and Clark (1981) used a system based on a combined electro-optical principle, which dates back to Chodera and Lord (1978) and was improved by Betts et al(1980). The complexity of the system together with considerable installation requirements and a limited resolution capacity contrast with a simple measuring device which is easily manageable.

The Kistler-force-plate, as used in motion analysis to register movement problems of horses and sheep (see Schnabl et al.. 1985; Knecevic, 1985), is an effective instrument for the verification of direction as well as time of total weights resting on the extremities in dynamic measurements. However, for purposes of static pressure distribution measurements, the distribution of weight on the individual regions of the sole area has to be evaluated.

Whilst it is true that the newer electronic pressure distribution measuring processes largely meet the demands within the human-physiological area with a view to area resolution, measurement accuracy and questioning quota, greater demands are made on the measuring apparatus as to mechanical robustness and reliability and simultaneous measuring accuracy in the case of the determination of pressure distribution on the sole area of cattle feet in measuring environments and testing conditions which are sometimes rough. Thus a measuring system has to be able to register the resulting weights on partial areas, i.e. pressures, in a way which covers all the areas. The more tightly the measuring sensor network is planned, the more exact is the local resolution of the partial weights.

The computerised measuring system presented in this paper is able to register the pressure distribution on cattle feet. Developing the electronic measuring device, importance was attached to a high degree of accuracy, area resolution, and questioning quota, combined with mechanical robustness. In addition, the measuring device should be easily manageable and transportable.

Description of the Measuring System

An electronic measurement installation was developed for determining pressure in the ground surface of claws. The electronic measuring system consists of a recording unit, a microcomputer with appropriate additional devices and adequate interfaces between recording unit and the microcomputer (figure 2). The recording unit is built up by three basic units:

- measuring plate (sensor matrix) for transformation of forces into proportional electric signals,
- signal processor for the processing of analogous measurement signals and conversion of these signals into digital values,
- matrix control for the selection of measuring sensors on the plate.

Due to favourable positioning ability of cattle feet during static pressure distribution measurements, the size of the measuring plate has been limited to 14 cm x 28 cm in the interest of high questioning rates. The sensitive measuring face is protected by a covering rubber sheet. For further clarification a cutaway model of the

platform is illustrated in figure 3. The newly developed measuring device makes it possible to quantify the pressure distribution in claws by force-measuring sensors. The sensors convert a vertical force into a proportional electric signal. Up to four sensors per square centimetre register independently the applied pressure. The sensors represent small individual plate condensers. The distance between the plates is proportional to the applied pressure. Therefore every change in the applied pressure on the sensor leads consequently to a change of the capacity of the condenser, which can be measured by a decreasing or increasing amplitude of the signal voltage. The properties of a compressible dielectric, which is between the plates of the condenser, are responsible for the measuring range. The most significant demands made on the dielectric are:

- a very high electric resistance
- reversible compressibility
- small hysteresis of the compression
- little influence on neighbouring zones.

A special silicone material has proved to be ideal in preliminary tests. The influence exerted on neighbouring areas through surface tension in the material could be considerably reduced by a nap structure. Small round silicone columns with a diameter of 0.8 mm and a height of 1 mm are thereby fixed equidistantly and in high density onto a silicone base foil (0.3 mm thick) by means of a casting procedure. The resulting signals from the sensors are transmitted to the microcomputer, compared with the initial zero value and stored in core. In about one second the signals of all sensors of the recording unit can be obtained and processed. The modular structure of the measuring device and favourable dimensions of the measuring plate of 350 mm x 510 mm x 35 mm warrant easy transport and simple assembly. The platform has been sunk into a wooden plate of about 5 m^2 which has a non-slide rubber covering and thus provides an even standing area for the animals under test.

Data Processing and Presentation

An appropriate Programme Operating System helps to preprocess the data: the individual weight values are put into weight categories and the number of sensors within each weight region is determined. Furthermore, the footprint area, total force or weight, maximal weight value, as well as impression point coordinates are calculated. These coordinates, however, can also be determined within freely selected partial areas, which allows, for instance, comparisons of weight and area between the medial and lateral foot for the cranial half of the foot. A visual overview of the huge mass of data is given in the colour-coded pressure distribution graph (figure 4).

In accordance with the measuring area, a co-ordination system can be found in the left half of figure 4. The multicoloured numbers on the upper edge denote the pressure graph. The figures below these indicate the number of sensors which have been impressed in the respective pressure category. The total of the colour dots represent the imprint of the foot on the flat measuring platform with an additional colour code for the individual pressure values (the top of figure 4 represents the front end of the foot, i.e. the cranial end). Black and blue coloured squares symbolise sensors, on which a low pressure has been exerted, whilst red squares stand for those that have undergone high pressures. The size of the imprint area (AREA-cm²), the weight 9FORCE-N0 and the maximum pressure (Pm-N/ cm²) with its co-ordinates can be taken from the right-hand side of figure 4, besides organizational data such as number of the picture within a series, date and time of print-out, date and time of weighting, identification code for the data-block stored.

The diagram, which represents the time course of area (red), weight (green) and maximum pressure (purple), consists of 33 pressure records registered during the weighting period of about half a minute.

For further statistical evaluation of the pressure distribution, procedures for image analysis were applied (Mair, 1989). The 33 single pressure distributions were averaged and summarized in one pressure distribution record. Only those pressure distributions were used which showed weight shiftings within 10% of the average weight. The averaged pressure distributions were forced by mathematical procedures into a uniform coordination system. After applying this procedure the localisations of areas with high local pressure underneath the claws can be compared among different cows. For purposes of comparison the claws are divided in four parts (figure 5). The main parts of one claw are termed sectors. The axial areas of the claws are divided in a cranial and caudal central zone. For characterization of the pressure distributions 7 claw quality factors were developed and are presented in the following:

- area factor (f): records the difference between lateral and medial sector areas.
- weight factor (9): gives information on weight differences between lateral and medial sectors.
- centre of gravity factor (s): resembles the relation between the centre of area and the centre of weight.
- weight factor for central zones (gz): gives the relation between the weight resting on central zones and the total weight on one limb.
- maximal pressure factor (m): characterizes the localization of maximal pressure. In the central zones this factor gets the value zero, along the white line the factor takes the value one.
- contrast factor (k): measures the variance of pressure forces.
- gradient factor (gr): measures the homogeneity of pressure distribution by taking the gradient between each pressure point.

These claw quality factors were standardized on the range between zero and one. Claws with high quality take in these factors the value one, in the opposite case the value zero.

Application of the Measuring System

The pressure distribution on foot-soles was measured in 10 Holstein Friesian cattle (1st and 2nd lactation). Age, duration of pregnancy, milk yield in previous

lactation and body weight of cows at the start of measurements are given in table 1. Preliminary tests revealed that their front feet as opposed to their rear feet could be positioned more easily and more exactly for measuring cycles (Diebschlag et al., 1986, Distl et al., 1986, Mair et al., 1988). The standing posture during the half-minute measuring period was considerably more stable. A measuring shoe developed for dynamic measurements proved unconvincing on both the front and back extremities. Although claw diseases mainly appear in the hind feet, for the present the main tests were limited to measure the pressure distribution on the front feet in order to get reliable results. The pressure distribution was registered in a standing posture, whereby sedation of the cattle could be dispensed with. In line with the measuring, the leg positioning and body carriage were recorded photographically in each instance.

On these 10 cattle, the pressure distribution on normally shaped and trimmed feet was recorded five times in intervals of 4 weeks. Each animal had to undergo 3 tests at each measuring day. The design of the measurements is illustrated in figure 6. During the 33-second measuring period within the measuring series, the pressure on the sole areas was recorded once every second by the device. One pressure distribution test therefore provided 33 individual pressure distribution records.

In order to give the first impression of the possibilities of the newly developed measuring device, figure 7 compares examples of pressure distribution from 3 measuring dates on the sole area of two cattle, in which the right front foot was taken each time. An initial visual comparison of the measuring pictures of the two animals shows the most marked differences are the localisations of the red squares, i.e. the areas of high pressure. These high pressure values have been found to lie in the heel area in most tests; however, one test animal put characteristically more weight on its medial claw, whilst the other one put considerably more weight on its lateral claw. By summarization and mathematical evaluation of the data the following results can be derived:

The footprint area in first lactating cows amounts on average to 57 cm² and in second lactating cows 59 cm². In relation to the total expected weight, the weight taken from the feet tested shows during the measuring process a relatively minor weight of about 10%. The absolute pressures recorded must be multiplied by 1.5, if the observed weight values should be scaled on the expected weight. The relative distribution of the footprint area and weight is given in table 2. Weight and foot contact area are not equally distributed over the four sectors and central zones. Also there seems to be no correlation between average pressure per cm² as well as maximal pressure per cm² of sectors and central zones to the corresponding areas (table 3). The highest average pressure per cm² was observed in the medial and caudal sector. Maximal pressure was highest in the medial and caudal sector in first lactating cows and in the lateral and cranial sector in second lactating cows. Average and maximal pressures in the central zones are significantly smaller than in the other sectors. However, in the lateral and cranial central zones of second lactation cows relatively high maximal pressures are reached. In table 4 the claw quality factors are compared between first and second lactating cows. The claws of second lactation cows seem to show a more equal weight and footprint area distribution, but the distribution of pressures seems to be not so homogeneous in second lactating cows as in first lactating cows.

The design of the measuring system enables pressure distribution to be recorded over 4 months. Claws were trimmed 3 weeks before measuring started. Deformation of claws during the measuring period did not occur. Wear of claws, especially of the cranial part, increased because the housing system was changed after the second measuring date. During the remaining experimental period, the cows were kept on slatted floors which were newly built. The average and maximal pressure per cm was almost highest at the first and the last measuring date (table 5 and 6). The average and maximal pressure per cm^2 was higher in medial claws than in lateral claws in first lactation cows: in second lactation cows the higher weight load shifts to the medial claw after the third measuring date. In second lactating cows the higher weight load shifts to the medial claw after the third measuring date. In second lactating cows the medial claws might be trimmed more strongly resulting in higher pressure on the lateral claws. In both groups the average and maximal pressure per cm^2 in the central zones reach the highest values with the last measuring date.

Table 7 displays the claw quality factors in dependence of measuring date and for both groups. The biggest differences between measurings are found for the gradient factor. The gradient factor seems to be a valuable indicator for inhomogeneous pressure distributions, which result also from fissures in the claw horn. The effect of trimming on the claws of the right front foot is shown in figure 8 and 9. The claws of the cow shown in figure 8 had no abnormal claw shape and were trimmed in three stages. In the first stage the lateral claw was cut, until a smooth ground surface was obtained. Thereon the medial claw was trimmed the same way. In the last stage the axial moulding was cut and final corrections of the claw shape were made. The contact area of the claws is enlarged by claw trimming, however, the average and maximal pressure per cm^2 decreases only a small amount. In figure 9 the pressure distribution of claws from cows with abnormal claw shapes (corkscrew claws without ulcerations or other pathological findings) before and after claw trimming is shown. The footprint area is enlarged about twofold by claw trimming and the local pressure peaks in the displayed claws are diminished.

The measuring device presented has developed into a reliable, compact and easily manageable system. The software for analysis of pressure distributions allows comparisons among pressure distributions with different coordinates. Claw quality factors were developed to characterize properties of pressure distributions. Final conclusions on the optimal pressure distribution are not yet possible, but the presented investigations contribute to the understanding of forces at the floor-claw interface.

References

Betts, R.P., T. Duckworth, and I.G. Austin, 1980: Critical light reflection at a plastic/glass interface, and its application to foot pressure measurements. . J. Med. Engineering and Technol. **4**, 136-142.

Brunner, W., B. Kurz and W. Diebschlag, 1983: Kapazitives Druckverteilungsmebsystem fur hohe Messstellendichte. Biomed. Tech **28**, 221-224.

Cavanagh, P.R. and A.E. Michiyoshi, 1980: A technique for the Display of Pressure Distribution beneath the Foot. J. Biomech. **13**, 69-75.

Chodera, J.P. and M. Lord, 1978: The Technology of the Pedobarograph. BRADU Report Roehampton, London, 159-179.

Dhanendran, M., W.C. Hutton and Y. Parker, 1978: The distribution of force under the human foot - an online measuring system. Measurement and Control No **11**, 261-264.

Diebschlag, W., CH. Spielmann and H. Krausslich, 1986: Development of a measuring installation for determining the pressure distribution underneath the hooves of cattle. Initial results. Fourteenth World Congress on Diseases of Cattle, Dublin.

Distl, O., F. Graf, W. Diebschlag, A. Mair and CH. Spielmann, 1986: Determination of punctual pressure distribution underneath ground surface of claws in cattle. 37th Annual Meeting of the European Association for Animal Production, 1st-4th September, Budapest.

Knecevic, P.F., 1985: Zur Geschichte der Bewegungslehre des Pferdes - eine historische Betrachtung der Untersuchungstechniken. Wien. tierarztl. Mschr. **72**, 399-405.

Kurz, B., W. Diebschlag and F. Stumbaum, 1986: Portables Druckverteilungsmebsystem fur biomedizinische Gangspuranalysen. Biomed. Tech. **31**, 19-24.

Lord, M., 1981: Foot pressure measurements: a review of methodology. J. Biomed. Eng. **3**, 91-99.

Mair, A., W. Diebschlag, O. Distl and H. Krausslich, 1988: Measuring Device for the Analysis of Pressure Distribution on the Foot Soles of Cattle. J. Vet. Med. A **35**, 696-704.

Mair, A.,1989: Analyse und Bewertung von Druckverteilungen mittels bildverarbeitender Methoden - dargestellt am Beispiel von Bodenkontaktkraften unter Rinderklauen. Dissertation an der Fakultat fur Maschinenwesen der Technischen Universitat Munchen.

Nicol, K. and E.M. Henning, 1978: Measurement of Pressure Distribution by means of a Flexible, Large-Surface. Mat. Biomechanics VI-A Univ. Park Press, Baltimore, 374-380.

Schnable, H., D. Girtler, M. Seebacher, M. Endler, P.F. Knecevic, W. Tauffkirchen and G. Benedikter, 1985: Die Mehrkomponententraftmessplatte als Hilfsmittel in der

Diagnostik von Bewegungsstorungen und Lahmheiten. Wien. tierarztl. Mschr. **72**, 285-289.
Stumbaum, F. and W. Diebschlag, 1980: Messsystem zur Erfassung der Druckverteilung zwischen Mensch und Sitz. Biomed. Tech. **25**, 223-227.
Webb, N.G. and M. Clark, 1981: Livestock foot-floor interactions measured by force and pressure plate. Fm. Bldg. Prog. **66**, 23-36.

Table 1:
Age, lactation number, stage of pregnancy, milk yield and body weight of cows when starting measurments.

	age (years)	lactation number	pregnant (months)	milk yield (Kg)	body weight (Kg)
	2.75	1	1	6365	566
	2.53	1	3	5710	615
	2.42	1	1	5551	571
	2.53	1	2	7380	526
	2.29	1	0	5302	500
$\bar{x}$	2.50	1.0	1.4	6062	556
s	0.17		1.1	835	44
	3.90	2	4	6550	688
	3.89	2	3	9022	640
	3.87	2	2	8278	650
	3.70	2	0	5413	702
	3.19	2	0	8292	574
$\bar{x}$	3.71	2.0	1.8	7511	651
s	0.30		1.8	1484	50

Table 2:
Relative distribution of footprint area and weight of claws in German Black and White cows at the front left limb.

	First lactating cows		Second lactating cows	
	relative area(%)	relative weight(%)	relative area(%)	relative weight(%)
claw				
med.	52.7±0.6	55.9±1.2	49.5±0.6	48.0±1.1
lat.	47.4±0.6	44.1±1.2	50.5±0.6	52.0±1.1
sectors				
cranial med.	28.6±0.4	26.6±0.6	27.7±0.4	24.9±0.6
caudal med.	24.1±0.5	29.2±0.8	21.8±0.5	23.2+0.8
cranial lat.	28.8±0.4	26.5±0.6	29.7±0.4	29.9±0.6
caudal lat.	18.5±0.5	17.6±0.8	20.8±0.5	22.1±0.7
central zones				
cranial med.	7.8±0.3	6.3±0.3	6.3±0.3	4.8±0.3
caudal med	2.6±0.1	2.0±0.1	2.1±0.1	1.6±0.1
cranial lat.	6.4±0.2	5.4±0.3	8.0±0.2	7.6±0.3
caudal lat.	2.8±0.1	2.3±0.1	2.2±0.1	1.8±0.1
total (absolute)	56.9cm^2±0.8	1070.7N±16.6	59.2cm^2±0.8	1139.5N±16.2

Table 3:
Average pressure(N/cm^2) and maximal pressure(N/cm^2) in claws of the front left foot in German Black and White cows.

