depending on the pathogen concerned and the cure rates achievable. There was a net loss for cows with quarters infected with *Corynebacterium* spp. at drying off, for both the teat sealant and untreated groups (£22 and £48, respectively) with only antibiotic-treated cows showing a gain.

Keywords: Dry cow antibiotic therapy, internal teat seal, economics.

Currently >95% of lactating dairy cows in the UK receive dry cow antibiotic therapy at drying off (Berry & Hillerton, 2002b). However, with the recent introduction of a non-antibiotic intramammary teat sealant for use at the end of lactation, to the European, New Zealand and North American markets, it is timely to review the available options for both prophylactic and therapeutic intramammary treatment of cows at drying off.

A recent study of the use of dry cow antibiotics confirmed that it remains effective in reducing new intramammary infections during the dry period and clinical intramammary infections in the first trimester of lactation (Berry & Hillerton, 2002b). This was true even in a low somatic cell count (SCC) herd and particularly for infections due to *Streptococcus uberis* or *Staphylococcus aureus*. However, dry cow antibiotics may not be the most effective control measure against Enterobacteriacae (Smith & Hogan, 1993; Bradley & Green, 2000). Use of a non-antibiotic intramammary teat sealant was as effective as an antibiotic at drying off in prophylaxis (Woolford et al. 1998; Berry & Hillerton, 2002a; Huxley et al. 2002). A reduction in new intramammary infections at calving due to Enterobacteriacae was found in cows treated with the internal teat sealant compared with those treated with dry cow antibiotic (Huxley et al. 2002). The incidence of clinical mastitis in the first trimester of lactation was comparable to that seen in the positive control (dry cow antibiotic) and reduced compared with the untreated control group. This effect was primarily for *Str. uberis* and *Staph. aureus*, with no significant reduction in clinical cases due to Enterobacteriaceae (Berry & Hillerton, 2002a; Huxley et al. 2002).

When deciding strategies, the loss-expenditure frontier must be considered in finding the economically optimal disease control policy (McInerney et al. 1992). Subjective judgements must be made about the likelihood of particular scenarios and decisions should be based not only on costs and benefits but also on assessments of relative risks. Economic analysis comparing the use of dry cow antibiotic or internal teat sealant is not available. Most economic analyses have concluded that the use of dry cow antibiotic can be financially beneficial either in terms of effect on increased milk yield, lower SCC or reduced clinical mastitis compared with untreated cows (Berry et al. 1997; Allore et al. 1998; Yalcin et al. 1999; Yalcin & Stott, 2000; Oliver et al. 2003). Deciding which strategy to use, at the individual cow level, can be helped by decision tree analysis. Decision tree analysis is a graphical representation of decisions, probabilities and events, displayed in a logical and time-sequenced manner which helps decision making. It has been used in veterinary economics to

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aid in decision making on treatment strategies (Ruegg & Carpenter, 1989; Marsh, 1993).

This paper is not a fundamental one but it addresses the practical need for decision making on different dry cow strategies for veterinary surgeons and farmers. Various methods are available for economic analysis. Generally it is recommended that the simplest appropriate method should be chosen (Mellor, 1999). In this study, decision tree analysis was used, at the individual cow level, to assign probabilities and monetary values to the different strategies available. The strategies considered were either dry cow antibiotic, the intramammary teat sealant or no treatment. This was also evaluated for cows of different intramammary infection states at drying off. The physiological impacts along with the relative cost of these strategies were evaluated. These included any possible changes in the prevalence of intramammary infection, the incidence of clinical mastitis and the culling incidence, along with disposal and replacement cost of animals, and any changes in milk yield or SCC.

Materials and Methods

Decision tree analysis

Decision tree analysis was carried out using Data 3.5 (Treeage software, Williamstown, MA, USA). Decision tree analyses were determined at the cow level in order to evaluate the effect of the different dry cow strategies. Decision tree analysis was assessed on a hypothetical cow in three different states of intramammary infection at drying off: uninfected in all quarters; infected only with a *Corynebacterium* spp. or coagulase-negative staphylococci (CNS) in one or more quarters; infected with other than the above in one or more quarters.

Nodes were used to indicate actions, events or end values, e.g., dry cow treatment, infection status at calving and clinical infection. Actions or events were connected by arcs or lines of a designated probability and generally represented influence or effect but could also have indicated time. Probabilities were shown below the line to the variable or chance outcome node. Decision nodes represented by the rectangular box indicated the possible actions, decisions or courses taken. Three courses of action were possible at drying off: treated with dry cow antibiotic; treated with teat sealant; left untreated. These were connected to the variable or chance nodes, which in turn were either connected to further chance nodes or end nodes. The chance outcomes or events are represented by circles and were either uninfected or infected, or infected with *Corynebacterium* spp. or CNS or clinical mastitis. Infected excluded those infections due to *Corynebacterium* spp. or CNS and still infected meant the quarter was still infected with the original infection. All chance nodes ended in the terminal or end nodes represented by a triangle and monetary values were ascribed to these end nodes.

