4B.5 THE OCCURRENCE OF ABOMASAL DISPLACEMENT IN DAIRY COWS MODIFIED BY THE WEATHER SITUATION

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1. INTRODUCTION

The left-side displacement of the abomasum (DA) or the right-side DA with dilatation and / or torsion is a frequent pathological phenomenon not only due to the increment of animal production, but also to the increase in size of the dairy cow. In the dairy cows' clinic the pathology's diagnosis has become a daily routine (Geishauser, 1996, Geishauser et al., 1998).

This pathology is responsible for the losses in production and income of the farms. Those take place not just due to direct loss, but also to the expenses with medicines and to the costs inherent to a more frequent veterinary intervention. The literature available explains well the pathology's relation with delivery, milk drying period and with feeding and handling errors. However, there are no data establishing its relation with the occurrence of various weather situations (Dirksen, 1962; Geishauser, 1995; Martens, 2000; Massey and others, 1993).

In Portugal, the indicators point to an increasing number of cases of abomasal displacement. This can be explained by a more efficient diagnosis by the veterinary surgeon, as well as by the increasing concern of producers with the pathology, which in turn entails better techniques of diagnosis.

The purpose of this work is to study the possible effects of various weather situations, on the occurrence of abomasal displacement, over a certain period of time, independently of the other causes, which are well documented and studied in the literature.

The objective was the question if the weather does influence the occurrence of DA. The weather situation was represented by various meteorological parameters. Beside the influence of these parameters on the occurrence of DA the temporal patterns of these parameters were used as a predictor for the DA.

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The indirect influence of weather changes in some pathologies has been studied particularly by the Biometeorology International Society (Carvalho, 1999). This society has discussed the weather as a cause of several diseases in humans, e.g. respiratory and heart diseases, diseases of the autonomic nervous system, among others.

2. MATERIAL AND METHODS

2.1. Observation of Abomasal Displacement

The concerned veterinary practice covers 62 farms. Despite providing herd health management services in the areas of handling, reproduction and management of about 15 000 milk cows (distributed over the Beira Litoral, Ribatejo and Oeste, Estremadura, Tagus Valley and Alentejo regions) no clinical intervention will be performed in all the farms. Feeding in the farms remains unchanged over the year. At present milk production is ranging from 8000 to 9500 litres in 305 days (Anables, 1999, 2000, 2001). The farms in which no clinical activity has been carried out were not included in this study. All together about 6500 dairy cows in 26 farms only at the Lisbon area are used in this study. The farms keep between 100 and 1000 cows in production (meaning an average of 250 animals per farm). The stables are of free type with cubicles, with beds of different materials, e.g. sawdust, rubber carpets, sand or straw. The deliveries are distributed all over the year with little fluctuations (Cannas da Silva, 2003).

All the farms feed with TMR (total mix ration). The main basic food is corn silage. The hay usually used is from lucerne or rye grass. The basis of the concentrates is corn flour, Soya 44 %, beetroot and citrine pulp as well as gluten feed.

The variation, both of the basic food and the ingredients, is very small and irrelevant. The aim of these farms is to keep feeding as uniformly as possible over the year. The amount of corn silage varies between 18 and 30 kg / cow / day. The amount of hay is never inferior to 2 kg / cow / day. Feeding is adequate to the level of production.

In the farms of the study the dry cows are fed differently, usually with rye grass hay, wheat or oat straw and the concentrate specific for dry cows.

The animals are moved to another park about 15 days before the date in which delivery is due so that there is a slow transition between the food of the dry period and the food of the production period, in order for the rumen to slowly adapt to the feeding of production.