	First lactating cows		Second lactating cows	
	average pressure (N/cm^2)	maximal pressure (N/cm^2)	average pressure (N/cm^2)	maximal pressure (N/cm^2)
extremity	18.8±0.2	58.6±10	19.2±0.1	56.4±1.0
claw				
med.	19.7±0.3	53.4±1.0	18.5±0.3	43.7±1.0
lat.	17.1±0.3	43.3±1.2	19.5±0.3	52.6±1.1
sectors				
cranial med.	17.2±0.3	44.4±1.0	17.2±0.3	38.7±1.0
caudal med.	22.4±0.3	50.3±1.0	20.2±0.3	41.4+1.0
cranial lat.	17.2±0.3	41.7±1.1	19.2±0.3	48.7±1.1
caudal lat.	16.7±0.5	34.1±1.4	19.7±0.5	45.2±1.3
central zones				
cranial med.	13.7±0.4	29.1±1.4	13.8±0.4	28.0±1.3
caudal med	13.5±0.3	23.1±0.9	12.3±0.3	19.4±0.9
cranial lat.	14.8±0..3	32.9±0.9	17.2±0.3	37.8±0.8
caudal lat.	14.0±0.4	22.3±0.7	13.9±0.4	21.2±0.7

Table 4:
Footprint area, average and maximal pressure of claws of the front left foot at each measuring date in first lactating Black and White cows.

parameter/claw position	measuring date 1	2	3	4	5	SE
footprint area(cm^2)	51.3	55.7	57.0	58.7	62.0	1.7
average presure (N/cm^2)						
extremity	19.3	17.9	18.1	18.3	20.5	0.3
claw med	21.9	18.6	18.6	18.8	20.8	0.6
lat	15.6	16.5	16.5	17.5	19.3	0.7
central zones	12.5	12.3	14.7	14.4	16.2	0.8
maximal pressure (N/cm_2)						
extremity	65.8	55.2	54.3	53.0	64.1	2.3
claw med	63.2	50.6	46.4	46.7	60.0	2.2
lat	34.8	41.0	39.9	47.0	53.7	2.5
central zones	23.5	24.0	26.4	26.8	33.6	2.1

SE : Standard error;

Table 5:
Footprint area, average and maximal pressure of claws of the front left foot at each measuring date in second lactating Black and White cows.

parameter/claw position	measuring date 1	2	3	4	5	SE
footprint area(cm^2)	55.2	61.0	62.0	59.5	58.2	1.7
average presure (N/cm^2)						
extremity	18.2	17.4	19.7	19.8	20.9	0.3
claw med	16.0	16.2	18.2	20.3	21.7	0.6
lat	19.7	18.1	20.8	19.1	19.7	0.7
central zones	13.3	13.0	15.8	14.9	14.6	0.8
maximal pressure (N/cm_2)						
extremity	54.2	50.7	53.8	60.5	62.6	2.3
claw med	35.5	34.9	40.3	52.2	55.8	2.2
lat	49.7	48.4	50.6	56.4	58.1	2.5
central zones	22.4	21.1	28.1	30.3	31.2	2.1

SE : Standard error;

Table 6:
Claw quality factors with standard errors in first and second lactating German Black and White dairy cows.

claw quality factor	first lactating cows		second lactating cows	
f	0.963	±0.019	0.925	±0.019
g	0.684	±0.032	0.823	±0.032
gz	0.775	±0.008	0.809	±0.008
s	0.836	±0.016	0.899	±0.016
m	0.909	±0.034	0.917	±0.034
k	0.641	±0.006	0.649	±0.006
gr	0.719	±0.015	0.625	±0.015

Table 7:
Claw quality factors in first and second lactation German Black and White dairy cows related to measuring date.

measuring date	claw quality factors in first lactation cows						
	g	f	gz	s	m	k	gr
1	0.889	0.704	0.872	0.817	0.906	0.610	0.579
2	0.919	0.777	0.857	0.866	0.899	0.630	0.643
3	0.863	0.684	0.775	0.836	0.909	0.641	0.719
4	0.897	0.824	0.815	0.896	0.953	0.653	0.614
5	0.886	0.749	0.846	0.861	0.969	0.621	0.526
SE	0.021	0.037	0.008	0.019	0.031	0.007	0.015

measuring date	claw quality factors insecond lactation cows						
	g	f	gz	s	m	k	gr
1	0.892	0.747	0.839	0.856	0.966	0.653	0.660
2	0.907	0.800	0.893	0.910	0.952	0.668	0.724
3	0.925	0.824	0.809	0.899	0.917	0.649	0.625
4	0.932	0.872	0.856	0.926	0.875	0.630	0.523
5	0.889	0.815	0.870	0.887	0.957	0.621	0.490
SE	0.021	0.036	0.008	0.019	0.031	0.007	0.015

Figure 1: Relationship between traumatization of dermis in sole and claw diseases, claw conformation and environmental factors

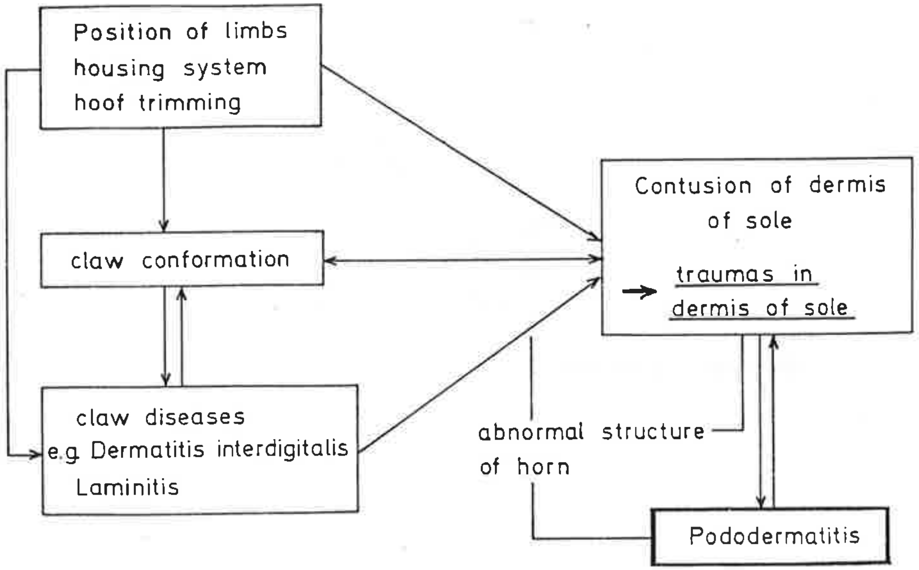


Figure 2: Components of the measurement installation

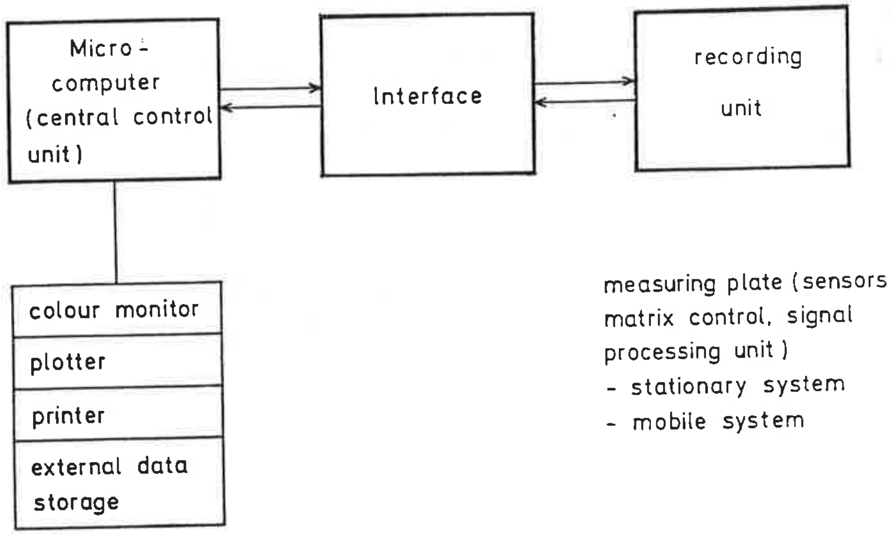


Figure 3: Cutaway model of the measuring plate. The window shows the direction of the cutting lines (lines-and-dots)

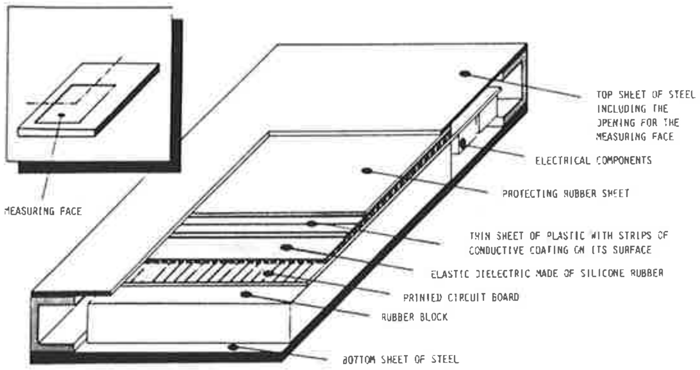


Figure 4: Pressure distribution graph with colour codes

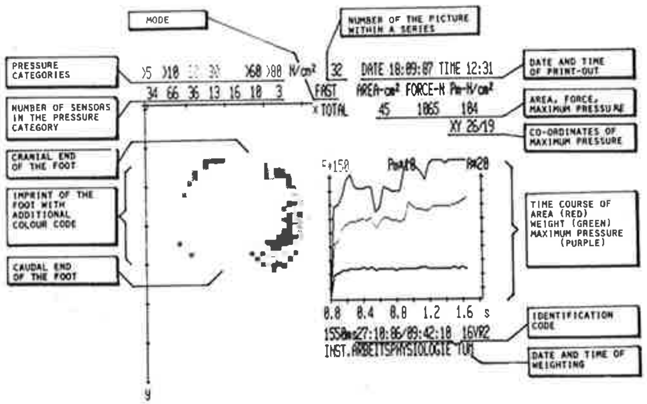


Figure 5: Sectors (cranial or caudal parts) and central zones (axial cranial or caudal parts) of the claw

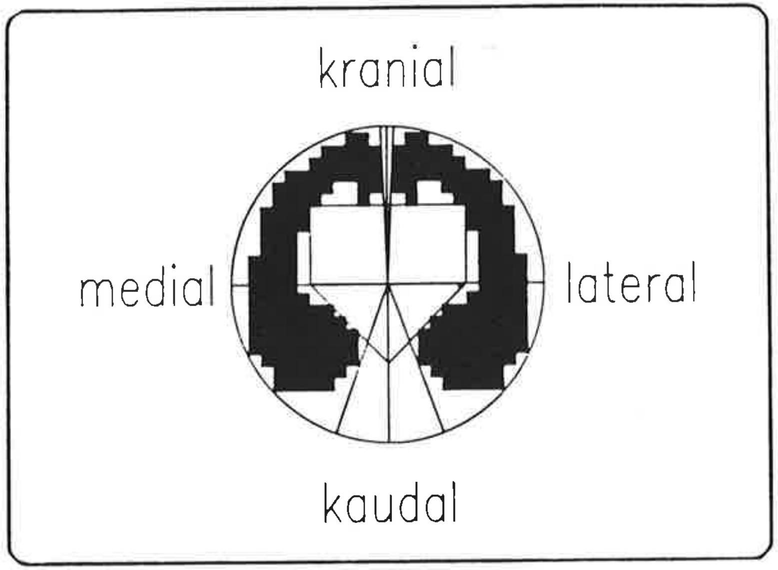


Figure 6: Design of the measurements in German Black and White cows

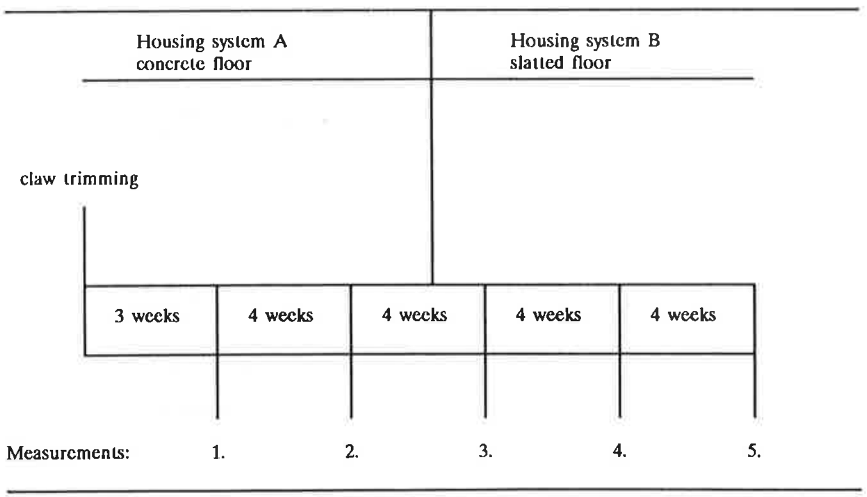


Figure 7: Comparison of pressure distribution on the right front feet of two Black and White cows at three measuring dates (intervals between measurings: 4 weeks)

Animal No.: 200

Area: 43 cm²

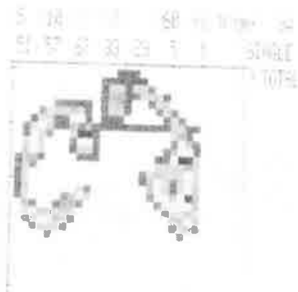
Force: 876 N
P-Max: 63 N

1.

Area: 59 cm²

Force: 1317 N
P-Max: 67 N

2.



Area: 61 cm²

Force: 1431 N
P-Max: 81 N

3. measuring

Animal No.: 208

Area: 59 cm²

Force: 1018 N
P-Max: 63 N

1.

Area: 74 cm²

Force: 1547 N
P-Max: 63 N

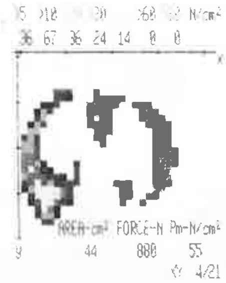
2.

Area: 65 cm²

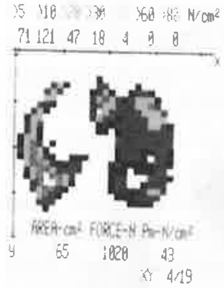
Force: 1304 N
P-Max: 70 N

3. measuring

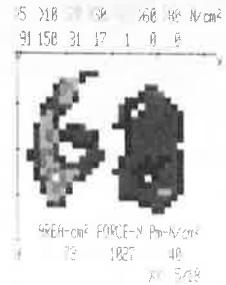
Figure 8: Pressure distribution in a German Black and White cow before claw trimming and at different stages of claw trimming



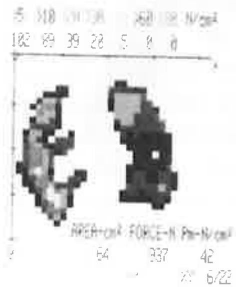
Stage 0: no claw trimming



Stage 1: lateral claw was ground planely

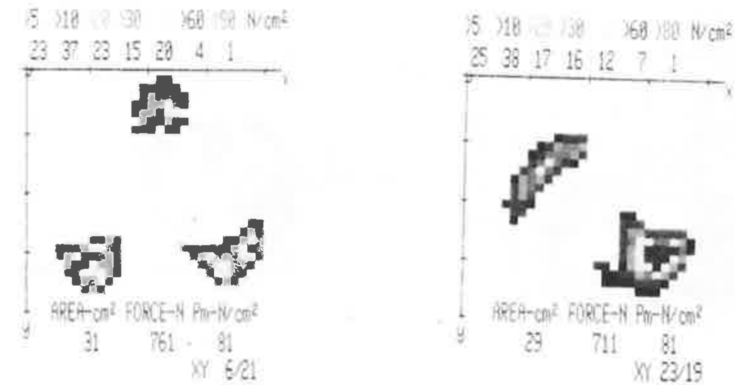


Stage 2: lateral and medial claw were ground planely

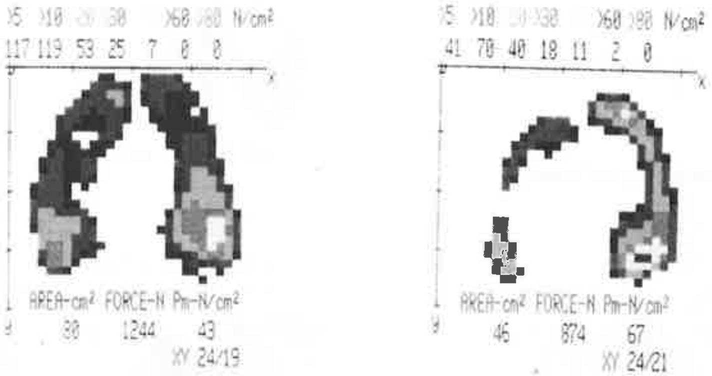


Stage 3: claw trimming was perfectly done

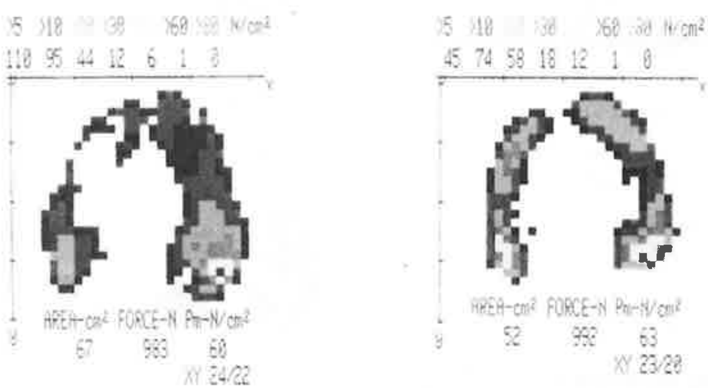
Figure 9: Pressure distribution in two German Simmental cows before claw trimming, 2 and 4 weeks after claw trimming



Stage 0: Pressure distribution under deformed claws



Stage 1: Pressure distribution 2 weeks after claw trimming



Stage 2: Pressure distribution 4 weeks after claw trimming

Pedometric Analysis of Cattle Locomotion.

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Introduction

The dominant form of cattle locomotion is walking (figure 1), although running, trotting and jumping are used to varying extents. The walking gait is typical of quadrupeds, being symmetrical with a back and a front leg used alternately for support (Dagg, 1977). The form of locomotion of quadrupeds with this gait has been more carefully researched in horses, using treadmills and cinematography (eg Fredericson et al, 1983), than for cattle. However Manson and Leaver (1988) have used a subjective 9 point scoring system to classify cattle gait and determine in particular the effects of nutrition on the incidence of abnormal gait. The frequency of gait has been measured with the pedometer, which is a device designed to record individual leg movements (not always steps) and sometimes to record time to enable a movement frequency to be automatically calculated by the device.

Typically in the dairy cow, locomotion frequency shows a strong circadian rhythm (figure 2) and is affected by management and genetic factors, and the environment (Phillips and Schofield, 1989). The need for detailed recording of cattle locomotion frequency arises from 1) the potential to accurately detect oestrus in dairy cows, 2) the possibility of increasing the efficiency of rangeland utilization and 3) concern for the welfare of cattle in intensive farming.

