Veterinary Research Communications, 14 (1990) 367–379

AN EPIDEMIOLOGICAL STUDY OF WINTER DYSENTERY IN FIFTEEN HERDS IN FRANCE

B. JACTEL[1], J. ESPINASSE[2], M. VISO[2] AND H. VALIERGUE[3]
[1]Ecole Nationale Vétérinaire, 94704 Maisons-Alfort Cédex, France
[2]Ecole Nationale Vétérinaire, 31076 Toulouse Cédex, France
[3]Centre d'Application de l'Ecole Nationale Vétérinaire d'Alfort, 89350 Champignelles, France

ABSTRACT

Jactel, B., Espinasse, J., Viso, M. and Valiergue, H., 1990. An epidemiological study of winter dysentery in fifteen herds in France. *Veterinary Research Communications*, 14 (5), 367–379

Winter dysentery is a highly contagious disease of cattle seen most often during the winter months. In the course of an epidemiological study, the management, production, hygiene and previous diseases in 15 herds were characterized by 32 variables. Each herd was then visited twice a week for 8 weeks and 8 to 10 cows were clinically examined during each visit. Winter dysentery occurred in half of the herds during the survey.

All data were analysed by classical statistical methods and by multivariate analysis.

Mild or severe disease provoked nasal discharge and was associated with significant economic loss. Winter dysentery outbreaks appeared to be associated with small farms in which the area available per cow is either too small or too large, the presence of coronavirus in the faeces and variations in the temperature of the stable and of the drinking water.

Keywords: cattle, coronavirus, epidemiology, winter dysentery

INTRODUCTION

Winter dysentery is a highly contagious disease of cattle reported from many countries including the United States (Kahrs *et al.*, 1973; Van Kruiningen *et al.*, 1985), Canada (MacPherson, 1957), Great Britain (Rollinson, 1948), Sweden (Hedstrom and Isaksson, 1951), Germany (Rolle *et al.*, 1955), France (Charton *et al.*, 1963; Espinasse *et al.*, 1981), Israel (Johnston, 1959; Komarov *et al.*, 1959), Australia and New Zealand (Durham *et al.*, 1979; Edwards and Sier, 1980). The main clinical signs are a sudden outbreak of profuse diarrhoea or the occurrence of dark green to black soft faeces with the presence of blood in 5 to 10% of the animals. According to Van Kruiningen *et al.* (1985), the diarrhoea is watery or porridge-like with a characteristic smell. Affected animals show respiratory signs such as nasolacrimal discharges or coughing and hyperthermia often precedes the onset of diarrhoea by 24–48 hours.

Epidemiological studies have shown that winter dysentery most often affects housed cattle during November to April. At any one time, the percentage of affected animals in the herd usually ranges between 5 and 10% but may reach 30–50% of the animals after two or three days. The disease is characterized by high attack rates (up to 100% after four days) but low case fatality rates (<1%).

Several hypotheses have been put forward concerning the origin of this disease since the first studies by Jones *et al.* (1931) and by Jones and Little (1931) in dairy herds in New Jersey. It was initially thought that winter dysentery was caused by *Vibrio jejuni*, now termed *Campylobacter jejuni*. However, more recent studies ruled out the role of this micro-organism in the aetiology of the disease (Charton *et al.*, 1963; Alenius *et al.*, 1988). The causative agent was suspected to be a virus by MacPherson (1957), who reproduced the disease experimentally by inoculating faeces passed through a Seitz filter, although the virus concerned was not isolated. Various viruses have been incriminated, including those responsible for infectious bovine rhinotracheitis or mucosal disease, parainfluenza 3 virus or rotavirus, but these are now all discounted. A coronavirus similar to that responsible for calf diarrhoea was suggested as the causative agent in studies performed in France (Espinasse *et al.*, 1981; 1982), Sweden (Alenius *et al.*, 1988), the United States (Van Kruiningen *et al.*, 1985; 1987; Saif *et al.*, 1988) and Japan (Akashi *et al.*, 1980; Takahashi *et al.*, 1980).

In addition, the roles of several predisposing factors, such as sudden drops in temperature, housing conditions, calving or restricted feeding, have been emphasized by Espinasse *et al.* (1981) and Campbell and Cookingham (1978).

The losses due to the disease, especially in milk production, which may decrease by 25 to 100% over two weeks, were investigated by Rollinson (1948), Hedstrom and Isaksson (1951), Johnston (1959) and Charton *et al.* (1963). However, Campbell and Cookingham (1978) suggested that these earlier estimations were pessimistic. The aim of this study conducted in France during 1984–85 was to determine the factors responsible for the onset of the disease, their chronology, the clinical signs and the economic consequences to the farmer.