2.2. Meteorological parameters which characterise the weather situation

The weather situation was represented by several meteorological parameters. The data were obtained from the Gago Coutinho Meteorological Station Lisbon containing following parameters: atmospheric pressure at sea level at 09 UTC (hPa), atmospheric pressure at sea level at 18 UTC (hPa), relative humidity at 09 UTC (%), relative humidity at 18 UTC (%), precipitation (mm), daily insolation (h), maximum air temperature (°C), minimum air temperature (°C), and average wind velocity (km/h). The meteorological parameters were modified and adapted to the special needs of this investigation (see in detail Cannas da Silva, 2003). Following parameters were used for the analyses on a daily basis: precipitation R, insolation S, wind velocity V (without modification) and mean atmospheric pressure P, temperature range of the day $T_r=T_{max}-T_{min}$, mean air temperature $T=(T_{max}-T_{min})/2$; mean water vapour pressure E, and mean relative humidity H.

2.3. Statistical procedures

To investigate the main periods of the time series x the auto-correlation AC function was calculated, which gives the auto correlation coefficient $r_x(\tau)$ as a function of the time lag τ. By the AC function the time series of the DA observation and all meteorological parameters were tested with a lag up to τ=15d.

Tab. 1: Descriptive statistics of the meteorological parameters for the entire two year period (all), the day with DA observation (DA) and the days without DA observation (nDA)

	P	P_9	P_{18}	E	H	H_9	H_{18}	T	T_{max}	T_{min}	T_r	R	S	V
All														
N	732	732	732	732	732	732	732	732	732	732	732	732	732	732
Mean	1018.5	1019.1	1017.9	14.1	71.3	74.8	66.2	17.1	21.0	13.2	7.8	1.9	7.6	13.0
Median	1018.6	1019.1	1017.8	14.1	72.2	75.0	67.0	16.6	20.2	13.4	7.4	0.0	8.5	12.4
Std.dev.	6.3	6.6	6.2	3.6	14.1	13.9	15.9	5.0	6.1	4.2	3.3	5.5	4.1	4.6
Min	988.8	986.1	991.5	5.1	26.8	30.0	18.0	6.1	8.5	1.7	0.5	0.0	0.0	3.2
Max	1037.0	1037.3	1036.6	24.4	98.0	98.0	98.0	29.8	37.5	23.5	19.0	46.0	14.0	34.3
Lower Q	1015.0	1015.4	1014.4	11.2	62.7	66.0	57.0	13.2	16.2	10.0	5.5	0.0	4.6	9.7
Upper Q	1022.2	1022.9	1021.6	16.7	81.4	85.0	77.0	20.9	25.3	16.5	9.8	1.0	11.2	15.8
nDA														
N	493	493	493	493	493	493	493	493	493	493	493	493	493	493
Mean	1018.5	1019.1	1017.9	14.2	69.9	73.8	64.6	17.5	21.5	13.5	8.1	1.7	7.8	12.9
Median	1018.5	1019.1	1017.7	14.5	70.8	75.0	65.0	17.3	20.9	14.0	7.8	0.0	8.6	12.4
Std.dev.	6.1	6.4	6.0	3.7	14.3	14.1	16.1	5.1	6.3	4.3	3.4	5.0	4.1	4.5
Min	988.8	986.1	991.5	5.1	29.7	30.0	18.0	6.1	9.0	1.7	0.6	0.0	0.0	3.7
Max	1037.0	1037.3	1036.6	24.4	98.0	98.0	98.0	29.8	37.5	23.5	19.0	37.0	13.8	34.3
Lower Q	1015.1	1015.6	1014.6	11.3	61.2	65.0	54.0	13.5	16.6	10.2	5.8	0.0	4.9	9.6
Upper Q	1021.7	1022.6	1021.1	16.8	80.6	84.0	76.0	21.6	26.0	17.0	10.2	0.0	11.4	15.5
DA														
N	239	239	239	239	239	239	239	239	239	239	239	239	239	239
Mean	1018.6	1019.1	1018.0	13.9	74.0	76.9	69.4	16.2	19.8	12.6	7.2	2.5	7.2	13.3
Median	1018.7	1019.0	1018.3	13.6	74.4	77.0	70.0	15.2	18.3	12.5	6.8	0.0	7.8	12.4
Std.dev.	6.7	6.9	6.7	3.5	13.3	13.4	15.0	4.7	5.8	4.0	3.1	6.5	4.1	4.7
Min	996.6	995.7	996.4	5.2	26.8	30.0	21.0	6.3	8.5	2.6	0.5	0.0	0.0	3.2
Max	1034.4	1035.5	1033.4	22.9	97.5	97.0	98.0	29.7	36.4	23.0	17.6	46.0	14.0	27.3
Lower Q	1014.6	1015.2	1014.3	11.2	66.6	68.0	61.0	13.0	15.4	9.7	4.9	0.0	3.8	9.8
Upper Q	1022.9	1024.2	1022.7	16.5	83.7	88.0	80.0	20.0	24.0	15.6	9.1	1.0	10.7	16.7