This paper concentrates on locomotion frequency recording by pedometer.

Historical Development

The use of pedometers for recording locomotion frequency in farm animals was first reported nearly 50 years ago, in this case to record increased locomotion in sows during oestrus (Altmann, 1941). Earlier researchers recorded animal travel on foot (Cory, 1927), and later Hancock (1954) used overhead observation techniques in paddocks and Dwyer (1965) followed range cattle in a vehicle. This latter system of recording has continued to the present day for range cattle (Bailey et al, 1990).

Pedometers were first used on cattle by Farris (1954), who reported an average increase in the activity of grazing dairy cows at oestrus of 218%. Later pedometers were used for monitoring the distance walked by free-ranging cattle (Anderson and Kothmann, 1977; Walker et al, 1985; Anderson and Urquhart, 1986) and for recording the locomotion frequency of dairy cows in different housed environments (Phillips and Schofield, 1989). Pedometers have also been used to monitor daily travel in sheep (Powell, 1968; Furnival et al, 1982), but with limited success because in both these

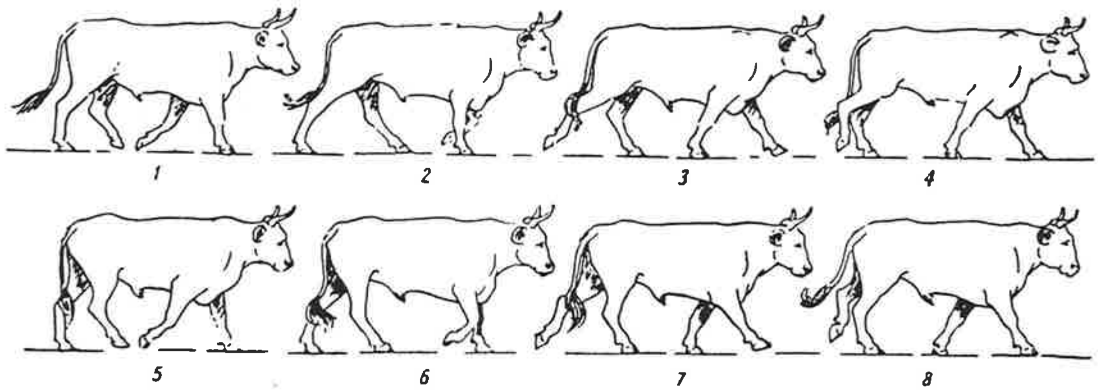


FIGURE 1. Sequential stages of cattle walking

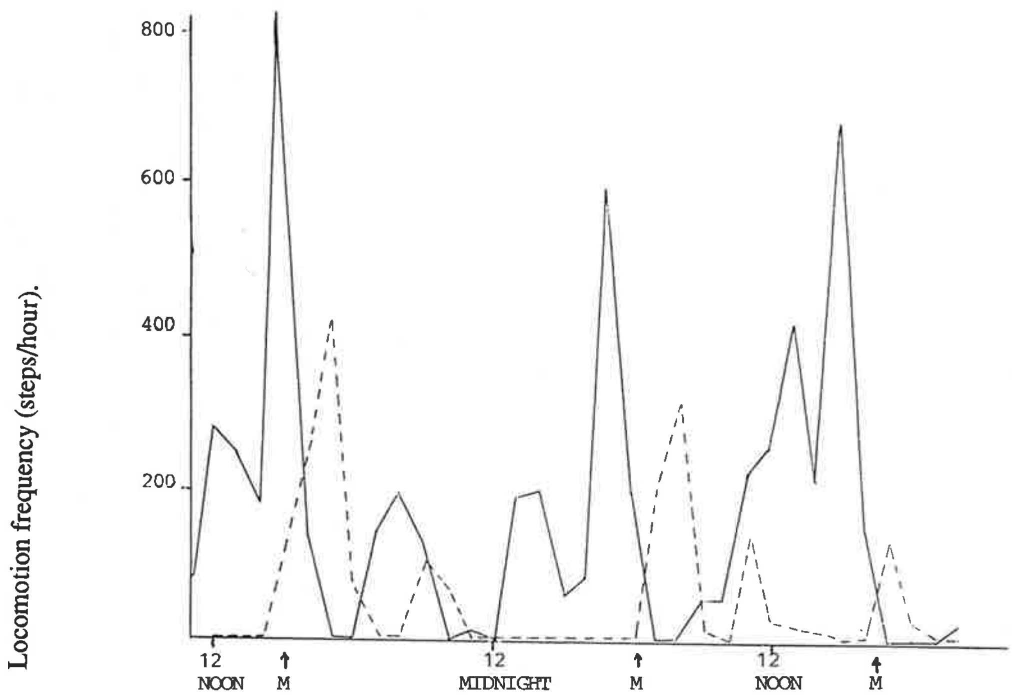


FIGURE 2. Locomotion frequencies of two dairy cows, one active mainly before milking (——) and one active mainly after milking (- - -), measured with an electric pedometer (Phillips and Owens, unpublished data). M = milking time

studies the pedometers were attached around the trunks of the animals and muscle tremors caused a high level of false readings. Sheep travel has however been monitored successfully by a small wheel attached by a harness to the animal (Cresswell and Harris, 1959) and by radiotelemetry.

Pedometer Mechanisms

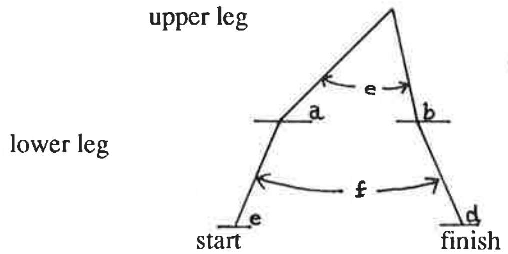
Early pedometers recorded the reciprocating leg action during walking with a weighted pendulum, usually with a damping mechanism incorporated as stops to the pendulum travel. These devices are manufactured to monitor human locomotion, but for cattle they need to be enclosed in a water and shockproof case and strapped around the metacarpus of the leg. Usually a hind leg is used as the front legs are more accessible to any attempts by the animal to remove the pedometer. It should be strapped to the leg sufficiently tightly to prevent any looseness which will irritate the animal, but not so tight that blood flow to the hoof is restricted.

The weighted pendulum is usually corrected to a calibrated dial by gears, but some devices now have digital readouts. Adjustments to the stride length can be made by varying the distance travelled by the pendulum, which reduces the distance recorded per leg action.

These simple mechanical pedometers are accurate when comparing locomotion frequency between days, for example to detect oestrus in the cow (Kiddy, 1977), but are not accurate between animals. This is partly because different pedometers, even of the same make, have different loading characteristics, a problem which can be minimized by calibrating each pedometer, by fitting more than one pedometer per animal, or by having large numbers of animals per treatment (Anderson and Urquhart, 1986). Not all 'human' pedometers are sufficiently robust for use with cattle (Kiddy, 1977). A second problem in relation to between-animal comparisons is that the coefficient of variation between cows in the arc through which the leg travels in one step is approximately 12% (Mackay and Phillips, unpublished data). A cow with a long stride may cause more than one incident to be recorded because of 'bounce-back' by the pendulum, whereas a cow with a short stride may not activate the pendulum at all. This can be a problem when comparing locomotion frequencies on different floors. Grooving concrete, for example, causes a significant increase in the leg arc, indicating a more confident stride (figure 3)We were not able in this study to detect any difference between leg actions on smooth and rough concrete. In the absence of a detailed knowledge of cattle: floor interactions there is a danger of anthropomorphic recommendations being made. Slatted floors however are known to affect locomotion, increasing the frequency of slipping and the time of head orientation towards the floor and reducing the confidence of cattle walking on them (Sommer, 1985).

An additional problem which affects digital pedometers is the need to make decisions as to which digit is indicated when the parts of two consecutive numbers appear and a split number is seen (Andersen and Urquhart, 1986).

Figure 3. Leg angles to the horizontal and the total leg arc for smooth, rough and grooved concrete.
(Mackay and Phillips, unpublished data)



Leg half	Point of stride	Concrete type smooth	rough	grooved	SED	Probability
Upper	Start (a)	40.7	42.5	37.0	1.88	0.04
	Finish (b)	92.0	97.0	98.5	3.67	0.23
Lower	Start (c)	67.2	71.0	68.8	1.66	0.12
	Finish (d)	126.2	128.8	134.8	2.36	0.01
Upper	Total arc (e)	51.3	54.5	61.5	4.86	0.15
Lower	Total arc (f)	59.0	57.8	66.0	3.28	0.07

Partly because of these problems and partly because any pedometer to be used by farmers for oestrous detection has to be simple to operate, attempts were made in the 1970's to construct electronic pedometers. Using an electronic step recording device together with a time piece in one or two microchips enables calculations to be made by the device as to whether a certain locomotion frequency has been exceeded. Usually step numbers are counted by the closures of a mercury switch, with this motion sensor producing a series of pulses that activate a counter. Bounce back or non-registration of incidents may be problems as with mechanical pedometers, particularly if the switch is not correctly positioned or the leg does not move far enough past the vertical at the beginning or end of the stride. The count is accumulated over a predetermined time period. For oestrous detection a separate counter accumulates reference values which are compared to the current value, and an indicator is energized if the current value exceeds a predetermined multiple of the reference value. Preset to zero is available by a reed switch which can be operated by a magnet held close to the leg (Rodrian, 1984).

The device is usually powered by small batteries and may contain a second indicator light powered by a separate battery to show when the main power source is exhausted. An alternative electronic pedometer (Gettens et al, 1986) combines the current count data with an identification code, and the transponder is then interrogated and data transmitted to a computer for processing.

A major problem with both mechanical and electronic pedometers is damage and loss. Williams et al (1981) reported that their mechanical pedometers lasted on average for 19 days in a study involving nearly 2000 half-day measurements. Mechanical pedometers have a tendency to higher damage susceptibility than electronic ones (Holdsworth and Markillie, 1982).

Table 1:
The Locomotion Frequency Factor :-

$$\frac{\text{locomotion frequency on the day of oestrus}}{\text{locomotion frequency on non-oestrous days}}$$

in published reports measuring daily locomotion frequency of dairy cows over the oestrous cycle.

		Locomotion Frequency Factor
Farris	(1954)	3.18
Kiddy	(1977)	3.93
Phillips & Schofield	(1988)	2.08
Perrington et al	(1986)	6.77
Schlunsen et al	(1988)	2.00
Vasquez et al	(1984)	1.85
Williams et al	(1986)+	3.72
	Mean	3.36

+ Buffaloes

Specific Uses of Pedometers

1) Oestrous detection

Locomotion frequency increases during oestrus by an average factor of 3.36 (Table 1), however the research conducted has not usually determined the oestrous duration accurately and usually relates the day on which oestrus occurred to non-oestrous days. This may underestimate the Locomotion Frequency Factor (LFF) since oestrus lasts on average only for 15 hours in Bos taurus and considerably less than this in Bos indicus (Schofield, 1988a). Commercial devices currently available either use an LFF value of 2 (Afimilk [1]) in conjunction with a 5% reduction in milk yield, or 2, 3, and 4 (Dairy Equipment Co [2]) giving an indication of oestrous intensity by different

1. S.A.E. Afikim, Kibbutz Afikim, 15148 Israel
2. Dairy Equipment Co., Madison, Wisconsin, U.S.A.

combinations of coloured lights. The LFF is important in determining the accuracy of oestrus detection, as the number of false positives is correlated with the correct diagnosis rate. A model developed by Schlunsen et al (1988) (Figure 4) suggests that the pedometers they used would only be sufficiently accurate (high correct diagnosis rate, low error rate) if combined with another indicator of oestrus eg milk yield, body temperature. Williams et al (1981) found that pedometer increases of 1 and 2 SD gave oestrus detection rates of 74 and 68% respectively, compared to 68% detection by herdsman observation. False positives were 42, 17 and 5% respectively, confirming Schlensen's theory. However Peters and Bosu (1986) found that pedometers were better than herdsman observation in detecting the first ovulation post partum. Recently Phillips et al (1990) developed an algorithm to increase the efficiency of oestrus detection by pedometer. This uses a smoothed variance estimate as a base upon which to establish the LFF that will predict oestrus. The locomotion frequency in successive 12 hour periods is recorded. Initially for each locomotion frequency recorded, C(n), the difference,A(n), from the recording 24h previously is calculated:

$$A(n) = C(n) - C(n-2)$$

This filters out the differences between diurnal and nocturnal activity. Successive differences are then smoothed by adding in a fraction of the previous value of A, to obtain the smoothed difference.

$$S(n) = FA(n) + (1-F)S(n-1)$$

F is a "forgetfulness factor", which determines how long the computation will remember a past reading. (F=1 indicates no memory of previous events). From the smoothed differences the root mean square variance was obtained:

$$R(n)=\sum_{1}^{N} S^2(n)/N$$

Finally a smoothed rms variance is calculated by averaging R with the previous estimate of averaged rms variance:

$$RR(n) = 0.5R^{1/2}(n) + 0.5RR(n-1)$$

This is then used as the base for comparison:

$$\text{if } S(n) > \text{LFF } RR(n)$$

oestrus has been detected.

The following tabulations show the influence of LFF and F on the accuracy of decision. See over.

Extra events indicated :

		F				
		1	0.5	0.3	0.2	0.1
	3	0	0	0	0	0
	2	2	1	1	0	0
LFF	1.5	6	4	2	2	2
	1.3	9	6	4	4	3

Events missed :

	3	4	2	2	2	4
LFF	2	1	1	0	0	1
	1.5	0	0	0	0	0
	1.3	0	0	0	0	0

Decreasing the factor F reduced the number of extra events indicated, and increasing LFF reduced the number of extra events but also increased the number of missed events. The optimum values were

$$\text{LFF} = 2$$
$$F = 0.2$$

since at these values there were no anomalies.

Further accuracy in the predictions of oestrus events can be achieved by relating LFF to the locomotion frequency of cow during non-oestrus. This relationship is illustrated in figure 5. The respective r_2 values for a linear, linear + quadratic, linear + quadratic + cubic, and an exponential fit to the points were 21.0, 29.6, 35.5 and 36.5. An exponential curve with the equation:

$$Y = 1.88\ (+/-\ 0.296) + 6.06\ (+/-1.20) \times e^{-0.427\ (+/-\ 0.100)}$$

therefore gave the best fit, but the high leverage of a small number of points should be noted. Even with the fitted exponential curve the threshold value, LFF, is relatively constant over the normal range of locomotion frequencies.

2) Measuring cattle travel in rangeland.
A knowledge of the distances walked by cattle on rangeland is important for fodder utilization research (Anderson and Kothmann, 1977) or for between-animal comparisons for selective breeding eg of bulls that can range long distances to find oestrous cows (Poole et al, 1979). Cattle travel is an important endergonic physiological process in range cattle, increasing energy requirements by 25-50% compared to housed cattle (Osuji, 1974). Pedometers have shown that in some circumstances cattle walk further in rotational grazed range than continuously grazed range, probably because the enforced close proximity of

cattle in the former increases escape behaviour to maintain normal inter-animal distance (Walker et al, 1985). Pedometers have also been useful to show that on rotationally grazed range, cattle increase distance walked by 30% on entry into a new paddock in an attempt to explore their new environment (Anderson and Urquhart, 1986). In the grazing context pedometers have also been used to 1) show that flies increase the distance travelled through irritation (Anderson and Urquhart, 1986); 2) record bite numbers when placed under the neck (Phillips and Denne, 1988) and 3) to demonstrate that Bos indicus cattle tend to walk further than Bos taurus cattle when grazing is sparse (Hafez and Bouisson, 1975).

3) Concern for the welfare of cattle in intensive agricultural practices.
Cattle and buffalo have reduced locomotion frequencies when they are kept in confined spaces (Schofield, 1988b; Barua et al, 1981), which reduces their welfare as their motivation for locomotion is thwarted. In addition lameness may be increased if cattle are standing in wet acid conditions, which soften the heel tissue, causing excessive wear and predisposing the hoof to laminitis (Phillips, 1990). Floor type also has important effects on locomotion (see figure 3). Other aspects of the environment for cattle affect locomotion frequency: in a cubicle house with minimal bedding material extending the photoperiod reduces locomotion frequency and increases lying time (Phillips and Schofield, 1989), In a straw bedded house the effect of increasing photoperiod on locomotion is less and there is no effect on lying time (Phillips and Weiguo, 1990) and at pasture there is also no effect of natural changes in photoperiod on lying time (Phillips and Hecheimi, 1989). The suggestion is that cattle activity is increased in a more hostile cubicle environment compared with softer lying areas, but that improving a hostile environment by providing extra light will reduce activity to a more normal level. Further research is needed to define 'normal' or preferred activity levels and to quantify the motivation for locomotion in relation to other behaviours.

Conclusions

The pedometer is an instrument of varying complexity which can be useful tool to measure locomotion frequency of cattle if its limitations are realized. With mechanical pedometers the greatest limitations are the need for accurate calibration and the high rate of damage and loss. With electronic pedometers the greatest limitations are currently the high cost and, as with mechanical pedometers, the motion sensing is not always accurate. However with the right inputs the electronic pedometer could become as small and inexpensive as a digital wristwatch, to provide a valuable tool for locomotion recording in the future.

Figure 4. Relationships between the error rate and diagnosis rate in the detection of oestrus by pedometer.