MATERIALS AND METHODS

Herds and animals

Fifteen herds of 10–40 dairy cows located near the Centre d'Application de l'Ecole Vétérinaire d'Alfort at Champignelles (Yonne) were studied. The study was divided into two parts: a preliminary visit to collect data about the management and production, and several regular visits to record data about the housing conditions and on clinical observations.

The management and the production variables

During the first part of the survey, each herd was characterized by 34 variables divided into four groups: G1, description of the farm (18 variables); G2, production (4 variables); G3, hygiene conditions (5 variables); G4, previous outbreaks of winter dysentery (6 variables).

The variables studied during the survey

During the second part of the survey, the herds were each visited on 16 occasions, i.e. twice a week for 8 weeks from January to March, to record data on the housing conditions and on clinical observations of 8–10 cows per herd. A herd was considered to be affected by winter dysentery when a sudden outbreak of diarrhoea of a consistency ranging from soft stools to dysentery occurred and when both a high attack rate and decreased milk production were recorded as described by Kahrs *et al.* (1973).

Seven variables pertaining to housing conditions were studied. These were the air temperature (TP1 and TP2) and air velocity (VA1 and VA2) in two places, the moisture level in the stable (HYGR) and the mean temperature of the drinking water (TH20) and of the feed (TALI). Temperature variables were measured objectively while air velocity and moisture level were approximated from, respectively, a candle flame and the amount of condensation on the cold surfaces in the stable. Seven variables relative to the clinical observation of the cows were identified at each visit. These were the rectal temperature (TREC), fattening stages (GRAS), nasal discharge (RESP), the colour (DIAR1), consistency (DIAR2) and smell (DIAR3) of the faeces, and the presence of coronavirus and/or *Campylobacter jejuni* in a faecal sample of 20 g (CORO). The birth date of the animal (NAIS) and the lactation month (LM) were also recorded.

Milk production was recorded regularly throughout the survey and for two months after the survey ended. The herd's milk production and bulk milk quality (fat and protein content) were recorded every two days and every fortnight, respectively.

Statistical analysis

A total of 209 environmental observations and 2208 clinical observations were used with Student's *t* test and with factorial analysis as developed by Benzecri (1980) and Fenelon (1981) and already used in epidemiological studies (Faye and Brochart, 1986). The factorial analysis is used to understand the information contained in a measurement table. The table is made up of (a) individuals (visits, herds or cows) in the rows, and (b) the results of the observations (called variables) made on those individuals (e.g. air temperature at each visit, nasal discharge observed in each cow etc.), in the columns. Classical statistical methods analyse the variables separately: factorial analysis is able to describe the relationship between all the variables and all the individuals. For such results, several stages must be followed.

Coding the table

Each individual is characterized by both qualitative and quantitative variables. The coding stage consists of transforming the initial table into a complete disjunctive form. Each variable is separated into different classes. For example, the variable diarrhoea (coded D) can take the modes absent (coded D1), mild (D2) or severe (D3). The individual 'x' affected by mild diarrhoea will get a '1' in the class D2 of the variable diarrhoea and a '0' in the classes D1 and D3. The table designed in this way is called a 'BVRT table' and is used in the following steps.

Building the cloud of points

The goal of the factorial analysis is to measure the similarity (or absence of similarity) between the individuals, each characterized by a succession of 0 and 1 values given to the different classes of the variables. The χ^2 distance is used to measure that similarity. This distance weights the class of each variable by the frequency of the positive answers. The position of each individual in the cloud of points is calculated, taking into account its succession of 0 and 1 values and its distance from all the other individuals. The same calculation is undertaken with each variable.

Reducing the data

The information contained in the cloud of points is very confused. Reducing the data, in order to simplify the analysis, consists of projecting the cloud of points onto a set of planes. Each plane is defined by two axes called 'factorial axes'. The first axis is the principal direction of expansion of the cloud. The cloud is then projected on that axis with respect to the maximum dispersion of points. The second axis is orthogonal to the first one and represents the residual dispersion of the cloud.