Mean atmospheric pressure P (hPa), atmospheric pressure at 09:00 UTC P_9 (hPa), atmospheric pressure at 18:00 UTC P_{18} (hPa), water vapour pressure E (hPa), relative humidity H (%), relative humidity at 09:00 UTC H_9 (%), relative humidity at 18:00 UTC H_{18} H (%), temperature T (°C), maximum temperature T_{max} (°C), minimum temperature T_{min} (°C), temperature range T_r (°C), precipitation R (mm), insolation S (h), wind speed V (km/h)

The phase shift between the time series of the DA observation and the meteorological parameters was identified by using cross correlation analyses.

The similarity in the time pattern of two time series DA and one of the meteorological parameters y, each with N data points, can be calculated by using the coefficient of cross correlation $r_{DA,y}(\tau)$, where τ is a variable that designates a time shift (lag) of one series with respect to the other between -15 days and +15 days. The correlation $r_{DA,y}(0)$ will give an indication of pattern similarity of the two sets of data without any time shifting. An objective measure of the actual time shift between two similar patterns is the τ=m at which the $r_{DA,y}(m)$ shows a local maximum. A local maximum with a time lag $\tau<0$ ($\tau>0$) means that the DA observation can be expected in advance (delayed) to the selected meteorological parameter.

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The critical value of the cross correlation coefficient r^* was calculated according to

$$r^* = \frac{t}{\sqrt{N-|\tau|+t^2-2}}$$

by the Student t distribution t(DF,p) with the degree of freedom DF=N-|τ|-2, and the level of significance p (Sachs, 1992). The level of significance p was preselected by 0.05, 0.01, and 0.001.

3. RESULTS

In this work, we consider 372 cases of abomasal displacement. In the year 2000 (2001) 173 (199) DA were observed distributed on 125 (114) days. A majority of 93% of these cases were observed on the left side and only 7% on the other side. The annual variation (Fig. 1) is shown by a box-plot for each month with a distinct maximum for January and a minimum for August.

The occurrence of DA was compared to Poisson density distribution. The empirical distribution (black bars) of the number of DA per pentad is shown in Fig. 2. The mean were 0.508 DA per day (not shown) and 2.54 DA per pentad, respectively. For this values the Poisson distribution were calculated (grey bars). The two distributions were tested by a χ^2 test. The Poisson distribution fits both empirical distribution on a statistical level of p=0.05.

To test if DA occurrence is randomly distributed over time, the distributions for the day of the week were calculated. In Fig. 3, the mean prevalence (per day) was depicted. The distribution shows a distinct deviation from an even distribution with a mean value of 0.508 DA per day. The assumption of an even distribution has to be rejected by a χ^2 test on a p=0.01 level. The distribution shows local maximum on Monday, Wednesday, and Friday.