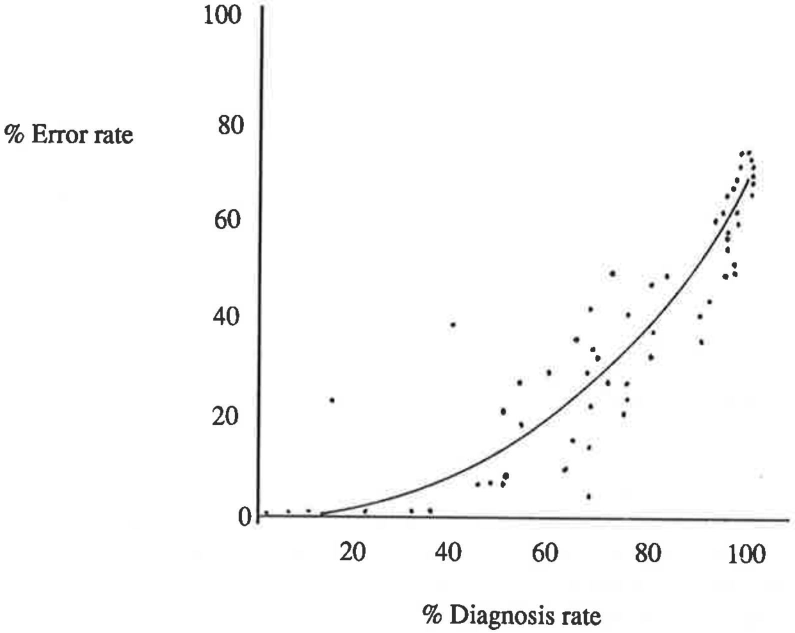
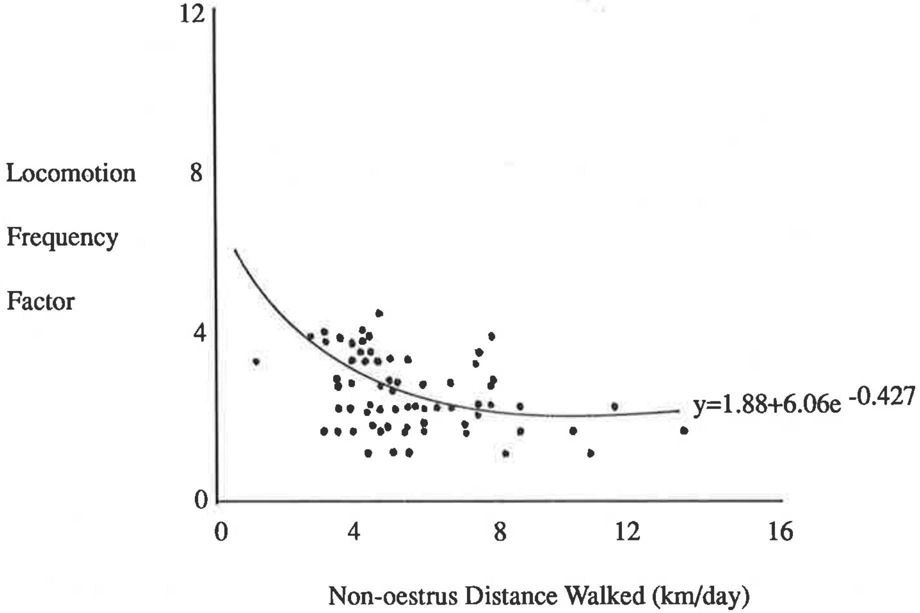


Figure 5. Relationship between the non-oestrus distance walked and the locomotion frequency factor.



References

Altmann, M (1941) Interrelations of the sex cycle and behaviour of the sow. J. Comp. Psychol. **31**: 481.

Anderson, DM and Kothman (1977) Monitoring animal travel with digital pedometers. J. Range Manag. **33**: 316 - 317.

Anderson DM and Urquhart NS. (1986) Using digital pedometers to monitor travel of cows grazing arid rangeland. Appl. Anim. Behav. Sci. **16**: 11-23.

Bailey, DW, Walker JW and Rittenhouse, LR. (1990). Sequential analysis of cattle location: day-to-day movement patterns. Appl. Anim. Behav. Sci. **25**: 137-148.

Barua, KC, Pal, RN and Sastry NSR (1981). Pedometer recordings of normal physical activity of lactating Murrah buffaloes in loose house. Haryara Agric. Univ. J. Res. **11**: 588-593.

Cory, VL. (1972) Activities of livestock on the range. Tex. Agr. Exp. St. Bull. 367, 47p.

Cresswell, E. and Harris, LE. (1959) An improved rangemeter for sheep. J. Anim. Sci. **18**: 1447-1451.

Dagg, AI. (1977) Running, walking and jumping, the science of locomotion. London: Wykeham Publications.

Dwyer, DD. (1963). Activities and grazing preferences of cows with calves in northern Osage County, Oklahoma. Okla. Agr. Exp. St. Bull. 588, 61p.

Farris, EJ. (1954). Activity of dairy cows during estrus. J. Amer. Vet. Med. Ass. 125:117.

Fredericson, I, Drevemos, Dalin G., Hjerton, G., Bjorne, K., Rynde, R. and Franzen, G. (1983). Treadmill for equine locomotion analysis. Eq. Vet. J. **15**: 111-115.

Furnival, EP., Philip, SA and Corbett, JL. (1982). Measurements with a pedometer of distance walked by sheep. Proc. Aust. Soc. Anim. Prod. 14: 654.

Gettens, JW., Scott, NR. and Sigrims, NA. (1986). Passive activity monitor for livestock. US Patent No. 4618861.

Hafez, ESE., and Bouisson, MF. (1975). The behaviour of cattle. In ESE Hafez (Ed). The Behaviour of Domestic Animals P, 203-245. London:Baillere, Tindall and Cassell.

Hancock, J. (1954). Studies in Monozygotic Cattle Twins. Ruakura Animal Research Station; Hamilton, New Zealand.

Holdsworth, RJ, and Markillie, NAR. (1982). Evaluation of pedometers for oestrus detection in dairy cows. Vet. Rec. July 3, p16.

Kiddy, CA (1977). Variation in physical activity as an indication of estrus in dairy cows. J. Dairy Sci. 60: 235-243.

Manson, FJ. and Leaver, JD. (1988). The influence of concentrate amount on locomotion and clinical lameness in dairy cattle. Anim. Prod. **47**: 185-190.

Osuji, PO. (1974). The physiology of eating and energy expenditure of the ruminant at pasture. J. Range Manag. 27: 437-443.

Pennington, Ja., Albright, JL., and Callahan, CJ. (1986) Relationships of sexual activities in estrous cows to different frequencies of observation and pedometer measurements. J. Dairy Sci. 2925-2934.

Peters, AT., and Bosu, WTK. (1986). Postpartum ovarian activity in dairy cows: correlation between behavioural estrus, pedometer measurements and ovulation. Theriogenol. **26**: 111-115.

Phillips, CJC. (1990). Adverse effects of feeding grazing dairy cows partially on silage indoors on reproductive performance and lameness. J. Agric Sci. (Camb) in press.

Phillips, CJC (1990) and Denne, SKPJ. (1988). Variation in the grazing behaviour of dairy cows measured by a vibrarecorder and bite count monitor. Appl. Anim. Behav. Sci. **21**: 329-335.

Phillips, CJC. and Hecheima K (1989). The effect of forage supplementation, herbage height and season on the ingestive behaviour of dairy cows. Appl. Anim. Behav. Sci. **24**: 203-216.

Phillips, CJC. and Schofield, SA. (1988). A comparison of oestrous detection by pedometer, milk progesterone content, electrical conductivity of vaginal mucus and milk yield changes. Proceedings of the VI World Conference on Animal Production, Helsinki. p584.

Phillips, CJC. and Schofield, SA. (1989). The effect of supplementary light on the production and behaviour of dairy cows. Anim. Prod. **48**: 293-303.

Phillips, CJC. and Weiguo, L. (1990). The effect of supplementary light on the behaviour and environmental preference of calves. Anim. Prod. 50: in press (Abstract).

Phillips, CJC, Schofield, SA. and Owens, AR. (1990). Variation in the acitivity rate, milk production and electrical impedance of cervical mucus over the oestrus period of dairy cows. J. Rep. Fert. (in press)

Poole, SH. and Boldt, EC (1979). Monitoring daily bull mobility with pedometers. Livestock Producer's Day Louisiana, Ag. Exp. St. Anim. Sci. Dept. pp 169-170.

Powell, TL. (1968). Pedometer measurements of the distance walked by grazing sheep in relation to weather. J. Br. Gassl. Soc. **23**: 98-102.

Rodrian, JA. (1984). Self contained estrus detection tag. US Patent No. 4455610.

Schlunsen, D., Shon, H., and Roth, H. (1988). Possibilities of a computer aided health and reproduction control in dairy husbandry. European Association of Animal Production No 40 "Automation of Feeding and Milking: Production, Health, Behaviour, Breeding". pp 46-56. Wageningen: Pudoc.

Schofield, S. A. (1988a) Oestrus in Dairy Cows. Technical Report No 3. Dairy Research Unit, University of Wales, Bangor. pp 89.

Schofield, S. A. (1988a) Oestrous detection methods and oestrus behaviour of dairy cows in different environments. PhD Thesis, University of Wales, Bangor.

Sommer, T. (1985). Untersuchungen zur Tiergerchtheit praxisublicher Gestaltung von Lauffloechen fur Milchvieh im Boxenlaufstall. Liz. Arbeit. Zool. Institut, Bern.

Vasquez, L., Whitmore, H., Rodrian, J., Puckett, H., Spehr, S., MacCoy, G., Lodge, R., and Ott, R. (1984) Use of electronic pedometers to measure hourly activity before and after conception in dairy cows. In Proceedings X Int. Cong. Anim. Repro. Art. Insemination. Vol. **3** pp 298. 1-298.5. Urbana-Champaign, Illinois.
Walker, JW., Heitschmidt and Dowhower, SL (1985). Evaluation of pedometers for measuring distance travelled by cattle on two grazing systems. J. Range Manag. **38**: 90-93.
Williams, WF, Osman, AM., Shehata, SHM., and Gross, TS. (1986). Pedometer detection of prostaglandin F2 α - induced luteolysis and oestrus in the Egyptian buffalo. Anim. Reprod. Sci. **11**: 237-241.
Williams, WF, Yver, DR. and Gross, TS. (1981). Comparison of estrus detection techniques in dairy heifers. J. Dairy Sci. **64**: 1738-1741.

Methods of Data Evaluations in Studies on Lameness

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Present day science is said to date from the introduction of the experimental method during the Renaissance (Beveridge, 1951). An experiment follows the formulation of a hypothesis and usually involves making an event occur under known conditions when as many influences (or variables) as possible are standardised or eliminated and precise measurements are made so that relationships between a manipulated influence (or variable) and an effect can be revealed. The 'controlled experiment' is the classical basis of biological, scientific work in which, at its most simple, similar groups are formed by assigning individuals to one group or the other by a random process. The groups are maintained under similar conditions and one variable is altered between the two groups. Measurements are then made in order to estimate the effect of this single variable. The results are subjected to statistical analysis to allow for the inherent variability of all biological material. A certain level of probability in the difference between the measured variable between the two groups is accepted as being 'statistically' significant. This is traditionally $p < 0.05$, which means that there is less than a one in 20 chance that the observed difference is due to inherent variability. It is worth drawing attention to the fact that there is still a possibility that it is caused by chance and also that a difference which is not statistically significant may actually be significant. More elegant experimental designs and statistical analyses allow the effect of more than one variable to be compared but the larger the number of variables, the larger the number of individuals needed in the experiment and the more critical the analysis, in order to avoid confounding or misleading conclusions being drawn.

An example of a 'controlled experiment' in lameness in dairy cattle is that of Manson and Leaver (1988) in which the effect of the quantity of concentrate fed on lameness was examined. Two groups, each of 24 cows, were maintained under similar conditions except that one group was fed 7 kg and the other 11 kg of concentrate per day during weeks 3 to 22 of lactation. The 'quantity' of lameness in the two groups was compared by assigning a 'locomotion score' to each cow at each examination. This new method of assessing lameness was based on a scoring system with a range of 1 to 5, including half scores; increasing scores indicating poorer locomotion; a cow giving a score of 3 or above was lame. The paper gave a table (Table 1) indicating the scoring system, and indicates that it is highly repeatable.The authors pointed out that this system allowed 'a measure of the cow incidence (proportion of cows with score 3 or over), the severity (the score) and the duration (number of weeks with score 3 or more)'. The greater precision of the measurement of lameness which was given by locomotion scoring helped in demonstrating that there were significantly more observations of lameness in the cows given the greater quantity of concentrate, brought about by a slightly increased number of lame cows (which was not significant statistically) and a marked increase in the duration of lameness (which was). It seems probable that the observed differences would not have been seen if more conventional, crude methods of assessing lameness had been used and suggests that the inclusion of ' locomotion scoring' would be valuable in all studies on dairy cattle lameness.

Although such controlled experiments may give clear results and indicate specific areas for further study, their limitations are considerable, especially in a complex area like dairy cattle lameness. In addition to the prohibitive expense of the purchase and maintenance of dairy cattle, there are greater scientific philosophical objections. In biological phenomena of a multifactorial nature, which undoubtedly applies to lameness, the controlled experiment singles out one or a few variables but rarely allows for their interaction. In addition, there are immense difficulties in ensuring that most variables are controlled so that the animals in the groups are similar, and the manipulation of the variable to be studied is rarely as simple as the quantity of concentrate fed. Finally, there is the problem of attempting to apply the results of the controlled experiment to the commercial field situation.

There are, however, enormous numbers of 'laboratories' in which nature's experiments are being carried out, usually of a complex interactive nature - so far as dairy cattle lameness is concerned, we call them 'farms'. They do not have the advantages of the controlled experiment for the results which are observed are the outcome of a large number of variables, few, if any, of which can be controlled and often varying with time but, if they can be measured and disentangled, they are directly applicable to the real situation and, therefore, to control. They also involve large numbers of 'experimental animals', which, incidentally, are purchased and maintained at no cost to the scientific investigator!

Because of the highly variable nature of the subjects and the complexity of the variables to which they are exposed, we need to be particularly rigorous in our thinking, seeking out appropriate controls whenever possible and not drawing too firm conclusions where such controls are lacking. Due to the numbers involved, the studies will involve computers and complex statistical analysis. It is perhaps worth adding a word of warning by quoting from Friedman (1974) who said 'Unfortunately, there has been a recent tendency to thoughtlessly throw some data into a computer together with a 'canned' multivariate analysis program, expecting that the coefficients and other numbers that come out will somehow reveal a new secret of life. It must be stressed that no method of analysis, no matter how mathematically sophisticated, will substitute for careful evaluation of data based on good scientific judgment and knowledge of the disease process being studied'.

Despite this necessary warning, epidemiological studies involving natural 'experiments' have been extremely productive in human medicine (the studies of Doll

and Hill on smoking and lung cancer in 1964 being a classical example). These types of study, called **observational studies**, are defined as 'studies which investigate disease aetiology using observations of naturally occurring diseases in groups of animals, rather than by experiment'. A good description of veterinary observational studies has been produced by Thrusfield and Aitken (1985).

Observational studies involve the measurement of the 'quantity of disease' in groups of individuals exposed to possible causal factors and the application of statistical analyses to establish significant relationships between them.

There are three main types of observational study:- **cross-sectional**, **cohort** and **case-control.** Each study classifies individuals into those with and without the disease and those with and without possible causal or risk factors. In addition to the allocation of individuals, it is possible to allocate farms into those with a high or low incidence of disease and attempt to establish associations between possible causal or risk factors between farms. The **case-control** method between individual lame cows and between farms of high and low incidence (arbitrarily defined by the investigator) has been used widely and has indicated certain causal relationships.

All three studies generate data of a similar nature in which 2x2 contingency tables are produced of diseased and non-diseased animals (or high and low disease farms) against the presence or absence of a postulated causal factor.

They are fundamentally different in the methods used to generate this data.

In all these types of observational studies it is critically important that the ways of estimating the 'quantity of disease' in populations are sound.

Let us imagine that a skilled observer visits a dairy farm one afternoon in January and carries out a 'locomotion score' on each cow as it enters the milking parlour. This produces, as it were, a 'snapshot' photograph of the quantity of lameness on that farm on that afternoon. An example from a 'real farm' indicates that 46 cows of a total of 161 had a locomotion score of 3 or above. This means that 46/161 are lame on that criterion or 28.6%. This figure is known as the **point prevalence rate**. A similar exercise could be carried out at, as frequent intervals as the observer could fit into the time available and in this example, it was done monthly. The twelve point prevalence rates for this herd during 1989 ranged from 19.8 to 44.0%. Whilst this indicates a large quantity of lameness, with considerable implications so far as animal welfare and production are concerned, it does not tell us how many cows in total were lame during the year nor how many times each cow was lame. However, since each cow was identified and has a line of 12 scores against its number, it is possible to calculate these additional measurements of lameness. To obtain the number of cows which were lame on at least one occasion, we can look along the line of values and count each cow which had a score of 3 or above. This showed that 145 cows out of a total of 201 were lame at least once - or 72.1% of all cows. This is a minimum number since it would be possible for a cow to become lame immediately after one observation and be treated and recovered before the next observation a month later. If the cows had been scored weekly, we would probably include all the cows which became lame during the year because it is unlikely that the duration of a lameness episode would be less than one week. If however, less frequent visits were made, it is probable that it would appear as if fewer cows had a lameness episode during the year. This is, in fact, what is observed on our 'real farm'. Taking the results for three-monthly visits, for example, - January, April, July and October, 115 of the 201 cows were recorded as having a score of 3 or above (57.2%).

It is obvious that some cows are lame more than once a year, and must therefore be considered in the measurement of the quantity of lameness. In order to do this it is necessary to make some arbitrary criteria in order to define a new case of lameness, and we have used the following when scoring at monthly intervals.:

i) A score of 3 or above separated from a previous lame score by a score of 2 or below; or

ii) since the observer noted on which limb the cow was lame, a different limb from a previously recorded lame score.