Probability estimation

The data from two selective dry cow strategies, using either an antibiotic and untreated group or an internal non-antibiotic intramammary teat sealant OrbeSeal (OrbeSeal™ Pfizer Animal Health, Sandwich, UK) and untreated control group were used to provide some of the physiological and economic parameters (Berry & Hillerton, 2002a, b). In the selective dry cow antibiotic trial, all cows were used and they were randomly allocated to treatment group. In the selective teat sealant trial, while cows were grouped according to cell count, all cows were used from four herds contributing the largest proportion of the cows with some selection of low cell count cows from the other three herds. Again, cows were randomly allocated within cell count groups to treatment groups. Data from the literature were used as both a source and to confirm some of the physiological effects and economic values that were derived from the above two studies (Neave et al. 1950; Eberhart & Buckalew, 1972; Houben et al. 1993; Houben et al. 1994; Woolford et al. 1998; Hassan et al. 1999; Yalcin et al. 1999; Yalcin & Stott, 2000; Huxley et al. 2002). Data were adjusted where possible for the UK situation and values are in pounds sterling.

Production data were available from the two herds at the Institute for Animal Health (IAH). They contributed the largest proportion of cows to the two trials and had comparable herd management (Berry & Hillerton, 2002a, b). The quarters of all of the IAH cows in both trials were either uninfected at drying off or infected with CNS or *Corynebacterium* spp. Yield and SCC data were from the monthly recordings carried out by National Milk Records (NMR, Chippenham, UK). The cumulative yield calculation complied with British Standard 4866 (1972) method 3 (averaging) and with the ICAR (1995) Agreement of Recording Practices for Test Interval Method. SCC was measured by the fluorimetric method, using a Fossomatic machine, by NMR according to NMR standard operating procedures.

The production data were 305-d and actual yield for the lactation preceding and the lactation subsequent to the trial dry period. Cows with a lactation <200 d or culled were excluded from the yield calculation to avoid a possible double calculation for yield loss due to clinical mastitis. Yield per cow was calculated using an arithmetic mean for all cows. Individual cow SCC records for the first 5 months of lactation were also available. Those with incomplete data for this period were omitted from the SCC arithmetic mean analysis. SCC data were analysed for differences between the treatment groups in first SCC recording and the maximum of the five monthly SCC records. The arithmetic mean, for all cows, of the geometric mean of the first 5 months SCC for each cow was also calculated for each treatment group.

Definitions of infection status were described in Berry & Hillerton (2002a, b). The data from these trials were

Table 1. Probabilities of chance (outcome) variables due to different dry cow strategies (*C.* spp., *Corynebacterium* spp.)

Cow	Strategy	Outcome	Probability
Cow status at drying off		Infected at calving	
Uninfected (Neave et al. 1950; Eberhart & Buckalew, 1972; Woolford et al. 1998; Berry & Hillerton, 2002a, b; Huxley et al. 2002)			
	Antibiotic		0·07
	OrbeSeal		0·07
	Untreated		0·2
Infected with other pathogens			
	Antibiotic		0·12
	OrbeSeal		1
	Untreated		1
Infected with *C.* spp. and infected with another pathogen at calving (Woolford et al. 2001; Berry et al. 2003)			
	Antibiotic		0·1
	OrbeSeal		0·1
	Untreated		0·3
Infected with *C.* spp. with same infection at calving			
	OrbeSeal		0·6
	Untreated		0·7
		Uninfected at calving	
Infected with *C.* spp.	Antibiotic		0·9
Infected with *C.* spp.	OrbeSeal		0·3
Infected with *C.* spp.	Untreated		0·1
Other probabilities			
Infected at calving (Neave et al. 1950; Woolford et al. 1998; Berry & Hillerton, 2002a, b; Huxley et al. 2002)			
	All strategies	Clinical mastitis	0·5
Infected at calving but not a clinical case of mastitis			
	All strategies	Subclinically infected	0·8
	All strategies	Resolve (self cure)	0·2
Clinical mastitis (Yalcin et al. 1999; Yalcin & Stott, 2000)			
	All strategies	Culling for mastitis	0·1

evaluated for incidence of new intramammary infections, clinical infections and cure rate of existing infections. These data were also compared with data from the literature (Neave et al. 1950; Eberhart & Buckalew, 1972; Woolford et al. 1998; Hassan et al. 1999).

Assumptions

The probabilities of chance outcomes based on trend data and monetary values, current UK 2003 prices, are shown in Tables 1 and 2.

Incidence of intramammary infections. It was assumed, using data from the literature and trial data in Table 1, that 10% of cows treated with dry cow antibiotic or OrbeSeal and 30% of cows left untreated would acquire a new intramammary infection in one or more quarters at calving (Neave et al. 1950; Eberhart & Buckalew, 1972; Woolford et al. 1998; Hassan et al. 1999; Berry & Hillerton, 2002a, b). Cows uninfected at drying off were less likely to acquire a new infection at calving than those infected with *Corynebacterium* spp. or CNS, and probabilities were adjusted accordingly (Table 1) (Woolford et al. 2001; Berry et al. 2003). A cure rate of 30% was assumed for quarters infected with *Corynebacterium* spp. at drying off, in the OrbeSeal group (Berry & Hillerton, 2002a).