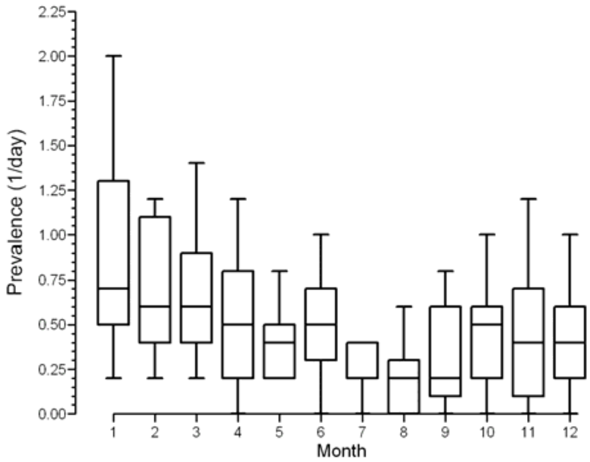

Fig. 1: Box plot of the mean prevalence of DA (1/day) calculated for each month with median, ± quartiles, and ± inner fences (1.5 inter quartile range)

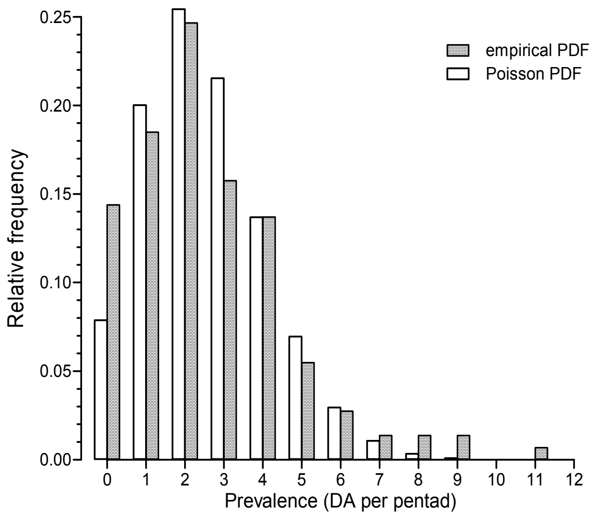

Fig. 2: Relative frequency distribution of the number of DA per pentad. The empty bars show the Poisson distribution for a mean value 2.54 DA per pentad, the grey bars the empirical density distribution. The Poisson distribution fits the empirical distribution on a statistical level of p<0.05.

Beside the influence by the day of the week the occurrence of DA on consecutive days was analysed. In Fig. 4, the absolute frequency of the duration of consecutive days with DA observations and the duration of consecutive days without DA (nDA) observations are presented. The overall frequency of periods with DA observations is the same (n=157) as for non DA observations (n=157). Therefore the absolute frequency of the two categories (DA and nDA) can be compared directly. The longest period of DA observations lasts for 7 days (n=1). Between 3 to 7 day duration the absolute frequency is low with values between 1 and 2. Only periods with a duration of 3 days and shorter were observed much more frequently between 105 (one day) and 13 (three days). The longest period without DA observations (nDA) was two weeks (14 days). The frequency of the periods without DA is higher, up to a period duration of two days. Only for one day the frequency of nDA is lower as for DA observations.

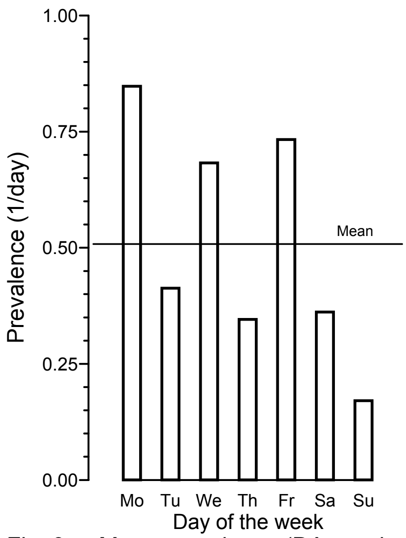

Fig. 3: Mean prevalence (DA per day) over the days of the week and mean value for all days (0.508 / day)

If the observations of DA and nDA periods were distributed randomly over the two year period this could not be tested. It could be demonstrated that the influence of the day of the week cannot be assumed as random because the DA observations were not evenly distributed. Therefore we have an interaction with the day of the week. Thereby for periods with DA observations we can assume an increase respectively decrease of the probability which cut or enlarge such periods, depending on the day of the week.