On our 'real farm', these criteria resulted in 37 cows with one episode, 55 with 2, 30 with 3, 20 with 4 and 5 with 5 separate lameness episodes, a total of 332 new cases of lameness (165 per 100 cows in the year). This latter figure is called an **incidence rate**, defined as the number of new cases arising over a period of time related to the population of risk and is more like a continuous video than a snapshot. Incidence rates are the basic tool of epidemiology and are much more useful than prevalence rates, though more difficult to obtain since the latter can be obtained by a single visit whereas repeated visits are necessary in order to obtain an incidence rate. To complete the story so far, the three-monthly data gave 47 cows with a single episode, 62 with 2 and 6 with 3, a total of 187, an incidence rate of 93 per 100 cows, thus underestimating the 'true' incidence rate.

The traditional method to determine the quantity of lameness is by the farmer (and/or veterinary surgeon) recording cases which are treated over a period of time, and we have also used this method on our 'particular farm'. This method is entirely dependent on the farmer's perception of lameness and may also be influenced by being involved in a lameness survey! One farmer may wish to please the team by completing as many forms as possible whilst another may conclude that a large number of forms reflects adversely on the management of the farm! When surveys involve only cows treated by veterinary surgeons, especially by different veterinary surgeons in different parts of the country, wide differences would be expected which may not accurately reflect the true position on the farm. This expectation is borne out by the published literature on the quantity of lameness on dairy farms in the British Isles. However, if it is possible to obtain accurate data on the site and type of lesion of every case of lameness seen by the farmer, not only can an incidence rate be calculated which should even include cases of short duration, but in addition, the major types of lameness should be distinguishable. In our survey, a lameness form is completed by the farmer, stockman, contractor, or veterinary surgeon every time a cows' foot is examined and those which are lame are distinguished from those which are trimmed but not lame. In

order to recognise new cases in the same cow, new cases were defined as

i) different limbs involved;

or

ii) episodes separated by at least four weeks.

With these criteria, 60 cows had one episode, 48 had 2, 15 had 3, 19 had 4, 9 had 5, 5 had 6 and one cow had 7 episodes, a total of 335 new episodes involving 147 out of 201 cows, or an incidence rate of 167 per 100 cows in the year. These figures on this farm are remarkably close to those obtained from locomotion scoring and again emphasises the value of this method, not only in its own right but also as a check on the farmer's perception of lameness and the likely accuracy of the completed lameness forms.

There is a final measure of quantity of lameness which is perhaps not useful epidemiologically but, nevertheless, indicates the time and effort which 'our farmer' had to put into 'lameness' on this farm; the total number of limbs lifted in order to treat lame cows was 417 in the year.

Both methods of course allow the incidence to be related to recorded managemental and environmental changes on the farm, such as season, feeding and housing.

In the light of these findings, it is of interest to see how such data fits into the three main types of observational study considered at the beginning of this paper.

1) A **cross-sectional** (or prevalence) study visits a population of animals and assigns all the cows into lame or not lame (e.g. 46 and 115 respectively, in our original January visit previously described). On the same occasion, the presence or absence of a postulated causal factor in each cow would be determined and a statistical analysis performed to see if there was any significant association. The causal factors considered in a lameness study could be for example, age, period in lactation, size, shape of feet, genetic makeup (mainly cow factors) but might include some environmental factors such as allocation to a particular cubicle house. Since the cows are divided into diseased and non-diseased at a single point in time, there must be a fairly high prevalence of disease or a long duration in order to obtain sufficient animals in the two categories to permit study. Ideally, and as in studies of human epidemiology, the original population sampled and subsequently divided into diseased and non-diseased should be randomly selected, rather than, as in the illustration I have used, being selected by a particular geographical association.

2) A **cohort** study involves the selection of two groups of individuals on the basis of their degree of exposure to a postulated causal factor - preferably exposed or non-exposed. The subsequent development of new cases of disease (incidence study) in the two groups is compared and the association analysed. This type of study is similar to a controlled experiment except that the factor

under study is imposed naturally. In lameness studies, this method would appear to lead itself particularly to a comparison of possible control methods such as foot bathing or trimming. Since it is assumed that all other factors are similar in the two groups, it would appear to be preferable to assign cows to the two groups on a paired basis (matched for age, lactation, size, for example) rather than by random selection.

3) In a **case-control** study, individuals with the disease (a case) are identified and equal numbers of individuals without the disease (controls) are selected to be paired with each case. Extreme care is exercised in the selection of controls in human studies, which is rarely possible in most studies involving farm animals. A recent study on the efficacy of various vaccines in protecting against kennel cough (Thrusfield, Aitken and Muirhead, 1989) describes a case-control study where cases and controls were selected with the rigour used in human epidemiology studies. Case-control studies have been described in cattle lameness which, in effect, compare farms having a high incidence rate with farms having a low incidence rate. For example, Chesterton, Pfeiffer, Morris and Tanner (1988) compared 32 'case' farms, where at least 10% of cows had lameness and 30 'control' farms which had no more than 3% of cows lame per year. Studies were then made on cow and environmental characteristics to see if significant differences existed between the 'case' and 'control' farms.

Although these three methods are those classically used and described in textbooks on human epidemiology, many veterinary studies do not fit them precisely. Martin, Meek and Willeberg (1987) draw attention to this in their discussion of observational studies and indicate the value of longitudinal studies, where populations (such as in farms) are observed over a period, thus allowing incidence to be measured under conditions where there are many varying causal factors. Such a longitudinal or prospective study in lameness has been described by Faye and Lescourret (1989).

There are, therefore, a variety of epidemiological methods, which, together with the power of the computer, may be applied to the study of diseases of a complex multifactorial nature like lameness, with the hope of discovering sufficient causal relationships to allow the national application of control programmes to reduce their effect on cattle welfare and production, even where the precise etiology is not known.

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TABLE 1

Description of locomotion scoring system

1.0	Minimal abduction/adduction, no unevenness of gait, no tenderness.
1.5	Slight abduction/adduction, no unevenness or tenderness.
2.0	Abduction/adduction present, uneven gait, perhaps tender.
2.5	Abduction/adduction present, uneven gait, tenderness of feet.
3.0	Slight lameness, not affecting behaviour.
3.5	Obvious lameness, some difficulty in turning, not affecting behaviour pattern.
4.0	Obvious lameness, difficulty in turning, behaviour pattern affected.
4.5	Some difficulty in rising, difficulty in walking, behaviour pattern affected.
5.0	Extreme difficulty in rising, difficulty in walking, adverse effects on behaviour pattern.

References

Beveridge, W.B. (1951) The Art of Scientific Investigation. W. Heinemann Ltd.

Chesterton N., Pfeiffer, D., Morris R.S. and Tanner C. (1988) Acta Vet. Scand. **84**, 185.

Doll R. and Hill A.B. (1964a & b) Mortality in relation to smoking. Ten years' observations of British doctors. British Medical Journal **1**, 1399 and 1460.

Faye B. and Lescourret F. (1989) Environmental factors associated with lameness in dairy cattle. Prev. Vet. Med. **7**, 267.

Friedman G.D. (1974) Primer of Epidemiology. McGraw-Hill Book Co.

Manson F.J. and Leaver J.D. (1988) The influence of concentrate amount on locomotion and clinical lameness in dairy cattle. Anim. Prod. **47**, 185.

Martin S.W., Meek A.H. and Willeberg P. (1987) Veterinary Epidemiology, Principles and Methods. Iowa State University Press 149.

Thrusfield M.V. and Aitken C.G.G. (1985) An introduction to veterinary observational studies. Soc. for Vet. Epidem. and Prev. Med. Proc., 1.

Thrusfield M.V., Aitken C.G.G. and Muirhead R.H. (1989) A field investigation of kennel cough. Efficacy of vaccination. Journal of Small Animal Practice **30**, 550.

On Indicators Of Laminitis And Heelhorn Erosion In Dairy Cattle: A Research Based On The Observation Of Digital Lesions, In The Course Of An Ecopathological Survey.

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Introduction

From January 1st to April 30th 1987, the Centre d'Ecopathologie carried out a survey on 160 dairy cattle farms in the East of France, in order to highlight the risk factors for laminitis and heelhorn erosion.

The survey included the recording of each case of lameness on the one hand, and the systematic examination of one of the hind feet of each of the 4,896 cows involved, on the other hand; all the lesions observed being then noted.

As a preliminary to the obviousness of the risk factors, we had first to define indicators of laminitis and heelhorn erosion.

We shall investigate here the different digital lesions for such indicators. For this purpose, we shall examine successively the occurrence of each lesion, its connection with lameness and how the lesions are related together.

Materials and Methods

The survey protocol was worked out in eleven meetings by a pluridisciplinary workshop of thirty-three members, composed of veterinary practitioners, breeding technicians, researchers, lecturers and statisticians.

The sample of 160 farms that were to be surveyed was made up from 260 proposed by the surveyors, the criteria being the size of the herd, its breed (FFPN, Holstein, Montbeliarde, Tarine, Abondance), its production level, its type of housing (tie-stall/free-stall/straw-yard).

The average size of the herd was 32 heads, the average milk-production was 5,735 kg per cow in 305 days.

The cases of lameness were studied and registered by the farmer himself.

A two-day training session, conducted by MM. Toussaint Raven (*) and Rousseau (**) (1) enabled the surveyors (veterinary practitioners and breeding technicians) to harmonize their criteria when observing and recording the digital lesions.

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Each of the 4,896 cows, whether it was lame or not, had one of its hind feet examined by the surveyor, at the end of the winter-housing period (April 1987), just before pasture-period.

The digital lesions were recorded after an exploratory foot-trimming was performed.

Eleven lesions were worked on in this study:

- brittle horn: chalk-like texture of the sole;
- heelhorn erosion: uneven wear in bulb horn, showing numerous shallow depressions or deep grooves;
- interdigital hyperplasia: proliferation of interdigital skin and hypodermis resulting in a firm lump;
- haemorrhage of the sole: red colouring of the horn of the sole;
- yellowish colouring of the sole;
- whiteline separation showing a crack between the horn of the wall and that of the sole;
- double sole: a layer of horn superposed to a new sole, both being clearly separated;
- detachment of the heelhorn: detachment of the horn in the bulb area, the horn tending to peel down towards the sole;
- sole ulcer: local reaction of the pododermis, with, in the more serious stages, formation of a granulation tissue;
- wall-rings: distinct concentric ridges in the wall, running roughly parallel to the coronary band;
- dorsal concavity of the wall: the dorsal side of the wall is concave.

Only the presence or absence of a lesion and lameness was taken into account, regardless of intensity.

As far as statistical analysis is concerned, we consider that a cow is affected by a lesion if the lesion has been on either claw of the foot examined.

The relationships between the digital lesions and lameness were studied by calculating the risk of lameness as related to each lesions (odds ratio).

We studied the relations between the lesions in two ways:

- as pair-related, by comparing their respective rate of occurrence (chi-square test);
- as multi-related (more than two lesions) by means of multivariate analyses (correspondence analysis and a hierarchical ascending classification) (2, 3).

Results

The occurrence of the digital lesions and lameness is as follows:

Out of 4,896 cattle studied, 8.2% were found to be lame.. Table 1 gives the distribution of the different lesions observed:

- at least 25% of the cows were affected by the four most frequent lesions, i.e. heelhorn erosion (55%), haemorrhage of the sole (49%), dorsal concavity of the

wall (29%) and yellowish colouring (27%);
- 10% to 25% of the cows were affected by three lesions, i.e. whiteline separation (20%), wall-rings (17%) and brittle horn (14%);
- less than 10% were affected by the following four lesions: double sole, detachment of the heelhorn, sole ulcer, interdigital hyperplasia.

Relation between digital lesions and lameness

11% of the cows surveyed were affected by no lesion whatsoever; in these 534 cows, 532 were found not to be lame.

Over 80% of the cows were affected by at least one digital lesion, although the farmer did not report any lameness.

99.5% of the lame cows were affected by one lesion at least.

Table 1 gives, for each type of lesion, the percentage of cows found lame among the cows which were affected by this particular lesion.

The lesions can be divided in to two categories:

a) those with which more than 25% of the cows were lame, i.e. double sole, detachment of the heelhorn, interdigital hyperplasia, sole ulcer;

b) those with which less than 25% of the cows were lame, i.e. heelhorn erosion, haemorrhage of the sole, yellowish colouring, dorsal concavity of the wall, whiteline separation, wall-rings and brittle horn.

Three-quarters of the cows (72.8%) were affected by at least two digital lesions; different lesions being present at the same time, this is likely to induce a statistical bias in the relationship between digital lesion and lameness.
In the sample of the 3,566 cows with at least two digital lesions, we tried to eliminate this bias in: interdigital hyperplasia, detachment of the heel-horn, double sole and sole ulcer, by comparing the occurrence of lameness in the cows affected by only one of the four lesions (13% to 27%) with the occurrence of lameness in the cows affected by none of them (6%) (Table II).

The relation between each of these four lesions and lameness is thus clearly confirmed.

Relationship between different digital lesions

a) Number of lesions present together:

Table III brings evidence of another characteristic of the interdigital hyperplasia, detachment of the heelhorn, double sole, sole ulcer category: more than half of the cows affected by at least one of the above mentioned lesions have developed at least five lesions; whereas 15% of the cows affected by none of these lesions developed at least five lesions.

Interdigital hyperplasia, detachment of the heelhorn, double sole and sole ulcer stand distinctly apart from the other lesions because of their low occurrence, their high relation to lameness and the high number of other digital lesions present at the same time. These three criteria lead us to consider them "serious"

lesions.

b) Pair-related lesions:

Out of the 55 possible pairs, 50 relations are significant at 5% level.

The analysis of the pair-related lesions although it cannot solve such complexity, enables us to emphasize two points:

- The statistically unrelated lesions are the following:
  i) heelhorn erosion and brittle horn;
  ii) heelhorn erosion and double sole;
  iii) interdigital hyperplasia and double sole;
  iv) haemorrhage of the sole and brittle horn;
  v) yellowish colouring and wall-rings.
- The most highly related lesions ($p < 0.0001$) are :
  i) wall-rings and dorsal concavity of the wall;
  ii) yellowish colouring and haemorrhage of the sole;
  iii) yellowish colouring and whiteline separation;
  iv) haemorrhage of the sole and heelhorn erosion.

c) Multivariate analyses:

The data table consists of the eleven digital lesions and the 3,566 cows having developed at least two lesions.

A correspondence analysis was performed with the cows as individuals and the eleven lesions as variables.

It enables us to distinguish between three types of combinations of lesions:
- wall-rings and dorsal concavity of the wall (axis 1);
- yellowish colouring, whiteline separation, double sole, detachment of the heelhorn and sole ulcer (axis 2, figure 1);
- heelhorn erosion, interdigital hyperplasia, detachment of the heelhorn, sole ulcer (axis 3, figure 1).

We have thus, on the first three factorial axes, combinations of digital lesions, which, in our opinion evoke respectively: chronic laminitis, subclinical laminitis, and heelhorn erosion.

Haemorrhage of the sole and brittle horn contributes little towards the inertia of the first three factorial axes.

A hierarchical ascending classification was performed on the 3,566 cows, which enabled us to select a six-cluster partition. Each cluster is significantly different from the occurrence of this lesion in the overall sample (3,566 cows) at 0.01 level (Table IV).

Among the six clusters, four are mainly characterized by a "serious" lesion: interdigital hyperplasia in cluster 3, detachment of the heelhorn in cluster 4, sole ulcer in cluster 5, and double sole in cluster 6.

We can distinguish between:

- Two clusters connected to "serious" laminitis, namely cluster 5 and cluster 6; both have in common:
  a) the yellowish colouring and the double sole;
  and respectively:
  b) cluster 5: the sole ulcer, detachment of the heelhorn and haemorrhage of the sole;
  c) cluster 6: the whiteline separation and the brittle horn.
- Two clusters connected to "serious" heelhorn erosion:
  a) cluster 3: with interdigital hyperplasia, wall-rings, sole ulcer and dorsal concavity of the wall;
  b) cluster 4: with detachment of the heelhorn, double sole, and heelhorn erosion.

In contrast, cluster 1 and cluster 2 are characterized by the three lesions with the highest occurrence and the absence of "serious" lesions:

- cluster 1: haemorrhage of the sole and heelhorn erosion;
- cluster 2: wall-rings and dorsal concavity of the wall, brittle horn.

It's in cluster 1 that the occurrence of lameness is the lowest (Table V); in that respect, too, cluster 1 and cluster 2 stand apart from the other clusters, in which the relation between lameness and serious lesion appears distinctly, each serious lesion being situated in a context of lesions combined to it.

Discussion

The occurrence of digital diseases and lameness in dairy cows varies from one study to another: Politiek (4) whose own estimation is that 25% of the cows are treated for a foot problem, quotes a 5% occurrence according to Eddy and Scott (5) and a 30% one according to Prentice and Neal (6). Peterse (7) states 10% to 25% of the cows in Dutch herds are treated for lameness originating in the claw. In France, Faye (8) using the data from a long-lasting ecopathological survey, quotes 22.5% of limb-diseases cases.

Concerning the occurrence of digital lesions, Andersson (9) finds 77.2% from a sample of cows examined in the abattoir. The occurrence of the haemorrhage of the sole is estimated by Bergsten (10) a 60% one in Swedish dairy herds, which is approximately the same as our results, versus 10.8% in Moroccan dairy herds, as quoted by Mahin (11). As to the occurrence of the sole ulcer, Peterse (7) quotes 15%, which is three times as high as in our survey.

The discrepancy between these figures is probably due to the various breeding conditions, and to the heterogeneousness in the way of collecting the information.

Thus, in our survey, the rate of lameness (8.2%), although nearing that quoted by Greenough, MacCallum and Weaver (12) for England (8%), is certainly under-estimated as it refers to winter-housing period (October-April). On the other hand, systematic examination of a hind foot on each of the 4,896 cows, performed at the end of the winter-housing period, by specifically trained surveryors, enables us to estimate

more accurately the occurrence of the different foot lesions; it also revealed the very low percentage of unaffected cows (10.9%).

Where the relation between lesions and lameness is concerned, it is difficult to compare our results with other studies, either because the observation of the lesions was limited to the lame cows only or because it was performed without taking lameness into account. Yet, as will be shown, they can be said to be similar.