It was assumed that 50% of cows infected at calving would be detected with clinical signs for all groups (Berry & Hillerton, 2002a, b). These cows were allocated only the cost of one case of clinical mastitis. The other infections were assumed to remain subclinical, with an associated decrease in yield and increase in SCC (80%) or to resolve spontaneously (20%) (Dohoo et al. 1984).

Cows that were infected at calving with a clinical infection were allocated a monetary cost of only a clinical case and no other costs, to avoid double calculation of yield losses. Cows that were infected at calving and not detected as having clinical signs were assumed to have a 5% loss in yield with the related decrease in feed costs, and for those still infected with *Corynebacterium* spp., a reduced loss in yield of 1·5% was assumed. For uninfected

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Table 2. Economic values assigned to the terminal end values

Possible end values	Economic cost	References
Clinical/recurrent case of mastitis	£49 per case	Assumption Houben et al. 1993
Lactation yield loss for case of mastitis	10%	Dohoo et al. 1984; Bartlett et al. 1991; Houben et al. 1993; Yalcin et al. 1999
Cull cow	£296 per cow	Yalcin & Stott, 2000
Replacement heifer	£700 per heifer	Yalcin & Stott, 2000; Borsberry, 2002
Cost to involuntarily cull cow	£666	Yalcin & Stott, 2000
Yield loss due to first clinical case	10%	Dohoo et al. 1984; Bartlett et al. 1991; Yalcin et al. 1999
Yield loss due to intra mammary infection at calving but no clinical case	5%	Dohoo et al. 1984; Brolund, 1985; Bartlett et al. 1991; Yalcin et al. 1999
Yield loss due to intra mammary infection due to *C.* spp. infection	1·5%	Assumption Dohoo & Martin, 1984; Brolund, 1985
Milk price	18 p/l	UK data-assumption
Dry cow antibiotic including labour	£13 per cow	UK data-assumption
OrbeSeal including labour	£13 per cow	UK data-assumption
Extra yield in cow treated with antibiotic	250 l	Assumption McNab & Meek, 1991; Berry et al. 1997; Oliver et al. 2003
Extra yield in cow treated with OrbeSeal	200 l	Assumption
Cell count bonus	0·1 p/l	UK data
Extra feed cost for increased milk yield	0·5 kg concentrate/l milk at 15 p/kg concentrate or 0·075 p/l	Yalcin, 2000

cows there was an increase in the monetary value as a result of an increase in yield associated with the lower SCC but there was also an increase in feed costs to compensate for this yield increase.

Culling and replacement costs. A culling rate of 5% was assumed for the dry cow antibiotic and OrbeSeal group and 10% in the untreated group (Tables 1 and 4) (Yalcin & Stott, 2000). Currently in the UK, all cows over 30 months enter into the official Over Thirty Month disposal scheme at set values. This is due to current restrictions placed on cattle entering the food chain with respect to Bovine Spongiform Encephalopathy control. Therefore, a similar price is paid irrespective of parity, price being determined primarily by carcase weight. The average cow value at culling over the first five lactations was £296 (Yalcin & Stott, 2000). If culling was involuntary, i.e., due to mastitis, then cow value at culling was assumed to be halved to cover any extra costs incurred (Yalcin & Stott, 2000). The current replacement cost for a pregnant heifer is approximately £700 (Yalcin & Stott, 2000; Borsberry, 2002). Replacements were assumed to be bought for those culled due to mastitis. Culled cows were assumed to have had two clinical cases of mastitis and were assigned the appropriate monetary values for these and the difference between cull and replacement costs (Table 2).

Production data. Both treatment groups, dry cow antibiotic or OrbeSeal, had a greater yield than the untreated group in the lactation following the trial dry period; the dry cow treated group had a higher yield than the OrbeSeal group (Table 3). Differences between the treatment groups were analysed using a General Linear Model Minitab statistical package (release 12.21, Minitab Inc., Pennsylvania, PA 16801, USA). The difference was statistically significant for the antibiotic treatment ($P<0·005$) but not for the OrbeSeal treatment. The 305-d yield preceding the trial dry period was higher, but not significantly, for the treatment groups in both trials than for the untreated groups. Milk production was assumed to be 7500 l with any yield increases incremental to this production. In the selective antibiotic trial, three cows in the antibiotic group and nine cows in the untreated group were culled for mastitis. In the selective OrbeSeal trial, six cows were culled from each group for mastitis

Table 3. Yield and SCC data for mastitis for the lactation subsequent to the trial dry period, for the two selective treatment trials (IAH herds)