By the fact that DA predominantly occurred between 5 and 35 days after calving (Dirksen et al., 2002) the temporal change of the calving would bias the occurrence of DA. To exclude such a bias calving should be distributed evenly over a year. The calving distribution over the months was tested by a χ^2 test showing an even distribution which means that there is no seasonal influence of calving on the observation of DA.

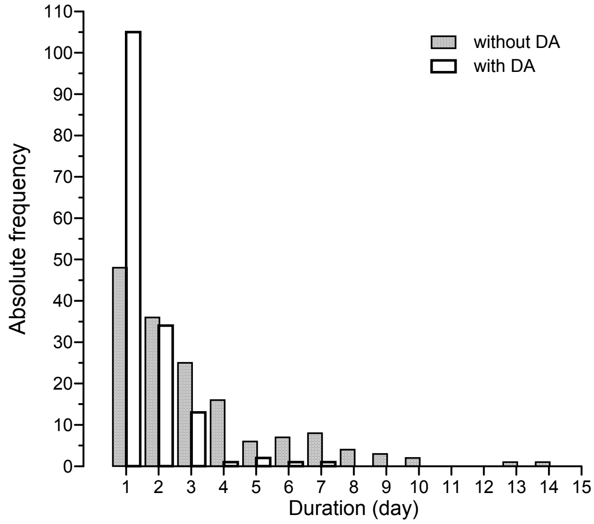

Fig. 4: Absolute frequency distribution of the duration of consecutive days with DA (DA) observations and the duration of consecutive days without DA (nDA) observations

Tab. 2: Correlation and regression analysis for the relationship of the prevalence of DA (median for each pentad) with the modified meteorological parameters (median per pentad) (N=146). Pearson correlation coefficients are statistically significant on the p=0.05 level (two-tailed). The coefficient of determination (r^2) gives the explanation of the variance by using a linear model. The parameters of the regression line, slope a and intercept b are depicted only for those cases which are statistically significant. For atmospheric pressure P and wind velocity V the correlation coefficient was not significant.

	E	H	T	T_r	R	S
r	-0.233	0.260	-0290	-.266	0.289	-0.224
r²	0.054	0.068	0.084	0.071	0.084	0.050
a	-0.031	0.009	-0.025	-0.042	0.007	-0.025
b	0.940	-0.166	0.944	0.836	0.438	0.710

Atmospheric pressure P (hPa), water vapour pressure E (hPa), relative humidity H (%), temperature T (°C), temperature range T_r (°C), precipitation R (mm), insolation S (h), wind speed V (km/h)

Tab. 1 depicts the descriptive statistic of the meteorological parameters for all cases (N=732), days with DA observation DA (N=239), and days without DA observation nDA (N=239). Comparing these two groups (nDA and DA), differences can be seen for some parameters (eg. mean or me-

dian). These differences were not statistically significant (Cannas da Silva, 2003).
The influence of meteorological parameters on the occurrence of DA was investigated by a correlation and regression analysis using the median per pentad of a selected meteorological parameter and the mean prevalence of DA per pentad. Some of the meteorological parameters show a weak linear relationship with the occurrence of DA (Tab. 2). Only atmospheric pressure P and wind velocity V were not statistically significant on the p=0.05 level. The coefficients of determination, which gives the percentage of the variance which can be explained by the linear model, were below 10 % for all parameters.
The highest values for the coefficient of determination were found for air temperature T and precipitation R with 8.4 % for both parameters. The prevalence of DA is higher for lower water vapour pressure E, high relative humidity H, lower temperature T, lower temperature range T_r, high precipitation R, and low insolation S, and vice versa.
The modified meteorological parameters were used as independent variables for the regression analysis. To investigate the relationship between these parameters the cross-correlation was analysed. Some of the coefficients show a strong correlation between meteorological parameters. The highest correlation was found between temperature T and water vapour pressure E. High correlation between temperature range T_r and water vapour pressure E has been found. Insolation S shows also correlation with temperature T and temperature range T_r.