In the case of heelhorn erosion, Toussaint Raven (13) closely connects this lesion with interdigitalis dermatitis, which is generated by *Bacteroides nodosus*; he describes how heelhorn erosion becomes more serious: detachment of the bulb horn, that goes from the postero-axial area towards the antero-abaxial area; ulcer at the heel-sole junction, a consequence of anarchic horn-growth, of overweight and of bruise; the detachment of the heelhorn and the sole ulcer generating lameness.

Greenough (12) also stresses that heelhorn erosion seldom results in lameness if there is no serious lesion also present (detachment of the heelhorn).

As to Mortensen (14), he uses interdigitalis dermatitis and interdigital hyperplasia as indicators related to heelhorn erosion.

We also find in our study the combination: heelhorn erosion, detachment of the heelhorn, sole ulcer, interdigital hyperplasia; we also distinguish between notion of primary indicator, not highly related to lameness (heelhorn erosion) and that of indicators of serious lesions, highly related to lameness (detachment of the heelhorn, sole ulcer, interdigital hyperplasia).

Concerning laminitis, Bergsten (10) distinguishes between a clinical and a subclinical form; clinical laminitis being characterized by lameness, stiff gait, abnormal bearing. Subclinical laminitis is revealed by foot-trimming: the haemorrhage, the exudation of serum in the corium, which he considers typical of laminitis, appear as bruises on the surface of the sole eight weeks later. Bergsten (10) and Peterse (7) use the bruise of the sole and the sole ulcer as indicators of laminitis.

Toussaint Raven (13, 15) holds the yellowish colouring to be the indicator of serum exuding in the corium; according to him, the haemorrhage of the sole can also be linked to serious heelhorn erosion or have a purely traumatic origin. He quotes the whiteline separation, double sole and sole ulcer as other evidence of laminitis. Greenough (16) distinguishes between four stages of seriousness in laminitis: acute and subacute from the general symptoms; subclinical when soft horn, yellowish colouring and diffuse haemorrhage can be noted; chronic, with wall-rings, convexity of the sole and disappearance of the dorsal convexity of the wall.

As to Mortensen (14) his indicators of laminitis are the following: the shape of the claw, the wall-rings, the detachment of the horn capsule, the quality of the horn, the haemorrhage of the sole, the double sole and the whiteline separation.

We often find the same indicators are quoted by the different authors. Yet whether these indicators belong to a laminitis syndrome or not is not totally clear.

Our study evidences two distinct categories of indicators of laminitis:

a) the pair: wall-rings/concavity of the wall, indicators of chronic laminitis

(Greenough (16)) combined with brittle horn;

b) the combination: yellowish colouring, whiteline separation, double sole, detachment of the heelhorn, sole ulcer, the indicators of subclinical laminitis (Greenough (16)) being present here - except the haemorrhage of the sole.

Indeed the haemorrhage of the sole is more an indicator of serious laminitis than an indicator of primary affection as is yellowish colouring. Moreover it cannot be considered a specific indicator of subclinical laminitis as it is also combined to heelhorn erosion.

Consequently we did not accept the haemorrhage of the sole as primary indicator of subclinical laminitis.

It may be that the recording of only the presence or absence of lesions accounts for this result, which would perhaps have been less contrasted if the recording had taken in to account the area and the extent of the haemorrhage on the sole.

Conclusion

In order to account for the three categories of indicators evidenced by the multivariate analysis on the one hand, and the relation between lameness and serious lesions on the other hand, we have defined five generic indicators:

a) two indicators of heelhorn erosion:

- benign heelhorn erosion: heelhorn erosion without interdigital hyperplasia or detachment of the heelhorn or sole ulcer (2,180 cows);
- serious heelhorn erosion: either interdigital hyperplasia or heelhorn erosion with detachment of the heelhorn or sole ulcer (566 cows);

b) one indicator of chronic laminitis:

- wall-rings or dorsal concavity of the wall, or brittle horn (1,963 cows);

c) two indicators of subclinical laminitis:

- benign laminitis: yellowish colouring without whiteline separation or double sole or sole ulcer (698 cows);
- serious laminitis: yellowish colouring with whiteline separation or double sole or sole ulcer (602 cows).

These generic indicators applied to 3,777 cows in the 4,362 affected by at least one lesion.They are interesting in three respects:

- they do not totally eliminate the complexity of the possible combinations between the different lesions: one cow can bear at the same time the indicators of heelhorn erosion, of subclinical laminitis and of chronic laminitis;
- in subclinical laminitis as well as in heelhorn erosion, one cow cannot bear at the same time both the indicators of the benign and of the serious forms of the disease. This makes it possible, at farm-level, to compare the risk factors of serious disease with the risk factors of benign disease, in order to identify the risk factors, if any, specific to serious diseases;

- and last, having at our disposal distinct indicators of subclinical and of chronic laminitis enables us to further the analysis by studying their occurrence on the dairy cattle farms and by comparing their respective risk factors; in so doing we attempt to answer the following question: are we faced with two different diseases or with two stages of one single disease?

References

(1) Rousseau (1985) Parer les pieds des bovins, ITEB, Paris.

(2) Benzecri (1973) L'analyse des donnees, Tome 1: la taxinomie, Tome 2: l'analyse des correspondences. Dunod, Paris (2e ed. 1976).

(3) Lebart, Morineau, Warwick (1984). Multivariate descriptive statistical analysis, correspondence analysis and related techniques for large matrices. Wiley, New York.

(4) Politiek (1986) Importance of claw quality in cattle. Liv. Prod. Sci. **15**, 133-152.

(5) Eddy & Scott (1980). Some observations on the incidence of lameness in dairy cattle in Somerset. Vet. Res. **106**, 140-144.

(6) Prentice & Neal (1972) Some observations on the incidence of lameness in dairy cattle in West Cheshire. Vet. Rec. **91**, 1-6.

(7) Peterse (1982) Prevention of laminitis in dutch dairy herds. 4th Int. Symp. On disorders of ruminant digit, Paris.

(8) Faye (1988). Environmental factors associated with lameness and limb disease in French dairy herds. Environment and Animal Health 6th Int. Cong, Skara.

(9) Andersson (1981) The influence of breed, age, body weight and season on digital diseases and hoof size in dairy cows. Zent. Vet. A, **28**, 141-151.

(10) Bergsten (1986) Effect of feeding intensity at calving on the prevalence of subclinical laminitis. 5th Symp. Int. On disorders of the ruminant digit, Dublin.

(11) Mahin (1982). Observations sur les lesions et la frequence de la pododermatite aseptique diffuse des bovins dans les conditions d'exploitations marocains. 4th Int. Symp. On disorders of ruminant digit, Paris.

(12) P. R. Greenough, F. J. MacCallum, A.D. Weaver. Les boiteries des bovins. Ed. du Point Vet.

(13) Toussaint Raven (1985) Cattle footcare and claw trimming. Farming Press, 38-51.

(14) Mortensen et Hesselholt (1982). Laminitis in Danish dairy cattle. An epidemiological approach. 4th Int. Symp. On disorders of ruminant digit, Paris.

(15) Toussaint Raven (1982). Some reflections after three Symposia on bovin digital disorders. 4th Int. Symp. "On disorders of ruminant digit", Paris.

(16) P. R Greenough. Laminitis in review. 4th Int. Symp. On disorders of ruminant digit, Paris.

Summary

The Centre d'Ecopathologie carried out a survey on laminitis and heelhorn erosion, on 160 French dairy cattle farmers (4,896 cows) during the 1986-1987 winter housing period, in order to demonstrate the risk-factors for these diseases. Lameness was recorded in the course of the survey. The lesions were noted at the end of the survey, by the systematic examination of a hind foot on each cow, whether it was found lame or not.

The rate of lameness was 8.2% over the course of the survey.

Of all the lesions, heelhorn erosion (55% of the cows) and the haemorrhage of the sole (49%) have the highest occurrence and the lowest relation to lameness. The double sole, the detachment of the heelhorn, the sole ulcer, and the interdigital hyperplasia are the fewest (4% to 9%) and the most highly related to lameness.

The analysis of the relations between the lesions enables us to distinguish between three types of combinations, corresponding to:

- chronic laminitis: wall-rings, concavity of the wall and brittle horn;
- subclinical laminitis: yellowish colouring of the sole; it is subdivided into "serious" or "benign", whether it is, or not, combined with the double sole, the whiteline separation, or the sole ulcer;
- heelhorn erosion, subdivided into "serious" or "benign", depending on the presence or absence of the detachment of the heelhorn, the sole ulcer, and interdigital hyperplasia.

Table I
For each lesion: percentage of the cows affected by the lesion in the overall sample, and percentage of cows found lame in those affected by the lesion.

	cows affected by the lesion		cows with the lesion	
type of lesion	number	%(*)	number	%(**)
Heelhorm erosion	2,699	55	285	11
Haemorrage of the sole	2,422	49	277	11
Dorsal concavity of the wall	1,495	29	181	12
Yellowish colouring of the sole	1,300	27	156	12
Whiteline separation	995	20	131	13
Wall-rings	852	17	134	13
Brittle horn	673	14	86	16
Double sole	428	9	89	21
Detachment of the heel horn	371	8	93	25
Sole ulcer	258	5	93	36
Interdigital hyperplasia	182	4	60	33
No lesion	534	11	2	0

(*) in percentage of overall number of cows(4,896)
(**) in percentage of cows affected by the lesion

Table II

Relation between interdigital hyperplasia, detachment of the heel horn, double sole, sole ulcers on the one hand, and lameness on the other, as studied on the sample of cows affected by at least two digital lesions (3,566 cows).

	lame		Not lame		odds ratio calculated from the reference population	
	number	%	number	%	value	significant at 5% level (*)
Reference population : Cows with at least two lesions among which none of the following: - interdigital hyperplasia - detachment of the heel horn - double sole - sole ulcer	149	6	2444	94	1	-
Cows with at least two lesions among which only one of the following	140	18	626	82	3.67	2.90 - 4.64
- interdigital hyperplasia	28	24	90	76	5.10	3.38 - 7.71
- detachment of the heelhorn	35	16	186	84	3.09	2.11 - 4.51
- double sole	37	13	244	87	2.49	1.71 - 6.61
- sole ulcer	40	27	106	73	6.19	4.34 - 8.83
Cows with at least two of the following, including	88	43	119	57	14.10	10.92 - 18.20
- either interdigital hyperplasia	30	50	30	50	19.07	12.91 - 28.16
- or detachment of the heelhorn	58	42	81	58	13.65	10.15 - 18.36
- or double sole	50	39	77	61	12.38	9.05 - 16.94
-or sole ulcer	51	47	58	53	16.76	12.76 - 22.92

(*) Miettinen's method

Table III

Relation between interdigital hyperplasia, detachment of the heel horn, double sole, sole ulcer and number of digital lesions, in a sample of cows with at least one lesion (4,362)

	Number of digital lesions per cow							
	1 - 2 lesions		3 - 4 lesions		5 lesions and more		TOTAL	
	number	%	number	%	number	%	number	%
Number of cows with at least one digital lesion, among which none of the following : - interdigital hyperplasia - detachment of the heelhorn - double sole - sole ulcer	1656	49	1179	35	516	15	3351	100
Number of cows with at least one of the following : - interdigital hyperplasia - detachment of the heelhorn - double sole - sole ulcer	138	14	303	30	570	56	1011	100

CHI-SQUARE = 771.74 p<0.0001

Table IV

Six-cluster typology of the 3,566 cows with at least two digital lesions, by means of a hierarchical ascending classification.

* occurrence comparison test p<0.01

		% of cows involved in the cluster	% of cows involved overall	test value (*)
Cluster 1: 1796 cows	No wall-rings	99.78	76.33	37.29
	No dorsal concavity of the wall	85.24	61.05	30.65
	No double sole	100.00	88.56	24.84
	No detachment of the heelhorn	100.00	89.90	23.18
	No sole ulcer	100.00	92.85	19.22
	No interdigital hyperplasia	100.00	95.01	15.86
	Haemorrhage of the sole	71.33	62.87	10.52
	No brittle horn	88.81	82.64	9.83
	Heelhorn erosion	70.82	68.40	3.11
Cluster 2: 797 cows	Wall-rings	72.65	23.67	34.88
	Dorsal concavity of the wall	88.83	38.95	33.43
	No double sole	100.00	88.56	14.63
	No detachment of the heelhorn	100.00	89.90	13.66
	No haemorrhage of the sole	55.58	37.13	12.03
	No sole ulcer	100.00	92.85	11.31
	No interdigital hyperplasia	100.00	95.01	9.30
	No yellowish colouring of the sole	78.04	64.83	9.07
	Brittle horn	25.97	17.36	6.98
	No heelhorn erosion	39.40	31.60	5.26
	No whiteline separation	78.80	72.71	4.41
Cluster 3: 178 cows	Interdigital hyperplasia	100.00	4.99	37.36
	Wall-rings	40.45	23.67	5.03
	Sole ulcer	15.17	7.15	3.69
	Dorsal concavity of the wall	49.44	38.95	2.84
Cluster 4: 286 cows	Detachment of the heelhorn	100.00	10.10	40.18
	No sole ulcer	100.00	92.85	6.24
	Double sole	22.73	11.44	5.61
	No interdigital hyperplasia	100.00	95.01	5.05
	No haemorrhage of the sole	46.85	37.13	3.45
	Heelhorn erosion	75.87	68.40	2.82
Cluster 5: 228 cows	Sole ulcer	100.00	7.15	38.86
	Detachment of the heelhorn	21.49	10.10	5.20
	No interdigital hyperplasia	100.00	95.01	4.40
	Haemorrhage of the sole	73.25	62.87	3.35
	Yellowish colouring of the sole	44.74	35.17	3.02
	Double sole	17.54	11.44	2.74
Cluster 6: 281 cows	Double sole	100.00	11.44	38.08
	No detachment of the heelhorn	100.00	89.90	7.53
	No sole ulcer	100.00	92.85	6.17
	No interdigital hyperplasia	100.00	95.01	5.00
	No heelhorn erosion	41.28	31.60	3.50
	Yellowish colouring of the sole	44.84	35.17	3.43
	Whiteline separation	34.52	27.29	2.72
	Brittle horn	23.49	17.36	2.66

Table V

Occurrence of lameness in the clusters resulting from the hierarchical ascending classification and risk of lameness in the sample of the 3,566 cows with at least two lesions.

	Lame		Not lame		Odds ratio calculated from the reference population	
	Number	%	Number	%	value	Significant at 5% level (*)
Cluster 1 Reference population	89	5	1707	95	1.00	
Cluster 2	60	8	737	92	1.56	1.12 - 2.19
Cluster 3	58	33	120	67	9.27	6.69 - 12.84
Cluster 4	56	20	230	80	4.67	3.34 - 6.53
Cluster 5	77	34	151	66	9.78	7.25 - 13.19
Cluster 6	37	13	244	87	2.91	1.97 - 4.30
Total	377	11	3189	89		

(*) Miettinen's method

INERTIA RATE OF THE FIRST THREE AXES	
AXIS 1	14.64 %
AXIS 2	12.54 %
AXIS 3	10.60 %

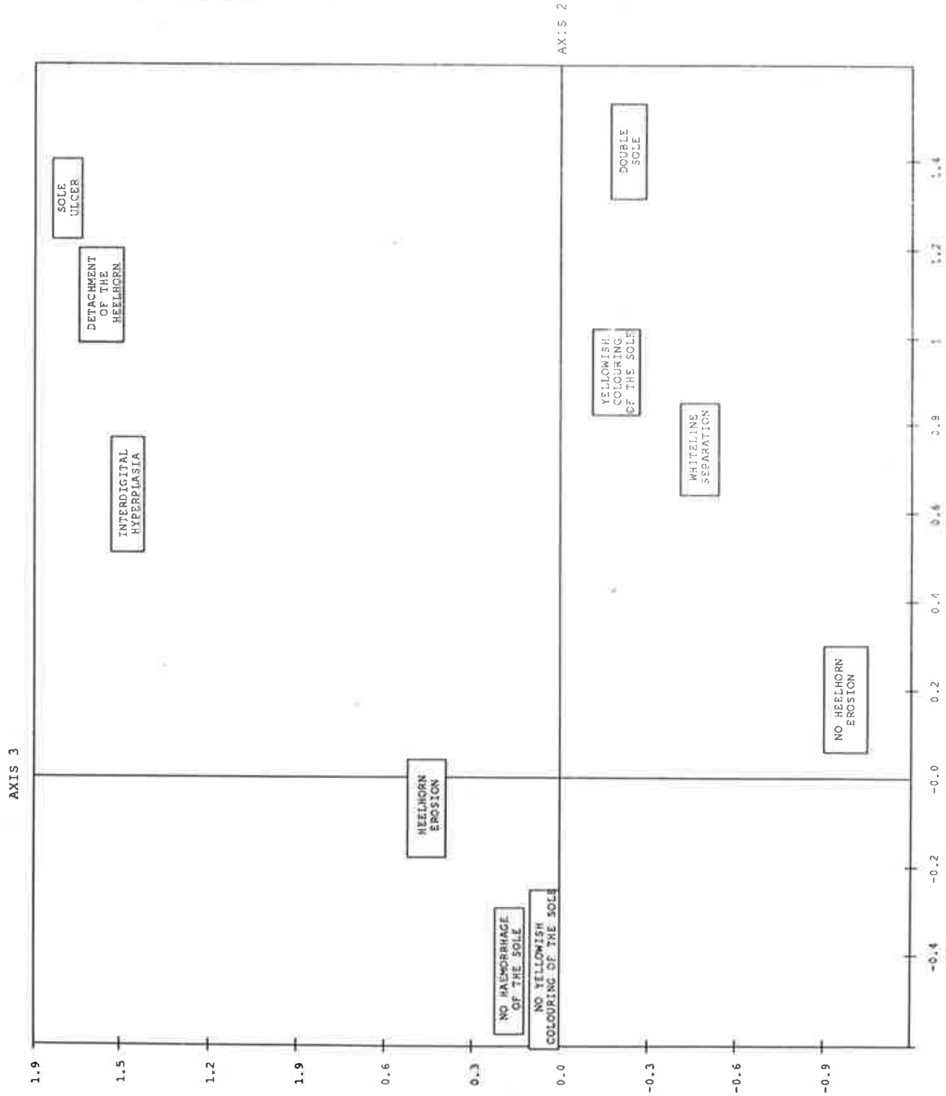

FIGURE1
Projection on the 2-3 plane of the lesions the most associated to axis 2 or axis 3.