Treatment group	No. of cows	Arithmetic mean yield litres (SE)	No. of cows	Arithmetic mean of geometric mean of SCC $\times 10^{-3}$ cells/ml (SE)
Dry cow antibiotic trial				
Antibiotic	96	8257 (157)*	100	107 (47·5)
Untreated	109	7716 (107)*	115	154 (62·7)
OrbeSeal trial				
OrbeSeal	82	7845 (151)	84	147 (26·4)
Untreated	81	7636 (155)	81	142 (16·4)

* Means are significantly different $P<0·005$

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Table 4. Prevalence of new infections at calving and percentage of those quarters detected as clinical infections for IAH cows

Treatment group	% cows infected at calving	% quarters infected at calving	% quarters detected as clinical infections	% cows culled for mastitis reasons
Selective dry cow antibiotic trial				
Antibiotic	9·5	3·2	63	3
Untreated	35	14·4	42	7
Selective OrbeSeal trial				
OrbeSeal	10·6	3·4	55	7
Untreated	30·8	11·6	55	7

(Table 4). These cows were omitted from the yield analysis to avoid double calculations on yield loss.

For both trials, the untreated cows had the highest first SCC and highest maximum SCC. Cows treated with dry cow antibiotic therapy had the lowest arithmetic mean for the first 5 months of lactation (Table 3). In the OrbeSeal trial, the groups had comparable arithmetic mean SCC (Table 3). A yield increase of 250 l was assumed for cows treated with antibiotic and 200 l for cows treated with OrbeSeal.

Feed costs. Although some of the yield increase may occur because a healthy udder is more efficient at converting nutrients into milk, an additional cost for feed was included to compensate for any increased yield. An increased feed cost for 0·5 kg of concentrate per extra kg of milk was assumed with a concentrate cost of 15 p/kg.

Milk price and quota price. Current milk price was assumed to be 18 p/l. Penalties and bonuses apply to both bacterial and SCC bulk milk thresholds. Intramammary infections including Corynebacterium spp. or CNS, result in an elevated individual cow SCC and, depending on the prevalence of infection, may increase bulk milk SCC. Thus, for those cows uninfected after calving, a bonus of 0·1 p/l was assumed on the total milk production. No penalties were assumed for any other infection state. However, there is minimal influence on butter fat and lactose up to a certain cell count and with maximum bulk cell counts at 400 000 cells/ml, cell count would be unlikely to incur financial losses due to these factors.

It was assumed that an increase in yield with lactation would be expected and hence no cost for extra quota would be required. Instead the extra cost was incurred when yield did not increase with lactation, and extra replacements would be needed. The decision tree was at the individual cow level and not herd level but the implications of this were not investigated. However, it is assumed that extra costs would be incurred with the need for more replacements.

Clinical mastitis case. The cost of a case of clinical mastitis in lactation has been updated using the calculation methods of Houben et al. (1994). In this calculation only treatment, milk discarded accounting for that used as replacement for milk powder, yield loss for that lactation and the negative effect on feed consumption were used.

It was assumed that 75% of cases would be treated only with intramammary antibiotics and the other 25% would be treated with a combination of intramammary antibiotics and systemic antibiotics (summary of records of IAH farm). In the UK, veterinary charges are not usually incurred for routine mastitis cases, only systemically ill cows are usually attended by a veterinary surgeon.

The cost of an initial clinical case of mastitis was calculated at £128 for a first case and £49 for a recurring case (Table 5). Treatment, labour costs and fatality losses accounted for £26·26 and lost milk either from milk discarded owing to treatment or decreased production accounted for £161. The £79 yield loss due to decreased production was only assumed for those cows that remained and were not culled for mastitis reasons. Lower food intake due to decrease in milk production reduced costs by £56·25. A recurring case had lower costs, as there were no extra losses due to a decrease in subsequent production. No losses were included for clinical mastitis during the dry period although the incidence of clinical dry period infections was higher in the untreated groups in both trials, in agreement with the literature (Neave et al. 1950; Oliver et al. 1956; Woolford et al. 1998; Hassan et al. 1999).

Treatment and labour costs. The purchase price of the product and a labour cost that included infusion of the intramammary products, cow identification and recording of the treatments were used. The labour costs for antibiotic treatment and OrbeSeal were assumed to be the same, this included 15 min of labour at £12 an hour. Total cost for antibiotic treatment was £13 per cow and for OrbeSeal also £13 per cow.

Results

Decision tree analysis

The decision trees on outcomes for the three possible infection states at drying off are in Figs 1, 2 and 3. Monetary values are shown on the right hand side and indicate net benefit or loss with negative values denoted by parentheses.