Interpreting the data

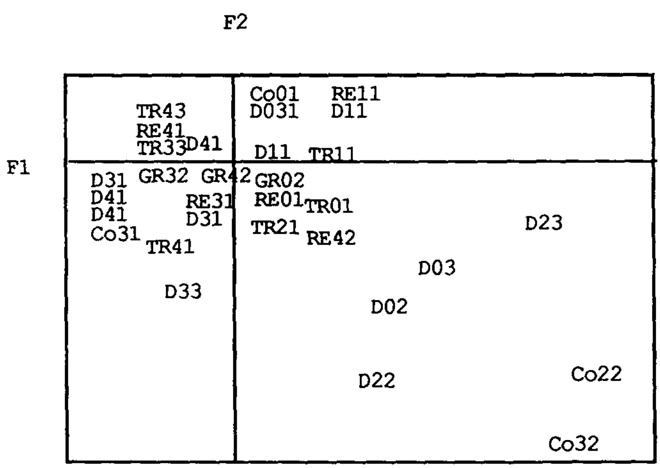
The output from the computer constitutes a set of figures, each representing a plane with two factorial axes. The points configure the projection of the cloud of individuals and of the cloud of variables. The interpretation step consists in grouping the more similar individuals and variables. Different computer programs may help in the interpretation of the factorial analysis (hierarchical ascending classification, aids to interpretation etc.) and have been used systematically (Jactel *et al.*, 1990). In the factorial analysis, the first three factorial axes are interpreted and the individuals and the variables whose contributions are the highest are retained. It is then possible to define a group of herds with frequent winter dysentery outbreaks by a set of management variables. It is also possible to describe and analyse a winter dysentery outbreak by a set of clinical epidemiological and economical variables.

RESULTS

Clinical findings

Half the herds experienced the disease and both severe and mild outbreaks were recorded. In mild outbreaks the disease was characterized by a softening and slight change in the colour of the faeces, which became brownish-green. This form was observed in four herds and was accompanied by low fatality rates and a moderate decrease in milk production but no weight loss in the animals. In severe outbreaks, the diarrhoea was profuse, watery and sometimes turned into dysentery. The faeces were reddish-brown. This form was accompanied by a noticeable weight loss in the animals and a marked decrease in milk production. In four weeks up to 100% of the herd contracted the disease. From the factorial analysis, the descriptive variables in both forms were very similar and it was therefore assumed that they were two different clinical expressions of the same disease.

Thirty-six faecal samples from animals affected by the mild or severe form of the disease were tested for coronavirus using the method described by Cauchy (1986). Six samples were positive. The evolution of the clinical signs led to five sub-groups being distinguished for each of the 16 visits. The first sub-group of these, T1, corresponded to the observation of the animals during the visit V_n, the second, T2, described the modalities assumed by these variables during the next visit (V_{n+1}) three days after V_n, while sub-groups T3, T4 and T5 corresponded to the modalities assumed by the variables during visits V_{n+2}, V_{n+3} and V_{n+4} respectively, 6, 9 and 12 days after V_n. This was done for each visit.



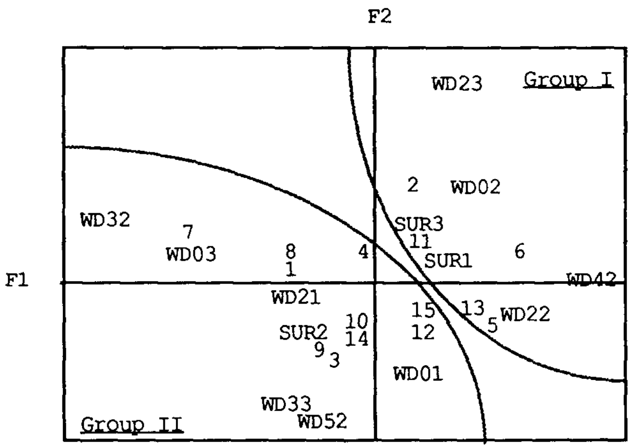
F1, F2 : factorial axis

Figure 1. Factorial analysis associating clinical parameters and environmental parameters. Coding system:
Letters code for the variable, the first number codes for the visit number and the last number codes for the mode of the variable
D = Diarrhoea (1, absent; 2, mild; 3, severe)
Co = Coronavirus (1, absent; 2, present)
TR = Rectal temperature (1, ≤39°C; 2, >39°C)
RE = Nasal discharge (1, absent; 2, present)
GR = Body condition (1, good; 2, bad)

An example of the graphical analysis is given in Figure 1. The axis F2, representing the chronology of clinical signs in affected animals, is opposed to the axis F1 representing healthy animals. These results, confirmed by the hierarchical ascending classification test and aids to interpretation program, led to the determination of a typical pattern of clinical signs observed in affected animals. This was hyperthermia (>39°C) for 48–72 h prior to the onset of digestive disorders, profuse and watery diarrhoea for 6–9 days, rectal temperature returning to normal (38.5°C) at the commencement of the diarrhoea, which was accompanied by respiratory disorders (mucopurulent nasal discharge without cough) persisting for 9–12 days, and by a marked weight loss in the animals for as long as a month.