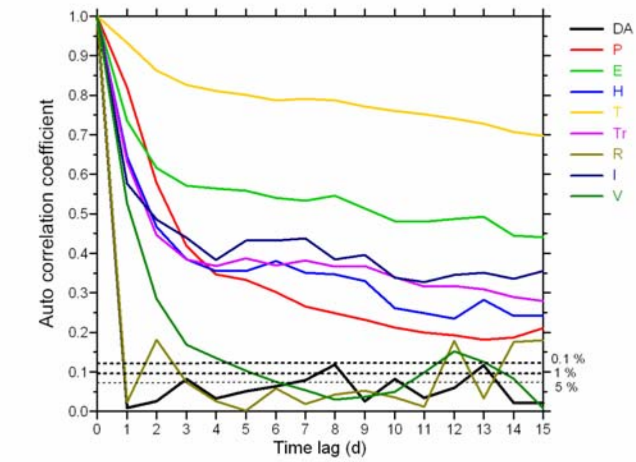

Fig. 5: Auto correlation coefficient for a time lag of 15 days for the time series of the DA observation and the modified meteorological parameters. The limits of significance are given for 0.1%, 1%, and 5%.

By means of auto-correlation analysis the persistency of the time series of the DA observation and the modified meteorological parameters were investigated (Fig. 5). The DA observation had the lowest correlation coefficient which means that this time series has no long term memory (anti-persistent), similar to a random walk process. A similar behaviour could be found for precipitation R and the wind velocity V.
For all other time series the auto correlation coefficient was above the 0.01% level of significance up to a time lag of ± 15 days. The highest persistency was found for the temperature T followed by water vapour pressure E.

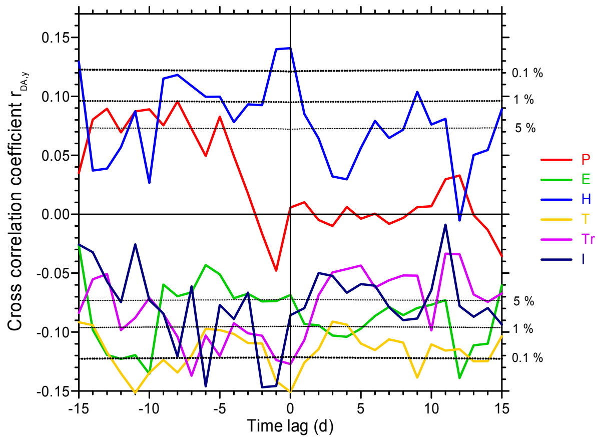

Fig. 6: Cross correlation coefficient rDA,y for a time lag of ±15 days between the time series of DA observations and the modified meteorological parameters. The limits of significance are given for 0.1%, 1%, and 5%.

The cross correlation coefficient $r_{DA,y}$ between DA observation and the modified meteorological parameters were used to find the phase position of the investigated time series. In Fig. 6 the cross correlation function for all meteorological parameters were included which were above the 5% level of significance. Therefore precipitation R and wind velocity V were eliminated.
A positive cross-correlation coefficient was found for relative humidity H and atmospheric pressure P. Relative humidity shows a distinct maximum for lag τ=0d, τ=-8d, and τ=9d. For atmospheric pressure P a significant correlation was found for a lag between τ=-5d and τ=-14d which means that the prevalence for DA is higher 5 to 14 days in advance when atmospheric pressure P will be increased. No correlation was found for τ>0.
The other meteorological parameters show negative correlation which means that an increase of the prevalence of DA is correlated with a decrease of the meteorological parameter. Temperature T showed high correlation with a maximum at τ=0d, τ=-9d, and τ=9d. The values for all lags are lying above the 5% level of significance. Beside the

temperature T also temperature range T_r and relative humidity H have maximum close to τ=0d. The temperature range T_r and the insolation S show higher values for a negative lag. Water vapour pressure E has two maxima at a lag of -13d to -10d and for a lag τ=12 d.