Using decision making at the individual cow level allowed the most cost-effective treatments to be determined, depending on quarter infection state at drying off. For a cow uninfected at drying off, there was little difference in benefit between antibiotic treatment (£11) and OrbeSeal (£6) (Fig. 1) and this could approach zero depending on the purchase price of the treatments. However,

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Table 5. Costs of a mastitis case for a cow yielding 7500 l (same parameters as Houben et al. 1994)

		Cost per case (£)	
Item	Description	Initial case	Recurring case/or cow culled for mastitis reasons
Labour	2 h at £6/h	12	12
Treatment	75% treated with 4 tubes at £2/tube	6	6
	25% treated with parenteral injections and tubes at £18 a treatment	4·5	4·5
	2% veterinary visit and treatment	0·8	0·8
Discarded milk	75 l under treatment at 18 p/l	13·5	13·5
	125 l in withhold period fed to calves at 10 p/l	12·5	12·5
Reduced feed intake	750 l at 0·5 kg concentrate/kg milk at 15 p/kg	−56·25	
Production losses	10% of yield at 18 p/l	135	
Total		128	49

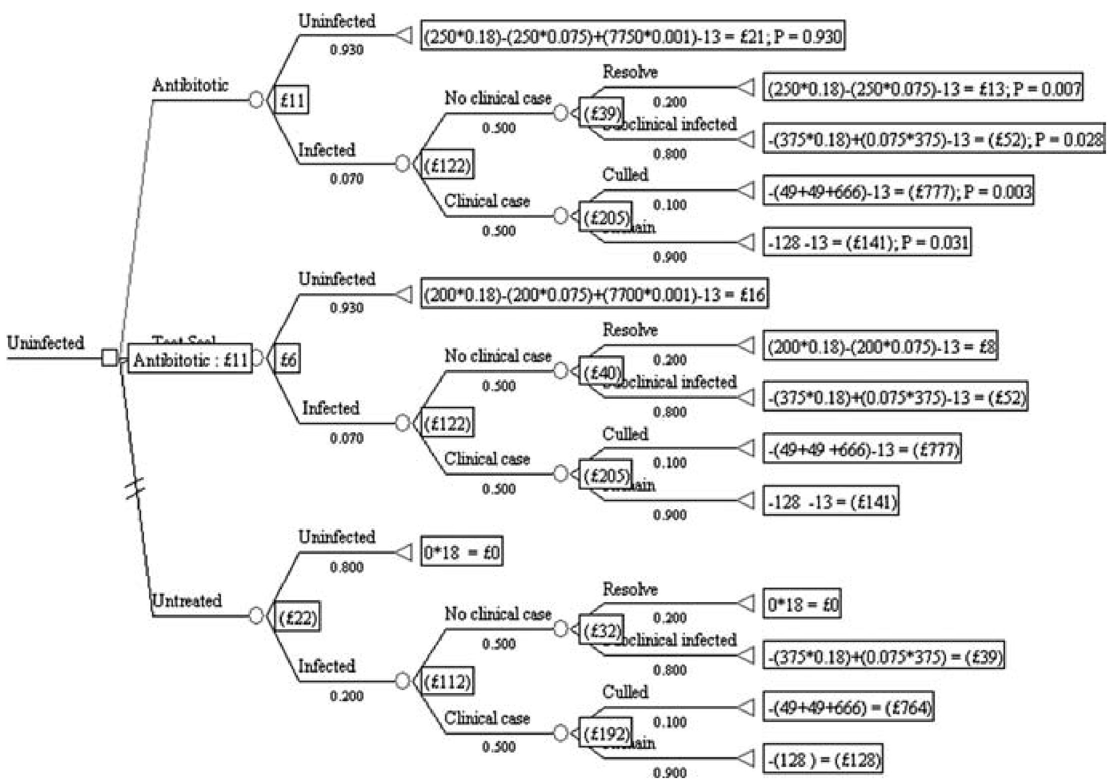

Fig. 1. Decision tree analysis for an uninfected cow at drying off.

Negative values are in parentheses

there was a potential loss of £22 if the cow was left untreated. This loss increased for those cows with quarters infected with *Corynebacterium* spp. for both the OrbeSeal and the untreated groups (£22 and £48 respectively) with only the antibiotic-treated cows showing a gain of £7 (Fig. 2). For cows with quarters infected with pathogens other than *Corynebacterium* spp. or CNS at drying off, there was a net gain of £2 for an antibiotic-treated cow with a cure rate of 88% but any losses or gains depended on cure rates.

Sensitivity analysis

If an increase in yield occurred greater than the 200–250 l assumed, the potential economic benefit of either treatment strategy increased. This increase in benefit also