Winter dysentery seemed most frequently to affect cows in early lactation. No significant correlation could be established between the frequency or severity of the disease and the age of the animal and coronavirus excretion seemed to be very transient, occurring only between 0 and 3 days after scouring developed.

Survey of the housing conditions



F1, F2 : Factorial axis

Figure 2. Factorial analysis associating herds and previous pathological parameters.
Coding system:
Simple numbers = herd number
Variables with highest contribution to the factorial axis:

Alphanumeric labels with WD: Letters code the variable 'Previous outbreaks of winter dysentery', using number codes for each year (0=1985, 2=1983, 3=1982, 4=1981) and a last number which codes for the severity of the illness (1=no disease, 2=mild form, 3=severe form).

Alphanumeric labels with SUR: Letter codes the variables 'Available surface/animal', while the number codes for the class (1=2–2.3 m^2/animal, 2=2.3–3 m^2/animal, 3= >3 m^2/animal).

The records of previous occurrences of the disease over a five-year period led to two groups of herds being distinguished (Figure 2). The first group consisted of five herds regularly affected by winter dysentery. For these a severe outbreak was recorded every four years, with a mild outbreak usually occurring in the second year, between two severe outbreaks. Three of the four herds which were affected by a mild form of winter dysentery during the survey belonged to this group. The second group comprised 10 herds where the incidence of the disease was very irregular. The animals developed either mild or severe scouring. All three herds in which a severe outbreak was reported during the survey belonged to this group. A characteristic example of the herds regularly affected by winter dysentery (Figure 2) was that of a small farm with two workers from the farmer's family and less than 20 dairy cows, which specialized in non-intensive milk production, the mean annual production per cow being <4000 kg. On these farms, milk quality (fat content >38.6% and protein content >30%) is emphasized more than milk quantity. As regards hygiene, the variable 'mean area available per cow' properly discriminates this type of farm, in which the area is regularly either smaller (<2.3 m^2/cow), or larger (>3 m^2) than in the farms where the incidence of the disease is less frequent. On the other hand, no particular breed, agricultural area used or duration of stabling were characteristic of the herds regularly affected.

Survey of 'follow-up visits'

To determine the environmental predisposing factors in winter dysentery, our analyses took into account variations in the environment (temperature, air velocity), which play a more important role than their actual level (Lucey *et al.*, 1986; Jactel *et al.*, 1990) prior to the onset of winter dysentery. Seven additional variables were used to characterize differences between visit V1 and later visits. Visits 1, 2 and 16 were not taken into account because very little information was available. The temperature of the stable was much lower than usual on visits 3 and 4 and on visits 11, 12 and 13 (Figure 3). The air and water temperatures usually differed significantly between two visits (Table I). A strong positive correlation was observed between the temperature of the stable and that of drinking water: the correlation was less marked with the temperature of the diet (Table II). The air velocity and moisture content variables were not significant. Moreover, the mean level of environmental temperature had little effect since some affected herds exhibited higher mean temperatures in the stable than healthy herds. The reciprocal was also checked. Thus, the variation of temperature between two visits appeared to play the major role.

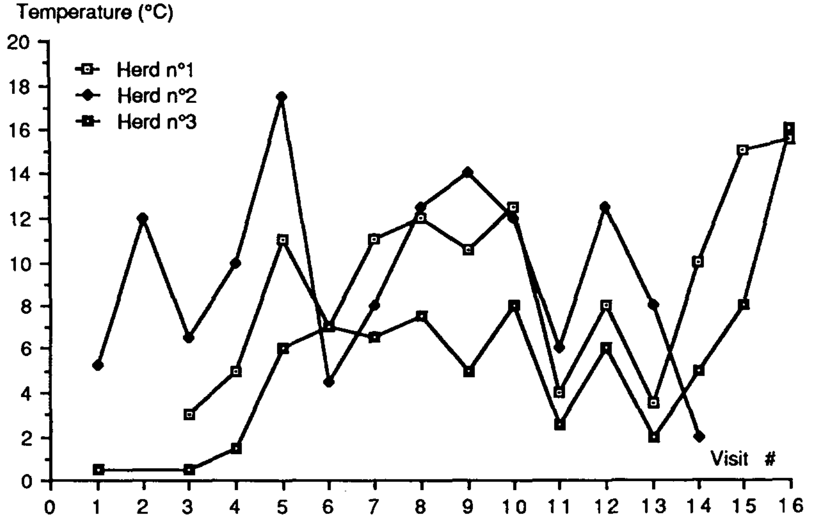


Figure 3. Ambient temperatures during the follow-up visits for three of the 15 herds