Correlation Between Sires and Daughters and Selection for Improved Structural Claw Soundness

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Introduction

With infertility and udder diseases lameness is considered as one of the most striking problems in modern dairy herds all over the world. In nearly all dairy herds "lameness" means "claw problems", because most of the lame cows are suffering from painful claw diseases or are affected by abnormal claw shape and/or claw function (claw disorders). Therefore, studying lameness in dairy cattle primarily means looking at the claws.

Modern animal production can only be successful economically and socially, if fundamental principles of preventive medicine are recognized: avoiding a disease is better (and cheaper) than to cure it! The precondition for being able to avoid a disease, however, is to know the reasons or pathogenetic factors for this disease.

Claw problems have many reasons. On one hand there are environmental factors like improper housing and feeding conditions, neglected or incompetent hoof trimming and other "management-influenced factors". On the other hand there are genetic factors affecting claw soundness.

It is a basic consideration, that breeding for claw soundness would be the most effective long term prophylaxis against claw diseases. So it could be an excellent contribution both to economical prosperity and to animal welfare.

But how to breed for a better claw soundness?
Theoretically there are two (conventional) ways:
the direct and the indirect one (figure 1);

- <u>The Direct Way</u>:

The parameter, which should be influenced by selection (frequencies of claw diseases and claw disorders in a female population) provides the basis for selection in itself;

pros: very precise evaluation of breeding values;

cons: high costs for recording data (clinical examination of about 50 daughters per sire in a conventional progeny testing scheme);

- The Indirect Way:

Indirect parameters are used for selection as indicator traits instead of the target parameter (claw health);

pros: easier to integrate in existing progeny testing schemes and less costs for collecting data;

cons: less precise evaluation of breeding values.

Because the costs for clinical examination of progeny groups in field are so high, breeding programmes in practice can only go the indirect way using indicator traits for claw soundness.

Of course such indicator traits have to fulfill some special requirements:

- easy to measure at low costs and high accuracy of measurement
- high enough heritability estimates and genetic variance
- sufficient high genetic correlations to claw health.

In research programme at the Institute for Animal Breeding and Health in Munich we tried to find such indicator traits for claw health and to design a practical breeding programme for improved structural claw soundness.

Single steps of this programme were:

Step 1: to determine suitable indirect claw parameters

Step 2: to estimate heritabilities, genetic and phenotypic correlations for claw disorders and those indirect parameters in progeny groups

Step 3: to estimate genetic correlations between claw parameters of sires and claw parameters of their daughters and

Step 4: to draw conclusions on the most promising claw traits and selection pathways in breeding for claw soundness.

Step 1: SUITABLE INDIRECT PARAMETERS

Several investigations were made from 1978 to 1982 to test a large scale of claw parameters (Distl et al., 1982. Distl et al., 1984, Pflug, Pflug et al., 1980, Raschel 1980, Schneider, 1980, Walz, 1979). Though providing high enough heritability estimates and genetic variation, chemical, biochemical and histological claw traits turned out to be rather complicated to be used in breeding practice. So genetic correlations with claw diseases are not proven yet. Some physical claw traits, which were easy to record, did not show high enough repeatability or genetic variation. According to results of other working groups in the USA, the Netherlands, Switzerland and Sweden, some morphometric measures of claws proved to come next to the "ideal indirect trait" for practical use in a breeding program. Figure 2 shows the claw measures we used in our main investigation. As we will show below, these measures are quite easy to record, they are highly repeatable and they provide high enough genetic variation and heritability estimates.

Step 2 and 3: MAIN INVESTIGATION

-Material and Methods:

Starting point of our main investigation were 235 German Simmental young bulls tested at Bavarian performance testing stations in 1982 (figure 3). In these young bulls claw measurements and judgments of claw shape and leg posture were recorded three times at the age from 6 to 12 months (Huber, 1983). Out of them 18 young bulls were selected according to their claw measurements for a progeny test (6 bulls with extreme big claws, 6 bulls with extreme small claws and 6 bulls with average claw measurements). The experiment was designed in a way, that about 40 daughters per sire should give heritability estimates and estimates of sire-daughter relationships with sufficient accuracy.

From March 1986 to May 1987 725 daughters of these 18 sires and 1213 herdmates on 638 farms in Bavaria were investigated at the beginning of first lactation (Baumgartner 1988).

The following traits were recorded:

- claw measures (figure 2): length of dorsal border, angle of dorsal border to ground surface, bulb length, bulb height, diagonal length and area of ground surface;
- claw and leg judgments
- claw disorders
- housing and feeding conditions, claw trimming;

Claw measures were obtained with dividers and quantified by comparing the distance with a rule or measured with special devices (goniometer, electronic planimeter). To estimate repeatabilities of claw measures two herds (20 and 40 cows) were measured three times. Repeatabilities were computed as mean product-moment correlations between single measurements. Claw and leg judgments were recorded according to a scheme based on Huber (1983). The following criteria were scored for both front and hind legs: front view, side view, fetlock, interdigital space, claw shape of lateral and medial claw. Claw disorders were registered by a clinical examination (Baumgartner, 1988).

All measuring and judging was done by one person.

- Statistical methods

For heritability estimations of claw parameters the following statistical model was applied:

$$y_{ijklmnop} = \mu + \text{herd}_i + \text{width of chest}_j + \text{days in milk when recorded}_k + \text{condition of the cow}_l + \text{claw trimming}_m + \text{month of recording}_n + \text{sire}_o + \text{remainder}_{ijklmnop}$$

Variance components were estimated by Henderson's Method III and Restricted Maximum Likelihood (REML). Heritabilities were estimated by the intraclass-correlations of half-sibs. Standard errors of the heritabilities were calculated according to Swiger et al (1964). Genetic correlations were estimated by variance components of the half-sib analysis. The correlations between claw measures of the young bulls and claw parameters of their daughters were computed by product-moment-correlations.

Results:

1. Claw measures

Table 1 shows means, standard deviations, minimum and maximum values of claw measures (figure 2) in 1938 German Simmental first lactating cows. For claw measures the following repeatabilities were found (Baumgartner, 1988):

- length of dorsal border, angle of dorsal border to ground surface, diagonal length: **0.9**
- bulb length, bulb height: **0.8**
- area of ground surface: **0.6**.

Comparing the two claws of one leg it seems, that in front legs the medial claw and in hind legs the lateral claw is bigger.

2. Judgments of leg posture and claw shape

Table 2 shows frequencies for judging leg posture and claw shape as "normal". In our material of young cows claw shape was rather "normal" whereas leg posture differed extremely from the ideal standard.

3. Claw Disorders

In our material we found few cases of lameness (about 2%). Almost all of them were slight cases and had their origin in a deep heel horn erosion of hind legs. In fact there is no direct phenotypic correlation between the other claw disorders and lameness, claw disorders must be considered as a symptom of disturbed integrity of

claw morphology and function in single animals; thus they must be considered as the starting point of more severe problems.

4. Heritability estimates

Heritability describes this part of the total variance, which is caused by additive-genetic effects. The higher the heritability estimates for a trait, the higher the genetic progress, which could be reached by selecting for it.

Heritability estimates of claw measures (table 4) range between 0.18 and 0.66 in front legs and between 0.17 and 0.42 in hind legs (Henderson-III). For judgments of leg posture and claw shape (table 5) estimates between 0.08 and 0.50 were found in front legs, in hind legs 0.13 and 0.48 respectively. Estimates for the frequencies of claw disorders (table 6) are between 0.10 and 0.35 in front legs and between 0.09 and 0.29 in hind legs.

Tables 4, 5 and 6 also show the additive-genetic standard deviations for all traits mentioned.

5. Relations between claw traits in daughters

Phenotypic correlations between claw measures and claw disorders were near zero.

Genetic correlations between claw measures and claw disorders in daughters (table 7) varied from 0.64 to -1.00 in front legs and from 0.99 to -0.80 in hind legs. Because these univariate genetic correlations are rather inconsistent and difficult to interpret, multiple correlations were computed between all claw measures and claw disorders. They gave estimates from 0.72 to 0.98.

6. Relations between sires and daughters.

Univariate correlations between claw measures of the sires and claw measures of the daughters were in the range from 0.59 to -0.64.

Correlations between claw measures of the sires and frequencies of claw disorders of their daughters ranged from 0.48 to -0.52 in front legs and from 0.51 to -0.52 in hind legs (table 8).

Multiple correlations between all claw measures of sires and claw disorders of their daughters reached estimates from 0.55 to 0.96.

The results of our main investigation we summarize as follows:

- the claw measures used (figure 2) are highly repeatable, easy to obtain and therefore technically suitable for being integrated in a practical breeding programme;
- heritability estimates and additive-genetic variance of all claw traits are high enough, so that in general breeding for claw soundness can be very successful;
- genetic correlations (both between claw measures and claw disorders in daughters and between claw measures of sires and claw disorders in their daughters) are high enough to use claw measures as indicator traits for claw soundness.

Step 4: SELECTION FOR IMPROVED STRUCTURAL CLAW SOUNDNESS

The objective of this last step of our research programme was to draw conclusions on:
- the most promising selection pathway
- the claw traits, which should be used within each selection pathway.

In conventional AI-breeding schemes, there are two ways to improve claw quality in cattle using indicator traits for claw soundness (figure 4): testing of female or male progeny in field or stations and the performance test of young bulls. Besides we see a large scale of possibilities to use indicator traits in breeding schemes with Moet (Distl et al, 1989).

Progeny test of daughters in dairy farms (figure 4):

Claw measures of daughter groups are recorded together with other traits in the routine procedure of existing breeding programmes.

Additionally, in the case of small herds, herdmates should be recorded in order to minimize herd effects being the most important influence on claw parameters.

Selection index calculations were made to investigate this selection pathway (Baumgartner et al., 1990).

For claw measures, judgments of leg posture and claw shape and various combinations of these relative selection responses were calculated. The selection response we could expect, if we used claw disorders directly as selection criteria, was the basis (=100%) for our relative selection response.

With an index combining all claw measures, a relative selection response of **67%** can be expected. For the selection response to be expected from single claw measures see table 9.

Combining some of them we found various index variants, of which INDEX-3 seems to be the best compromise between costs, labour and predicted selection response.

In comparison to the index based on all claw disorders a relative selection response of 52% might be expected, when all judgments of leg posture and claw shape scored by the official staff in Bavaria are used.

If we combine our INDEX-3 with judgments of leg posture, a relative selection response of **83%** can be found (all calculations with 40 progeny). So the mean superiority of indices using claw measures instead of claw judgments is at least about 20% to 30% in relative selection response.

In conclusion we are proposing, that the following claw measures should be recorded in 40 to 50 daughters per sire instead of judging claws: length of dorsal border in both front and hind legs, bulb length in front legs and diagonal length in front and hind legs. Judgments of leg posture should be made and used in a selection index for claw soundness. Having a small herd structure like in Bavaria with single daughters

tested in many herds, herdmates should be recorded additionally to minimize the large herd effects on claw traits (Baumgartner et al., 1990).

Performance test of young bulls at test stations (figure 4):

Looking at the genetic correlations between claw measures of young bulls and claw disorders in their daughters it seems very promising to use claw measures of young bulls as indicator traits for claw soundness in their daughters.

Claw measures of young bulls could be taken at the age of about one year at performance testing stations or at AI-stations. Besides reducing generation intervals drastically this selection pathway provides an opportunity to record claw traits in a standardized environment and is economically more efficient than recording data of progeny and herdmates in field. For a performance test the following claw measures should be recorded in front and hind legs: length of the dorsal border, angle of dorsal border to ground surface, bulb length, bulb height, diagonal length, area of ground surface and hardness of the dorsal wall. Additionally judgments of claw shape and leg posture should be made.

In 1989 we recorded data of about 100 German Simmental young bulls in a Bavarian performance testing station for further investigations.

Conclusions

At the present stage of research on genetic influences on claw disorders it is clear, that claw measures are valuable indirect parameters when selecting for improved structural claw soundness.

Now it is the breeders' decision to use these traits together with others, which are already part of existing breeding programmes.

Looking at a progeny test of daughters in dairy farms we found very promising results. Further investigations of male progeny and of young bulls in performance testing stations will show, whether these selection pathways can be used to reach an optimum of economical efficiency and genetic gain.

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References

Baumgartner, Ch. (1988): Untersuchungen uber Klauenmasse als Hilfsmerkmale fur die Selektion auf Klauengesundheit an Tochtergruppen von Deutschen Fleckviehbullen. Diss. med. vet., Munchen.

Baumgartner, Ch., O. Distl und H. Kraublich, (1990): Eignung von Indikatormerkmalen fue die Zucht auf Klauengesundheit beim Deutschen Fleckvieh. Zuchtungskunde, in preparation.

Distl, O., F. Graf & H. Kraublich (1982): Genetische Variation von

morphologischen, histologischen und elektrophoretischen Parametern bei Rinderklauen und deren phanotypischen und genetischen Beziehungen. Zuchtungskunde **54**, 106-123.
Distl, O., M. Huber, F. Graf and H. Kraublich, (1984): Claw measurements of young bulls at performance testing stations in Bavaria. Livest. Prod. Sci. **11**, 587-598
Distl, O., D.S. Koorn, B.T. McDaniel, D. Peterse, R.D. Politiek and A. Reurink, (1989): Claw traits in cattle breeding programmes: Report of the EAAP working group "Claw Quality in Cattle". 40th Annual meeting of the European Association for Animal Production, Dublin, Ireland, August 27 - August 31 1989.
Huber, M., (1983): Untersuchungen uber Klauenparameter an Jungbullen in den Bayerischen Eigenleistungsprufungsanstalten. Diss. med. vet., Munchen.
Pflug, W., (1978): Die Anpassung des Fleckviehs in Sud- und Sudwest-Afrika unter besonderer Berucksichtigung der Klauen. Diss. med.vet., Munchen.
Pflug, W., DR. Osterhoff, H. Kraublich and K. Osterkorn, (1980): The adaptability of Simmental Cattle in South and Southwest Africa with special reference to their claws. S. Afr. J. Anim. Sci. **10**, 91-97.
Raschel, H. (1980): Genetische Beeinflubung der loslichen Protein des Horns von Rinderklauen. Diss. med. vet., Munchen.
Schneider, P. (1980): Einfluss des Vaters auf Gliedmassenstellung und Klauenformen, sowie Abriebfestigkeit und Wassergehalt des Klauenhornes der Nachkommen. Diss. med. vet., Munchen.
Swiger, L.A., W.R. Harvey, D.O. Everson and K.E. Gregory (1964): The variance of intra-class correlation involving groups with one observation. Biometrics **20**, 818-826.
Walz, J. (1979): Histologische Untersuchung zur Erfassung der Klauenhornqualitat beim Rind. Diss, med. vet., Munchen.

Table 1:
Claw measures of German Simmental first lactating cows
(n = 1938)

measure	unit	mean	s	min	max
front leg					
length lateral	mm	78.6	9.7	57	130
length medial	mm	81.4	9.9	59	134
bulb length lateral	mm	47.5	7.8	25	75
bulb height lateral	mm	36.1	6.4	12	59
angle lateral	grades	47.9	6.3	19	67
area lateral	cm^2	44.7	8.1	26.2	76.6
area medial	cm^2	46.0	8.2	25.0	89.0
diagonal lateral	mm	135.9	13.3	105.1	193.7
diagonal medial	mm	141.4	13.1	103.7	197.7
hind leg					
length lateral	mm	80.1	8.5	62	118
length medial	mm	79.5	8.4	60	119
bulb length lateral	mm	35.6	5.9	17	58
bulb height lateral	mm	27.7	5.0	11	46
angle lateral	grades	45.9	5.9	26	65
area lateral	cm^2	43.9	6.8	26.6	75.1
area medial	cm^2	37.3	6.8	20.5	63.7
diagonal lateral	mm	130.3	11.8	101.3	195.6
diagonal medial	mm	126.0	11.3	95.4	172.3

Table 2:
Judgments of leg posture and claw shapes in German Simmental first lactating cows (n=1938): frequencies for "normal".