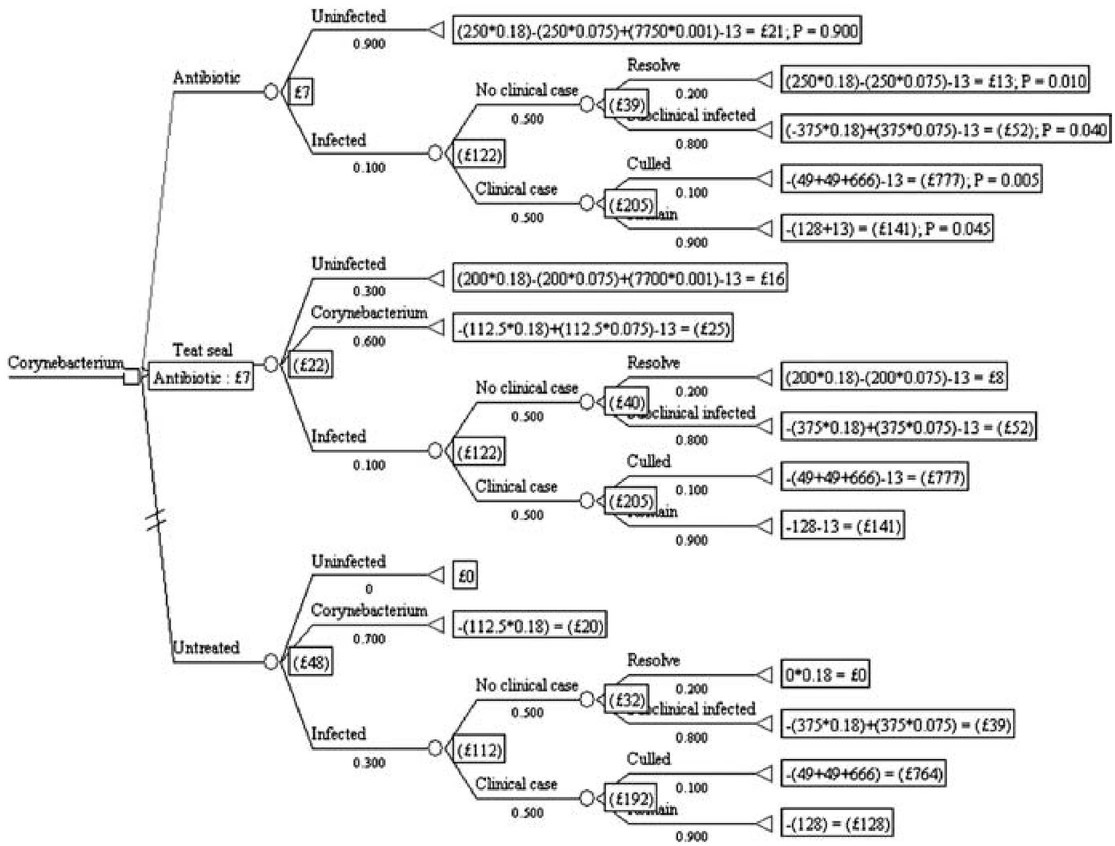

Fig. 2. Decision tree analysis for a cow infected with *Corynebacterium* spp. at drying off.

Negative values are in parentheses

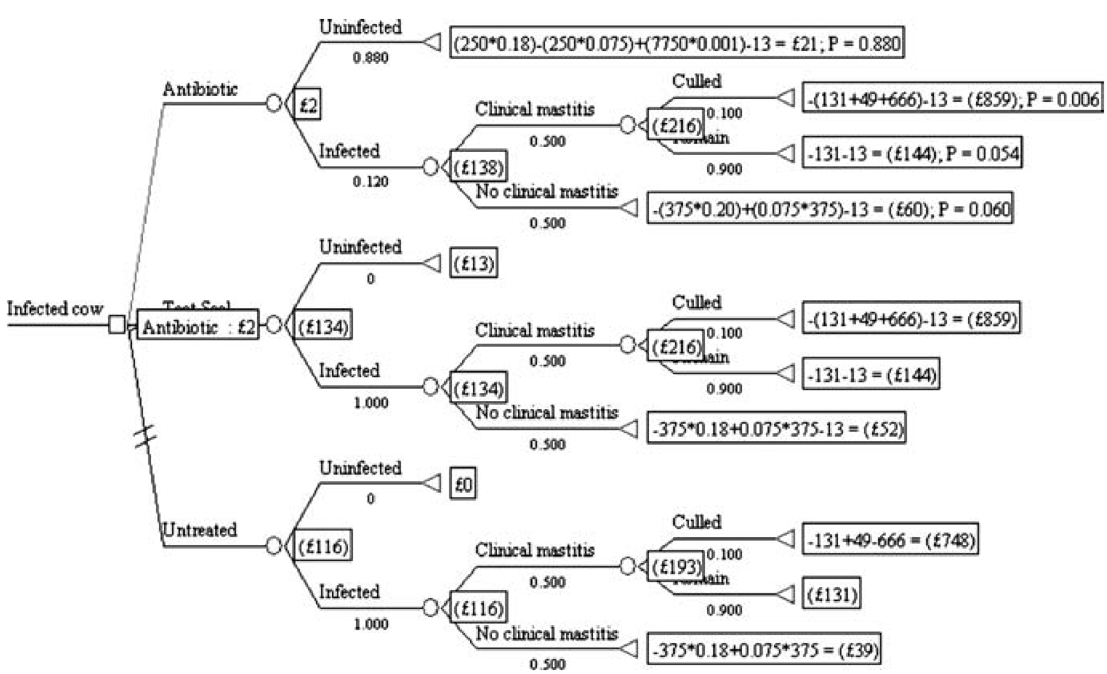

Fig. 3. Decision tree analysis for a cow infected at drying off.