TABLE I
Variation in the environmental parameters

	TP1	DT1	TH2O	DTH	TALI	DTA
Mean	11.79	0.58	8.96	0.29	9.13	0.38
Standard deviation	4.12	3.79	3.46	3.46	6.16	6.4
Student's *t*		2.19		1.2		0.75
Probability > T		0.02		0.23		0.45

TP1 : Inner stable temperature (°C)
DT1 : Difference in inner stable temperature between two successive follow-up visits
TH2O: Temperature of drinking water (°C)
DTH : Difference in temperature of the drinking water between two successive follow-up visits
TALI : Temperature of feed (°C)
DTA : Difference in temperature of feed between two successive follow-up visits

TABLE II
Correlation between environmental parameters

r^2	TPI	TH2O	TALI
TP1	1	0.58	0.33
TH2O		1	0.26
TALI			1

All r^2 values are significant

TP1 : Inner stable temperature (°C)
TH2O: Temperature of drinking water (°C)
TALI : Temperature of feed (°C)

Environmental variables were compared with clinical variables to indicate the number of animals exhibiting a given sign together with the observation of a particular environmental parameter. Analysis of this table (factorial analysis, hierarchical classification, aids to interpretation) showed that the onset of winter dysentery (mild and severe outbreaks) tends to be preceded by a sharp drop in the temperatures in the stables by more than 1.7°C followed by a rise. The outbreak then occurs 2–4 days after the temperature decrease. The most predisposing temperatures were the temperature of the air inside the stable less than 9°C and the temperature of drinking water and feed less than 6.5°C and 5.4°C, respectively. These three indicators correlated with each other.

Milk production

The overall attack rate ranged between 22 and 90% in the herds studied. In mild outbreaks, the maximum decrease in milk production compared to a theoretical lactation curve (Wood, 1967) ranged between 6 and 11%. The overall production drop persisted for 8 to 15 days, after which former milk production levels were regained. It is noteworthy that when milk production returned to preclinical levels (Figure 4) the observed lactation curve exhibited a rapid rise compared to the theoretical curve. In severe outbreaks the maximum decrease in milk production was 30% and lasted for an average of 28 days. The later return to initial level followed the same pattern as for the mild outbreaks. In late lactation, winter dysentery could lead to premature drying-off.

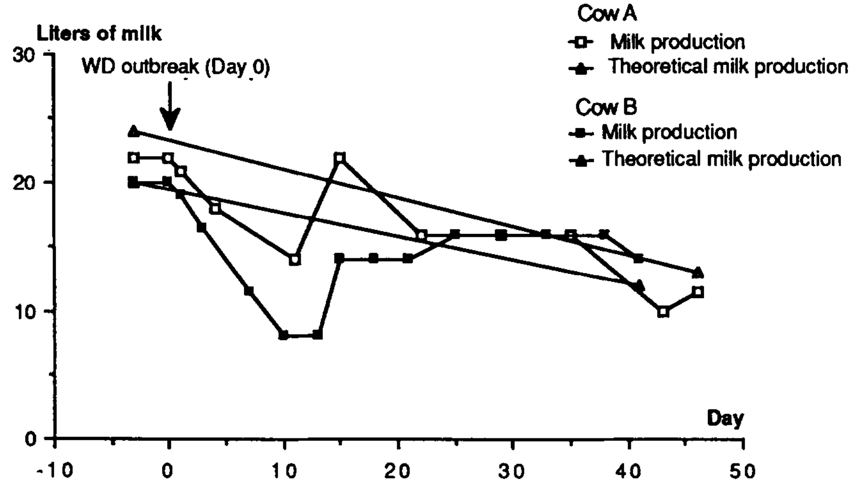


Figure 4. Daily milk production of two cows (A and B) with respectively a mild and a severe form of winter dysentery (WD)

In both cases, the mean fat and protein content of bulk milk declined by 1.5 g/l in the assay performed immediately after the period of diarrhoea. In this evaluation of the economic consequences, the cost of treatment and the indirect effects of weight loss on reproduction performance were not taken into account (Table III).