The cross correlation analysis showed following results. For some meteorological parameters (eg atmospheric pressure P) high cross-correlation was found for a negative lag. This means that the occurrence of DA can be expected in advance of a change of this meteorological parameter. Especially for atmospheric pressure P this could be interpreted by the approach of pressure pattern like a cold front. For parameters which describe the thermal properties of the air mass (like temperature T or relative humidity H) a minimum could be found for the day of the DA occurrence (± 1 - 2 days). For insolation S and the temperature range T_r and temperature T a minimum of the cross-correlation coefficient between a lag around 0d and 2 to 4 days could be found. This can be interpreted that between the day of the DA occurrence (τ=0d) and some days in advance a decrease of these parameters go parallel with the increase of the DA prevalence. This is a good indication, that the change from sunny (insolation and temperature range) warm (temperature) and dry (relative humidity) weather to overcast, cool and humid days is correlated with the increase of the DA prevalence.

4. DISCUSSION

In 1950, Begg described the first cases of displacement of the abomasum. Today this disorder has become very common in dairy cattle. It is considered that increased production of gas in the abomasum and hypomotility as well as dilatation of the abomasum are essential prerequisites for the occurrence of this disease (van Winden and Kuiper, 2003). Numerous controlled studies have been performed in an attempt to clarify risk factors for abomasal displacement in dairy cows. Risk factors for DA are: cows in the first four to six weeks after calving, production level, dry and milking cow nutrition (negative energy balance, low dietary crude fever, high level grain feeding), metabolic alkalosis, concurrent diseases (ketosis, retained placenta, a stillborn calf, metritis, twins, parturient paresis), age, breed, genetic predisposition, lameness, and some environmental aspects (Dirksen and others, 2002).

The purpose of the study reported here was to evaluate whether parameters like air temperature, wind, atmospheric pressure, insolation, and precipitation as well as seasonal and circadian rhythms are associated with an increased risk of abomasal displacement in dairy cows.

To eliminate any bias due to a clustering of the occurrence of DA caused by other factors than the meteorological situation, the distribution over time was tested. Over the two year period the empirical data of DA observations can be described by a Poisson density distribution for the mean prevalence per day and per pentad (Fig. 2).

The Poisson distribution means that DA can be handled as a rare event. By the fact that more than 90 % of DA occur between 5 and 35 days after calving, the temporal distribution of calving over the year was analysed. It could be shown that calving was evenly distributed over the two year period. This means that no annual variation of calving could be found in the data set. The evenly distributed calving over the entire year is a very important attribute of the data-set, because this means that the even distribution avoids an annual bias which would also bias the influence of meteorological parameters due to their strong annual variation.

The assumption that DA is evenly distributed over the days of the week has to be rejected. This has to be taken in mind if the duration of consecutive days with or without DA observations is investigated (Fig. 4). The uneven distribution of DA over the days of the week can be explained by the behaviour of the farmers. All farms are serviced on each day of the year. However, farmers identify problems for example on Saturday or Sunday but will report usually on Monday. In that day, the cases from Saturday to Monday are counted, and normally some more cows are observed. Therefore, there will be fewer cases next day. So it can be considered that the DAs on Monday do not represent 1/7 of the probability. A similar situation can be expected on Fridays, when more cases will be reported by farmers than under the assumption of an even distribution (probability is 1/7 per day) to avoid a call of the veterinarian on weekend.