Negative values are in parentheses

occurred with a decrease in the cost of the strategy. As dry cow antibiotics and OrbeSeal are commercially available at comparable prices, any economic benefit for an uninfected cow arises mainly from the potential yield increase or from the decrease in incidence of new infections at calving. With a smaller increase in yield, intervention strategies, either antibiotics or teat sealants, become less economically attractive. Yield increases had the largest effect on the economic benefits of either treatment strategy.

For a cow infected at drying off, in most circumstances dry cow antibiotic appears to be the most economic option and this is related to potential cure rates of the pathogen concerned. A break-even point for cure rate was around 86·5% of infections resolved and a yield increase of 200–250 l. Break-even point was also influenced primarily by potential yield increase in the subsequent lactation but also the cost of the strategy. Adjusting the self-cure rate for the infected cow in the OrbeSeal treated group to 10% still resulted in a loss of around £108. Leaving cows with infected quarters untreated was economically more viable than using OrbeSeal, primarily because there was a cost to using OrbeSeal.

Increasing the milk price increased economic viability for uninfected cows treated with dry cow antibiotic or OrbeSeal but had little effect for the other infection states, except for antibiotic-treated cows. Changing the probability of a new intramammary infection at calving or the probability of clinical infections had minimal influence on the economic benefit. The model was relatively insensitive to the cow cull price.

Discussion

Economic implications of the different dry cow strategies were calculated primarily for the UK. Assumptions may vary depending on the differences in any of the parameters for an individual country. Most models claim that dry cow therapy is a cost-effective control measure particularly in high SCC herds (McNab & Meek, 1991; McInerney et al. 1992; Allore et al. 1998; Yalcin et al. 1999; Yalcin & Stott, 2000). Other models have not attempted to evaluate strategies at an individual cow level or to take into account differing infection states at drying off.

Using decision making analysis at the individual cow level allowed the most cost-effective treatment to be determined, according to the quarter infection state at drying off. It is also indicated that treatment should be at the cow level rather than the quarter level (Berry et al. 2003). Variables such as probability of infection are also influenced not only by country but also by region and type of farming. Individual herd management influences the prevalence and type of intramammary pathogens found in the herd (Hillerton et al. 1995a; Barkema et al. 1999). This type of modelling could be used to advise on specific situations but it would be too long and speculative to include these variables in this discussion.

The economic values used in this decision tree analysis were all conservative and likely to be underestimates, with no losses included for any cases occurring during the dry period. Thus, any losses from not using a dry cow strategy are likely to be greater rather than smaller, and the potential benefits of using either antibiotic or OrbeSeal are likely to be increased. Prophylactic use of either antibiotic or OrbeSeal was more cost-effective than leaving uninfected cows untreated at drying off. Cows with infected quarters at drying off incurred losses when either OrbeSeal or no treatment was applied.

The expected cure rate for an infected quarter could also influence decision making on which treatment to use. Only cure rates of 86·5% and above resulted in antibiotic treatment being an economically viable decision. However, the yield increase assumed for those cows cured was a conservative estimate and with a larger increase in yield this break-even cure rate is lowered. Cure rate for the antibiotic treatment is also influenced by pathogen type with cure rates for *Staph. aureus* infection often being as low as 25% and those for *Str. uberis* infection as high as 85%. It is also influenced by other factors such as lactation number, number of quarters infected and cell count of the milk (Smith et al. 1967; Sol et al. 1994; Williamson et al. 1995). It would also be possible to generate decision trees which were pathogen specific. Those cows in herds with a high prevalence of *Staph. aureus* are at a greater risk of acquiring new *Staph. aureus* infections if untreated, and the same could be assumed for other infection types (Eberhart, 1986; Berry & Hillerton, 2002a, b). The low self-cure rate assumed in the decision tree meant that leaving infected cows untreated was a non-viable option. As decisions on culling are complicated and influenced by more than just the infection state of the cow, many cows may still remain in the herd (Houben et al. 1993; Houben et al. 1994; Stott et al. 2002). For herds with a high prevalence of such infections at drying off, the best option may still be to use dry cow antibiotic, as this may provide prophylactic effect against further infections.

Decision tree analysis indicated that antibiotics might be the most cost-effective treatment for cows infected with *Corynebacterium* spp. but again this would be influenced by the cure rate achieved for these infections. The prevalence of *C.* spp. or CNS is a reflection of less than adequate teat disinfection (Bramley et al. 1976; Hillerton et al. 1995b). Cows with a *C.* spp. infection at drying off were shown to be at greater risk of acquiring a new infection than uninfected quarters (Woolford et al. 2001; Berry & Hillerton, 2002a, b; Berry et al. 2003). Therefore, it may also be relevant to consider teat disinfection methods and possible infection status due to *C.* spp.