TABLE III
Economic consequences of winter dysentery in three herds

	Severity of disease		
	Mild	Severe	Severe
Herd number	4	1	7
Length of the disease (days)	10	8	10
Milk loss (kg)	25	80	788
Quality loss (g/kg)	–	2	1
Mortality (number of animals)	–	1	–
Economic loss in terms of milk production (FF) (A)	50	932	1789
Economic loss in terms of fatalities (FF) (B)	–	4000	–
Total economic loss (FF) (A + B)	50	4932	1789

FF: French francs

DISCUSSION

The analysis of 2208 observations confirmed the increase in rectal temperature 48–72 h prior to the onset of diarrhoea (Rollinson, 1948; Roberts, 1957; Kahrs *et al.*, 1973; Scott *et al.*, 1973), a phenomenon also reported by Van Kruiningen *et al.* (1985) in their experimental study. In contrast, neither coughing nor strong smelling faeces was observed in our survey.

As in previous studies (Scott *et al.*, 1973; Horner *et al.*, 1976), no *Campylobacter jejuni* was detected in the faeces (Table IV). This observation, together with the results of the coronavirus test on the faeces, confirms the possible involvement of a coronavirus in the aetiology of winter dysentery (Komarov *et al.*, 1959; Charton *et al.*, 1963; Espinasse *et al.*, 1981; Van Kruiningen *et al.*, 1985) and its association with calf coronavirus (Horner *et al.*, 1976; Durham *et al.*, 1979; Akashi *et al.*, 1980; Espinasse *et al.*, 1981). A recent study by Van Kruiningen *et al.* (1987), which seemed to demonstrate a marked antigenic relationship between the coronavirus isolated from winter dysentery outbreaks and calf diarrhoea coronavirus, was confirmed by Saif *et al.* (1988). Nasal discharge is always observed in affected animals. Some other coronaviruses are known to be involved in respiratory disorders (Thomas *et al.*, 1982; Saif *et al.*, 1986). However, our survey indicates that faecal excretion of viral particles is very rapid and transient. It may even start during the period of hyperthermia prior to any sign of diarrhoea, which could explain the difficulty in detecting a coronavirus in affected cattle (Van Kruiningen *et al.*, 1985). It would be advisable to examine the faeces for the presence of virus as soon as the rectal temperature exceeds 39°C.

TABLE IV
Faecal flora of diseased cows at the time that diarrhoea occurred

Bacterial genus	Number of positive samples ($n = 34$)
Proteus	4
Bacillus	13
Streptococcus	10
Pseudomonas	2
Escherichia	5
Campylobacter	0

The frequency of outbreaks of the disease in a herd may vary from a few months to 10 years and our observations suggest that immunity may last for two years. In herds regularly exposed to the disease the outbreaks would be rather mild, whereas when the intervals between recurrences are large (>3 years) the outbreaks would be more severe on an economic basis.

The role of predisposing factors is clearly emphasized by our study. A high incidence of the disease occurred on farms with traditional management conditions where the area available per animal was larger or smaller than that usually recommended. These observations confirmed previous observations (Espinasse *et al.*, 1981; 1982).

Environmental factors related to climatic conditions have already been demonstrated by other authors (Scott *et al.*, 1973; Campbell and Cookingham, 1978; Van Kruiningen *et al.*, 1985). The epidemiology of winter dysentery in France was associated with the winter months and early lactation in housed cattle. In contrast with previous studies (Scott *et al.*, 1973), the age of the animals was not a determining factor in our study. The sudden drop in body temperature, due for example to drinking water, which precedes the onset of the disease, is in agreement with previous observations made by Bull (1957), MacPherson (1957) and Johnston (1959). More recently, Stermer *et al.* (1986) demonstrated that the ingestion of 3.9 kg of water at 1°C by a dairy cow led to a significant decrease in rectal temperature of 0.3°C within 20 min, and it is supposed that the intake of very cold feed or water induces a thermal stress which facilitates the onset of diarrhoea. Moreover, as suggested by Collins *et al.* (1987) and by Buglin *et al.* (1989), dairy cows may be healthy carriers of coronavirus, so that a sudden change in the environmental conditions may provoke the development of clinical features. These remarks confirm the concept that there is a relationship between the disease and the environment (Dennis, 1986). The latter may, in some cases, contribute to the transmission of aetiological agents and to reducing the host immune resistance (Dennis, 1986).