For the investigation of the relationship between weather and DA nine meteorological parameters were available. The redundancy was quite high with two parameters for atmospheric pressure (for 9:00 and 18:00 UTC) and two values for the relative humidity (for 9:00 and 18:00 UTC). For wind only the mean velocity was available, wind direction was missing. No data were accessible for cloud cover. Based on these nine parameters other meteorological parameters were assessed: mean air temperature, mean water vapour pressure, mean relative humidity, and mean air temperature. These modified meteorological parameters were used for the statistical analyses.

To discuss the influence of various meteorological parameters on the organism combined parameters are in use. One is the wind chill temperature which combines the air temperature and the wind velocity to one single value to describe the energy loss. The second relationship combines air temperature and relative humidity and is called Heat Index or Temperature-Humidity Index. This value is used to describe the heat stress of the organism. These two empirical relationships (wind chill temperature and thermal heat index) were adopted to cover the special needs of cattle and can be found in *http://agweather.mesonet.ou.edu/models/cattle/description.html*.

These values were not taken into account by several reasons: (1) The cows used in the study were not living outside the farm building. They are protected by a roof which modifies the parameters to a quite extent. Therefore the meteorological parameter does not represent the thermal environment of the animals directly. (2) The meteorological parameters were not available on hourly basis. Therefore the combined values could not be calculated in sufficient accurate way.

For the investigated farms the direct influence of air temperature (heat stress) is not relevant because the stables are provided with fans and/or thermostats associated with water spraying to reduce heat stress in summer.

For the correlation and regression analysis only weak correlations could be found. The coefficient of determination was between 0.050 and 0.084 which means that only 5 to 8 % of the total variance could be explained by a linear model with only one meteorological parameter (Tab. 2). On the other hand the cross-correlation between the 8 modified parameters was quite high. This means that the meteorological parameters can not be handled as independent variables to detect the expected relationship.

A higher (lower) probability of DA can be expected for following parameters: (i) low (high) water vapour pressure, (ii) high (low) relative humidity, (iii) low (high) air temperature, (iv) low (high) temperature range, (v) high (low) precipitation, and (vi) low (high) insolation. For wind velocity and atmospheric pressure no statistically significant linear regression could be found.

The change from warm, sunny, and dry days to cool, overcast, and humid days could be identified as a risk factor by the cross-correlation analyses. Further on, a higher prevalence of DA can be expected in advance of a temporal change of atmospheric pressure.

Van Winden (2002) summarises environmental aspects like season, weather, and housing system and housing quality. Reports of occurrence of DA in different seasons are not concise; in general most cases occur in winter (Cameron et al., 1998; Constable et al., 1992; Correa et al., 1990). This seasonal influence was also found for Slovenia by Zadnik et al. (2001). The hypothesised reason for this high incidence is the declining quality of the stored roughage over winter, with possibly poor intake of roughage as a result. There is evidence that besides season weather conditions influence the incidence of DA. Rainfall, low temperature and strong wind increase the incidence of DA cases when cows are at pasture, probably via a reduced intake of roughage. No recent epidemiological reports are available about the effect of housing systems and –quality, nor about the effects of walking exercise of the cows (van Winden, 2002).

There exist some references where higher occurrence of cases of DA in the beginning of spring and beginning of summer are described (Constable and others, 1992; Radostits, 2000). This can be partly explained by the regression analyses if we assume low insolation, high precipitation, a lower temperature range and higher relative humidity for spring and early summer.

From the present work it can be concluded that the meteorological situation has an influence on the occurrence of abomasal displacement. Therefore the weather situation should be included among the predisposing causes of the occurrence of abomasal displacements. Other factors which predispose the occurrence of DA should be planned in combination with the weather forecast. Avoiding the simultaneous manifestation of known risk-factors with stress caused by the weather situation would reduce the appearance of DA.

5. REFERENCES

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