Production data in these trials were based on testing at monthly intervals. The full effect of mastitis on production or SCC may often be underestimated or missed because the lowest production level, or the event itself, was not recorded or measured. This may account for the variable production losses attributed to mastitis (Dohoo & Martin, 1984; DeGraves & Fetrow, 1993). Production losses due to clinical mastitis in this assumption were of the order of 10%, which is not excessive when considering the literature on production losses after clinical mastitis and attributed to elevated SCC (Dohoo et al. 1984; Bartlett et al. 1991; Yalcin et al. 1999).

The increase in yield used for cows given dry cow antibiotics agrees with previous studies (McNab & Meek, 1991; Osteras & Sandvik, 1996; Berry et al. 1997; Oliver et al. 2003). Any yield differences in these current trials were assumed to reflect yield loss attributable to sub-clinical mastitis, as cows removed early owing to mastitis were not included in the calculations. To negate any possible bias in production figures due to time differences between the two trials, a lower figure was used for the antibiotic treatment compared with the actual yield difference. The use of OrbeSeal merits further work on a more detailed analysis of yield, possibly using daily yield measurements, on a larger number of cows with comparable herd management.

It was assumed that an increase in yield with lactation would be expected under current quota conditions and management. Hence no cost for extra quota would be required. Instead it was assumed that the extra cost was incurred when yield did not increase with lactation, and extra replacements would be needed.

Previous work shows differences in SCC in early lactation between antibiotic-treated and untreated cows but these have not always been statistically significant (McNab & Meek, 1991; Osteras & Sandvik, 1996; Berry et al. 1997). A decrease in cell count after calving was assumed for the antibiotic- and OrbeSeal-treated cows although in practice only antibiotic-treated cows had a lower cell count. This may reflect the higher cure rates for *C.* spp. achieved with antibiotics and slight elevation in cell count resulting from these cell counts (Brolund, 1985; Berry & Hillerton, 2002a, b).

No cost implications have been included if infection status had to be determined. The most accurate method would be bacteriology, ideally on duplicate samples or repeated sampling of all quarters and not a composite sample, prior to drying off. Currently in the UK, the commercial cost of bacteriology would exceed the cost of a treatment. Some 75% of herds obtain monthly, individual cow, cell counts as part of the production data sought for management.

Keeping treatment records is a legal requirement and should give some indication of infection status. However, only 40% of infections are detected on clinical signs and previous clinical history is not always an accurate determinant of clinical infection status in the next lactation (Dodd et al. 1964; Houben et al. 1993). In Sweden, cows at drying off are given an udder health score that takes into account the SCC for the last three recordings, lactation number, yield, days in milk and breed and this is used to give an indication of infection status (Brolund, 1985). It would be possible to generate a scoring system to give an indication of infection status similar to the Swedish system to aid in deciding on infection status of cows and hence possible economic strategies to be used.

Decision trees can identify and quantify economic values on treatment strategies but other important factors may influence decision making. Some of these are difficult to quantify economically such as an end monetary value of not using antibiotics as dry cow therapy. However, this may not mean that, long term, fewer antibiotics are used, as untreated cows had more clinical cases of mastitis in the subsequent lactation. Restricting antimicrobial use at drying off also reduces theoretically the potential selection pressure for antibiotic resistance. To date there is no evidence to suggest that dry cow antibiotics do pose a risk (Schultze, 1983; Watts et al. 1995). Whilst dual use of both antibiotic and OrbeSeal in the same quarter might be a more complete option for different infection states or types of cow, this would then negate the non antibiotic attraction of the OrbeSeal. At present, this combination use is not licensed in the UK. In the USA, the combination of OrbeSeal with antibiotics is actively marketed and OrbeSeal is not available for use without antibiotics.

It is also difficult to determine the economic value of animal welfare. Whilst welfare may be an area of public concern, and intrinsically it would be assumed that good welfare equates to more profit, this is not always the case. Organic farming is often cited as being more welfare friendly. However, under this system, more new infections occur at calving than under conventional dairy systems (Berry & Hillerton, 2002a, b). The relevant organic authorities in the UK permit the use of OrbeSeal in dairy cows. For organic farming, OrbeSeal presents an economically viable alternative to not treating dry cows, as routine antibiotic use at drying off is restricted.

Whilst the likelihood of antibiotic contamination in milk due to dry cow therapy is low, a non-antibiotic alternative obviously eliminates this risk. Currently resources are used to monitor and regulate antibiotic residues in food products. This cost has not been included in any budgeting, as this system would still be required, even if no dry cow antibiotics were used, to check for antibiotic residues from other sources.

The present results show that dry cow antibiotic remains a cost-effective measure compared with no treatment at drying off under UK conditions. The benefits of dry cow therapy vary according to the infection status of the cow. Analysis indicated that OrbeSeal was a cost-effective alternative but the benefit varied with the incidence of intramammary infections within the herd and at the individual cow level. The cost-effectiveness for all strategies varies depending on the input parameters used. Better information on infection status at drying off, prevention of new infections and resulting cure is necessary in order to advise farmers properly. No monetary value was placed on using a non-antibiotic strategy, something that may be attractive or essential under certain farming conditions.

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