Analysis of individual production curves allows more accurate estimation of milk loss than a study of the herd mean production (Kahrs *et al.*, 1973). Loss of milk production ranged between 25% and 95% in severe cases but in mild outbreaks milk production was little affected. The later rapid rise in the lactation curve would correspond to the effect of treatment or to a reaction after a prolonged decrease in production (Lucey *et al.*, 1986). Generally speaking, economic studies have a tendency to overestimate the production losses but to underestimate the economic consequences to the farmer, which include the animal's weight loss, the effect on their future reproduction performance and the cost of treatment.

ACKNOWLEDGEMENTS

The authors thank Ms G Bourroche (INRA) for the translation of this paper and the 'Direction Générale de l'Enseignement et de la Recherche' (Ministère de l'Agriculture) for its financial support.

REFERENCES

Alenius, S., Juntti, N., Niskanen, R., Järnberg, E., Näslund, K. and Larsson, B., 1988. Epizootic diarrhea (winter dysentery) of dairy cattle in Sweden caused by bovine coronavirus. *XV Congresso Mundial de Buiatria, Palma de Mallorca, 1988*, 2, 1505–1506

Akashi, H., Inaba, Y., Miura, Y., Tokuhisa, S., Sato, K. and Satoda, K., 1980. Properties of a coronavirus isolated from a cow with epizootic diarrhea. *Veterinary Microbiology*, **5**, 265–276

Benzecri, J.P., 1980. *L'analyse des données, Tomes 1 et 2*, (Dunod Editeur, Paris)

Buglin, M.S., Ward, A.C.S., Barrett, D.P. and Lane, M., 1989. Detection of rotavirus and coronavirus shedding in two beef cow herds in Idaho. *Canadian Veterinary Journal*, **30**, 235–239

Bull, W.S., 1957. Entefur therapy in calf enteritis and winter dysentery. *The North American Veterinarian*, **38**, 3–6

Campbell, S.G. and Cookingham, C.A., 1978. The enigma of winter dysentery. *Cornell Veterinarian*, **4**, 423–441

Cauchy, J.C., 1986. *Epidémiologie du coronavirus bovin. Mise au point d'une méthode de diagnostic sur les matières fécales par un test ELISA*. (Unpublished thesis for Doctor of Veterinary Medicine, Ecole Nationale Vétérinaire d'Alfort)

Charton, A., Faye, P., Lecoanet, J., Desbrosse, H. and Le Layec, C., 1963. Etude clinique et expérimentale d'une entérite hémorragique hivernale des bovins associée à la présence dans le tube digestif d'un ultravirus pathogène. *Recueil de Médecine Vétérinaire*, **139**, 897–908

Collins, J.K., Riegel, C.A., Olson, J.D. and Fountain, A., 1987. Shedding of enteritic coronavirus in adult cattle. *American Journal of Veterinary Research*, **48**, 361–365

Dennis, M.J., 1986. The effects of temperature and humidity on some animal diseases. A review. *British Veterinary Journal*, **142**, 472–485

Durham, P.J., Stevenson, D.J. and Farquharson, B.C., 1979. Rotavirus and coronavirus associated diarrhea in domestic animals. *New Zealand Veterinary Journal*, **27**, 30–32

Edwards, M.J. and Sier, A.M., 1980. Bovine epizootic diarrhoea in western Australia. *Australian Veterinary Journal*, **36**, 402–404

Espinasse, J., L'Haridon, R., Viso, M., Savey, M., Laval, A., Le Layec, Cl., Blot, J.P. and Cohen, J., 1981. Mise en évidence d'un agent du type coronavirus dans les fèces des bovins atteints d'entérite hémorragique d'hiver (winter dysentery). *Bulletin de l'Académie Vétérinaire de France*, **54**, 465–472

Espinasse, J., Viso, M., Laval, A., Savey, M., Le Layec, Cl., Blot, J.P., L'Haridon, R. and Cohen, J., 1982. Winter dysentery: a coronavirus-like agent in the faeces of beef and dairy cattle with diarrhea. *The Veterinary Record*, **110**, 385

Faye, B. and Brochart, M., 1986. Enquête écopathologique continue. 7. Approche épidémiologique des mammites post partum chez la vache laitière. *Annales de Recherches Vétérinaires*, **17**, 297–313

Fenelon, J.P., 1981. *Qu'est-ce que l'analyse des données?* (Lefonen Editeur, Paris)

Hedstrom, H. and Isaksson, A., 1951. Epizootic enteritis in cattle in Sweden. *Cornell Veterinarian*, **41**, 251–253

Horner, G.W., Hunter, R. and Kirkbridge, C.A., 1976. A coronavirus like agent present in faeces of cows with diarrhoea. *New Zealand Veterinary Journal*, **23**, 48

Jactel, B., Espinasse, J. and Grelet-Puterflane, Y., 1990. L'entérite hémorragique hivernale en France. Etude épidémiologique. *Cahiers de l'analyse des données* (in press)

Johnston, K.G., 1959. The virus diarrhoeas of cattle and similar diseases. *Australian Veterinary Journal*, **35**, 101–110

Jones, F.S. and Little, R.B., 1931. The etiology of infectious diarrhoea (winter scours) in cattle. *Journal of Experimental Medicine*, **53**, 835–843

Jones, F.S., Orcutt, M. and Little, R.B., 1931. Vibrios (*Vibrio jejuni*) associated with intestinal disorders of cows and calves. *Journal of Experimental Medicine*, **53**, 853–863

Kahrs, R.F., Scott, F.W. and Hillman, R.B., 1973. Epidemiologic observations on bovine winter dysentery. *The Bovine Practitioner*, Nov., 36–39

Komarov, A., Goldsmit, L., Kalmar, E., Adler, J.H. and Egued, M., 1959. Isolation of a viral agent from winter dysentery of cattle. *Refuah Veterinaria*, **16**, 152–159

Lucey, S., Rowlands, G.J. and Russell, A.M., 1986. Short term associations between disease and milk yield in dairy cows. *Journal of Dairy Research*, **53**, 7

MacPherson, L.W., 1957. Bovine virus enteritis (winter dysentery). *Canadian Journal of Comparative Medicine*, **21**, 184–192

Roberts, S.J., 1957. Winter dysentery in dairy cattle. *Cornell Veterinarian*, **47**, 372–388

Rolle, M., Mundt, N. and Zintz, G., 1955. Vibrio jejuni als enteritiserregerbeim rind. *Tierärztlische Umschau*, **10**, 391–392

Rollinson, D.H.L., 1948. Infectious diarrhoea of dairy cows. *The Veterinary Record*, **60**, 191–192

Saif, L.J., Redman, D.R., Brock, K.V., Kohler, E.M. and Heckert, R.A., 1988. Winter dysentery in adult dairy cattle: detection of coronavirus in the faeces. *The Veterinary Record*, **123**, 300–301

Saif, L.J., Redman, D.R., Moorhead, P.O. and Theil, W., 1986. Experimentally induced coronavirus infections in calves: viral replication in the respiratory and intestinal tracts. *American Journal of Veterinary Research*, **47**, 1426–1432

Scott, F.W., Kahrs, R.F., Campbell, S.G. and Hillman, R.B., 1973. Etiologic studies on bovine winter dysentery. *The Bovine Practitioner*, **8**, 40–43

Stermer, R.A., Brasington, C.F., Coppolk, C.E., Lanham, J.K. and Milam, K.Z., 1986. Effect of drinking water temperature on heat stress of dairy cows. *Journal of Dairy Science*, **69**, 546–551

Takahashi, E., Inaba, Y., Sato, K., Ito, Y., Kurogi, H., Akashi, H., Satoda, K. and Omori, T., 1980. Epizootic diarrhea of adult cattle associated with a coronavirus-like agent. *Veterinary Microbiology*, **5**, 151–154

Thomas, L.H., Gourlay, R.N., Scott, E.J., Howard, C.J. and Bridger, J.C., 1982. A search for a new microorganism in calf pneumonia by the inoculation of gnotobiotic calves. *Research in Veterinary Science*, **33**, 170–182

Van Kruiningen, H.J., Hiesand, L., Hill, D.L., Tilton, R.C. and Ryan, R.W., 1985. Winter dysentery in dairy cattle: recent findings. *Compendium on Continuing Education for the Practicing Veterinarian*, **7**, S591–S598

Van Kruiningen, H.J., Khairallah, L.H., Sasseville, V.G., Wyand, M.S. and Post, J.E., 1987. Calfhood coronavirus enterocolitis: a clue to the etiology of winter dysentery. *Veterinary Pathology*, **24**, 564–567

Wood, P.D.P., 1967. Algebraic model of the lactation curve in cattle. *Nature*, **216**, 164–165

(Accepted: 17 March 1990)