Trait	front leg	hind leg
Front/hind view	65.4%	60.7%
side view	98.2%	79.4%
fetlock	58.1%	22.9%
interdigital space	51.0%	54.0%
claw shape lateral	75.4%	83.5%
claw shape medial	64.1%	88.4%

Table 3:
Frequencies of claw disorders in German Simmental first lactating cows (n=1938)

claw disorder	front leg	hind leg
interdigital hyperkeratosis	31.6%	2.7%
hyperplasia interdigitalis	13.5%	0.8%
dermatitis interdigitalis	9.6%	12.5%
heel horn erosion lateral	7.6%	49.9%
heel horn erosion medial	8.8%	49.5%
sole contusion lateral	4.4%	28.2%
sole contusion medial	8.5%	11.2%
gap in white line lateral	2.6%	9.4%
gap in white line medial	3.6%	1.7%
double sole lateral	1.1%	7.1%
double sole medial	1.8%	3.1%

Table 4:
Heritability estimates (HENDERSON -III) with standard errors and additive-genetic deviations for claw measures.

	front leg			hind leg		
measure	h^2	s_{h^2}	s_a	h^2	s_{h^2}	s_a
length lateral	0.33	0.13	5.6	0.29	0.12	4.6
length medial	0.37	0.14	6.0	0.17	0.09	3.5
bulb length lateral	0.18	0.09	3.3	0.17	0.08	2.4
bulb height lateral	0.22	0.10	3.0	0.41	0.15	3.2
angle lateral	0.41	0.16	4.0	0.42	0.16	3.8
area lateral	0.32	0.13	4.6	0.39	0.15	4.2
area medial	0.66	0.21	6.7	0.31	0.13	3.8
diagonal lateral	0.36	0.14	5.7	0.37	0.14	5.4
diagonal medial	0.44	0.16	6.5	0.25	0.11	4.4

Table 5:
Heritability estimates (HENDERSON-III) with standard errors and additive-genetic standard deviations for judgments of leg positions and claw shape.

trait	classes	h^2	s_{h^2}	$s_a(\%)$	span of h^2 each class per trait separate
front leg					
front view	7	0.50	0.18	33.7	(0.12 - 0.54)
side view	5	0.22	0.10	6.6	---
fetlock	4	0.08	0.06	14.0	(0.08 - 0.38)
interdigital space	4	0..38	0.15	30.8	(0.13 - 0.38)
claw shape lateral	6	0.22	0.10	20.0	(0.13 - 0.24)
claw shape medial	6	0.31	0.13	26.6	(0.18 - 0.37)
hind leg					
hind view	7	0.33	0.13	17.5	(0.08 -0.49)
side view	5	0.17	0.09	17.1	(0.10 - 0.41)
fetlock	4	0.48	0.17	29.2	(0.13 - 0.48)
interdigital space	4	0.27	0.12	26.0	(0.13 - 0.27)
claw shape lateral	6	0.24	0.11	18.4	(0.11 - 0.24)
claw shape medial	6	0.13	0.07	11.7	(0.04 - 0.13)

Table 6:
Heritability estimates (HENDERSON-III) with standard errors and additive-genetic standard deviations for frequencies of claw disorders.

claw disorder	front leg h^2	s_h2	s_a	hind leg h^2	s_h2	s_a
Interdigital hyperkeratosis	0.21	0.10	21.4	0.16	0.09	5.6
hyperplasia interdigitalis	0.31	0.13	18.7			
dermatitis interdigitalis	0.15	0.08	11.1	0.11	0.07	11.5
heel horn erosion lateral	0.19	0.09	11.1	0.09	0.06	15.0
heel horn erosion medial	0.15	0.08	11.1	0.15	0.08	19.4
sole contusion lateral	0.10	0.07	6.9	0.29	0.12	25.1
sole contusion medial	0.20	0.10	13.4	0.25	0.11	16.8
gap in white line lateral	0.17	0.09	7.0	0.14	0.08	10.7
gap in white line medial	0.35	0.14	10.1	0.19	0.09	6.1
double sole lateral	0.16	0.09	5.6	0.18	0.09	10.8
double sole medial	0.10	0.07	4.4	0.21	0.10	7.8

Table 7:
Genetic correlations using paternal half-sib analysis between claw shape measures and frequencies of claw disorders in the front and hind legs.

	claw measure								
	length of dorsal border		bulb length	bulb height	angle	area		diagonal	
claw disorder	lat	med	lat	lat	lat	lat	med	lat	med
front legs									
interdigital hyperkeratosis	0.20	0.29	0.24	0.27	-0.06	0.48	0.20	0.19	0.27
hyperplasia interdigitalis	0.47	0.43	-0.06	0.08	0.18	0.41	0.34	0.31	0.31
dermatitis interdigitalis	-0.19	-0.15	0.44	0.60	0.47	-0.06	-0.35	-0.03	-0.17
heel horn erosion									
lateral	0.07	-0.15	0.06	0.04	0.01	0.15	0.13	0.03	0.04
medial	0.38	0.09	0.21	0.14	-0.18	0.34	0.42	0.45	0.42
sole contusions									
lateral	0.42	0.47	0.28	0.18	-0.44	0.09	-0.01	0.26	0.07
medial	0.37	0.47	-0.24	-0.67	-0.65	0.17	0.33	0.27	0.41
double sole									
lateral	0.45	0.41	-0.06	-0.16	-0.43	0.45	0.40	0.64	0.54
medial	0.47	0.37	-0.67	-0.48	-1.00	0.39	0.41	0.32	0.36
hind legs									
interdigital hyperkeratosis	-0.32	-0.38	-0.01	-0.04	0.15	-0.45	-0.33	-0.50	-0.19
dermatitis interdigitalis	0.97	0.99	-0.55	-0.51	-0.64	0.76	0.64	0.98	0.82
heel horn erosion									
lateral	-0.18	-0.12	-0.28	-0.25	0.21	-0.52	-0.40	-0.58	-0.42
medial	-0.32	-0.08	-0.39	-0.40	0.50	-0.60	-0.39	-0.56	-0.38
sole contusions									
lateral	0.36	0.53	0.13	0.01	-0.28	0.22	0.18	0.16	0.18
medial	-0.39	-0.11	0.32	0.31	0.57	-0.56	-0.35	-0.38	-0.36
double sole									
lateral	-0.70	-0.67	0.46	0.50	0.52	-0.73	-0.72	-0.80	-0.66
medial	0.26	0.30	0.49	0.56	0.02	-0.03	0.23	0.07	0.31

Table 8:
Correlations between claw measures of the sires and frequencies of claw disorders of the daughters in front and hind legs.

	claw measures (sires)				
claw disorder(daughters)	length of dorsal border	bulb length	angle	area	hardness of the dorsal wall (SHORE D)
front legs					
interdigital hyperkeratosis	0.00	-0.14	0.15	-0.30	0.14
hyperplasia interdigitalis	0.02	0.15	0.44	-0.21	-0.20
dermatitis interdigitalis	-0.36	0.19	0.47	-0.10	-0.40
heel horn erosion					
lateral	0.20	0.02	0.45	0.40	-0.48
medial	0.38	0.17	0.13	0.48	-0.25
sole contusions					
lateral	0.15	0.06	-0.08	0.19	0.07
medial	-0.03	-0.52	-0.06	-0.15	0.19
double sole					
lateral	0.11	-0.02	-0.36	-0.11	0.10
medial	-0.19	0.37	0.00	-0.17	0.42
hind legs					
interdigital hyperkeratosis	0.00	0.51	0.04	0.23	0.19
dermatitis interdigitalis	0.51	-0.20	-0.41	0.14	0.20
heel horn erosion					
lateral	0.11	0.11	-0.05	-0.02	0.19
medial	0.37	0.02	-0.28	0.19	0.26
sole contusions					
lateral	0.07	-0.05	0.23	-0.15	-0.11
medial	0.04	0.10	0.05	0.12	-0.23
double sole					
lateral	-0.52	0.02	0.47	-0.34	-0.23
medial	0.08	-0.02	0.30	-0.01	0.00

Table 9:
Relative selection response in claw soundness per generation using claw measures (40 progeny)

	taken from		
measure	front leg	hind leg	both
length of dorsal border	27%	42%	47%
bulb length	42%	1%	43%
bulb height	22%	5%	25%
angle of dorsal border	2%	7%	8%
area of ground surface	12%	8%	20%
diagonal length	19%	10%	67%
all measures	59%	45%	30%
all judgments of leg posture and claw shape (both)			52%
all judgment of leg posture (both)			41%
length of the dorsal border (both), bulb length (front), diagonal length (both) = INDEX-3			63%
INDEX-3 plus judgments of leg posture (both)			83%

Figure 1: Conventional selection pathways

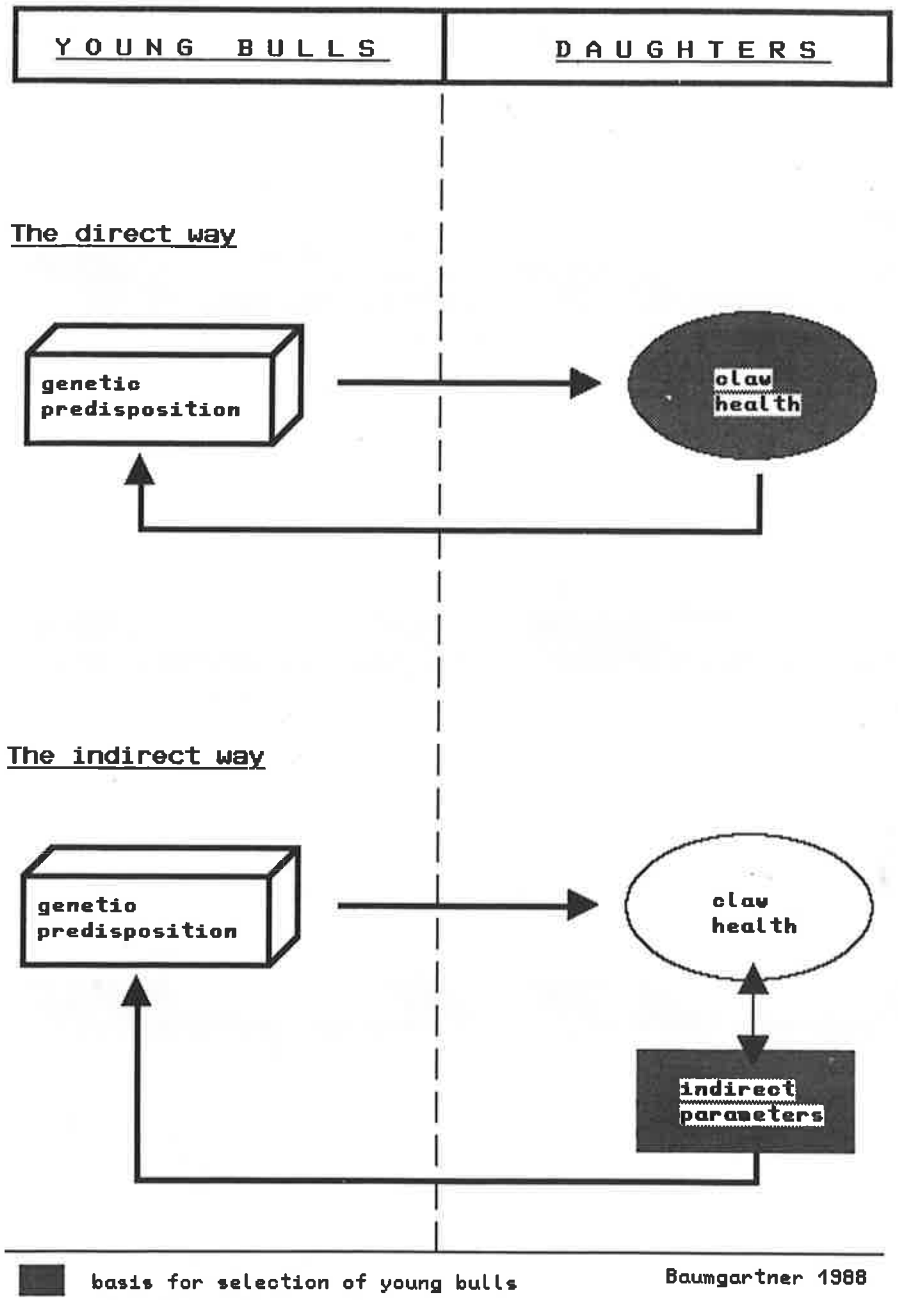
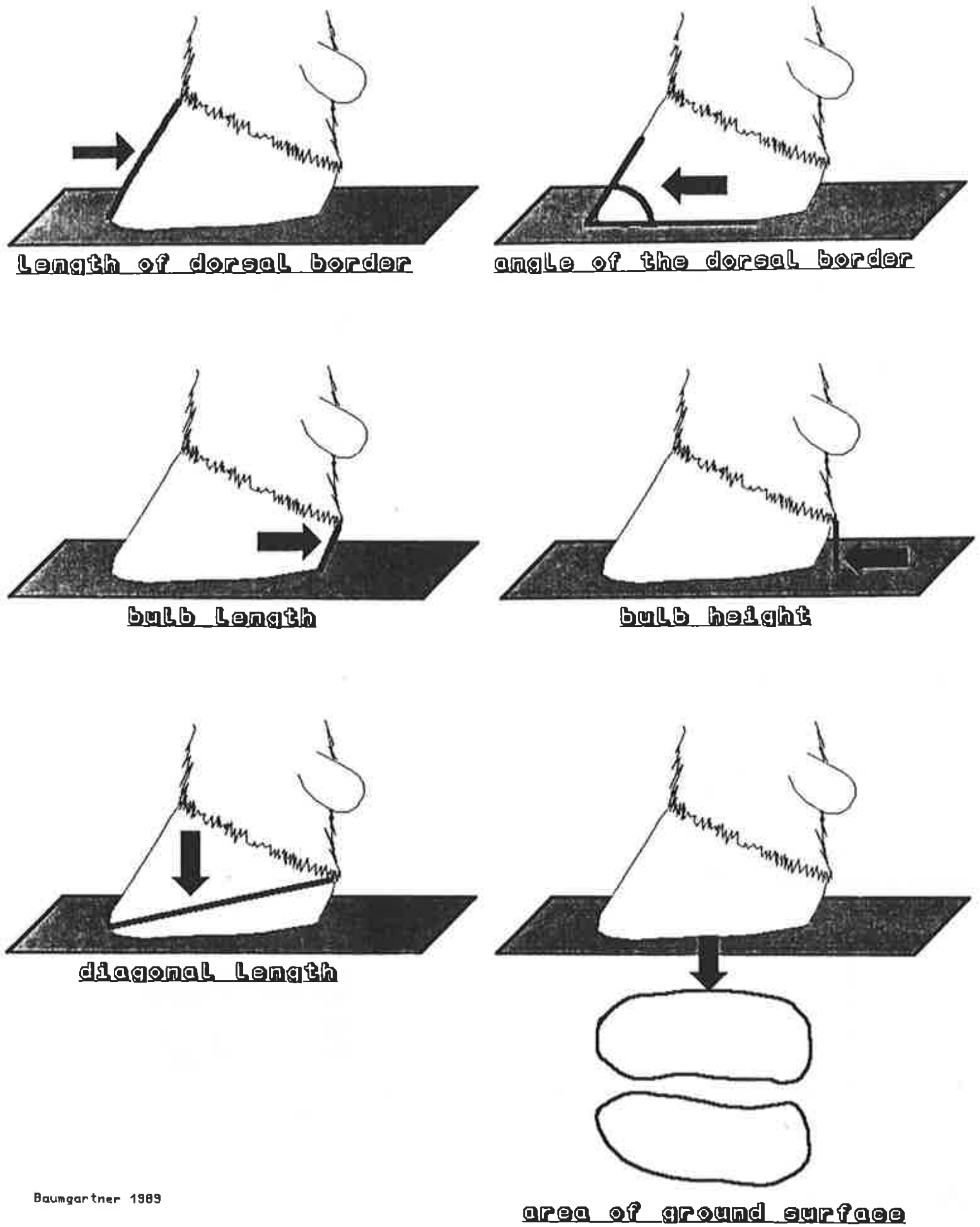
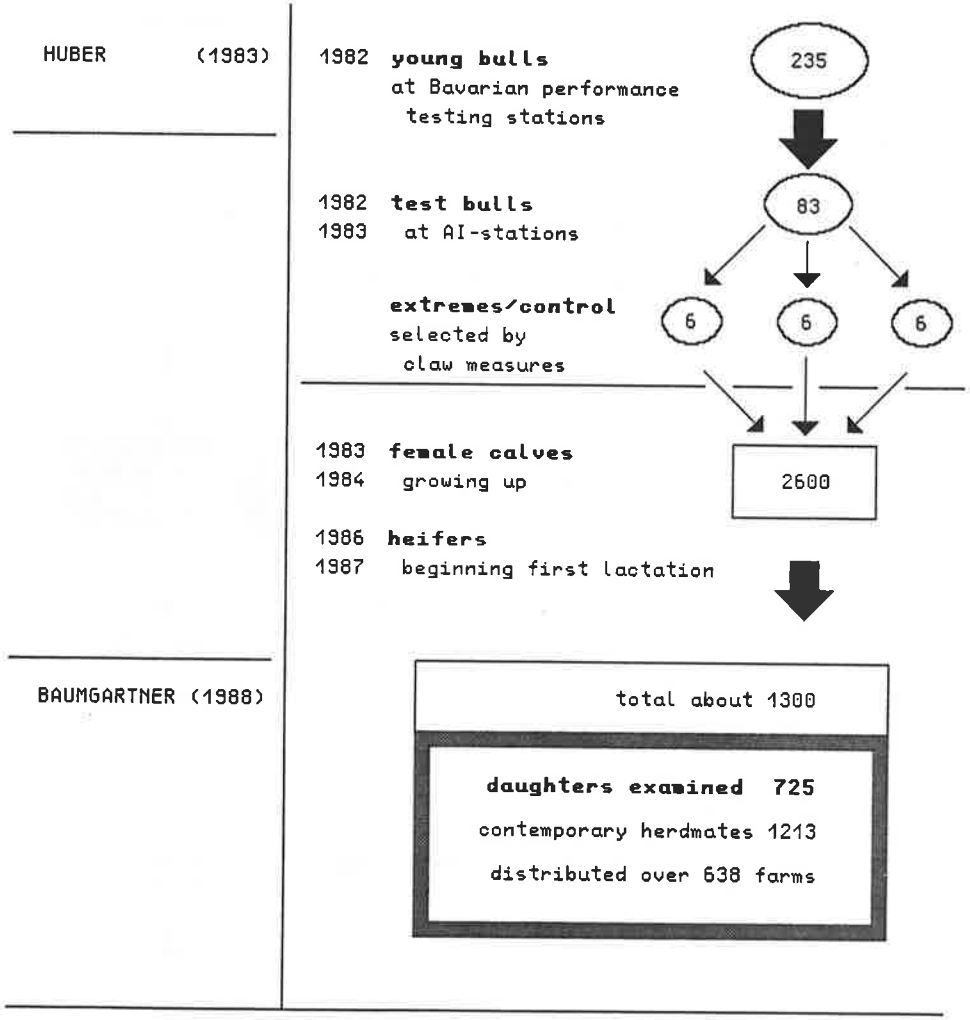


Figure 2: Claw measures



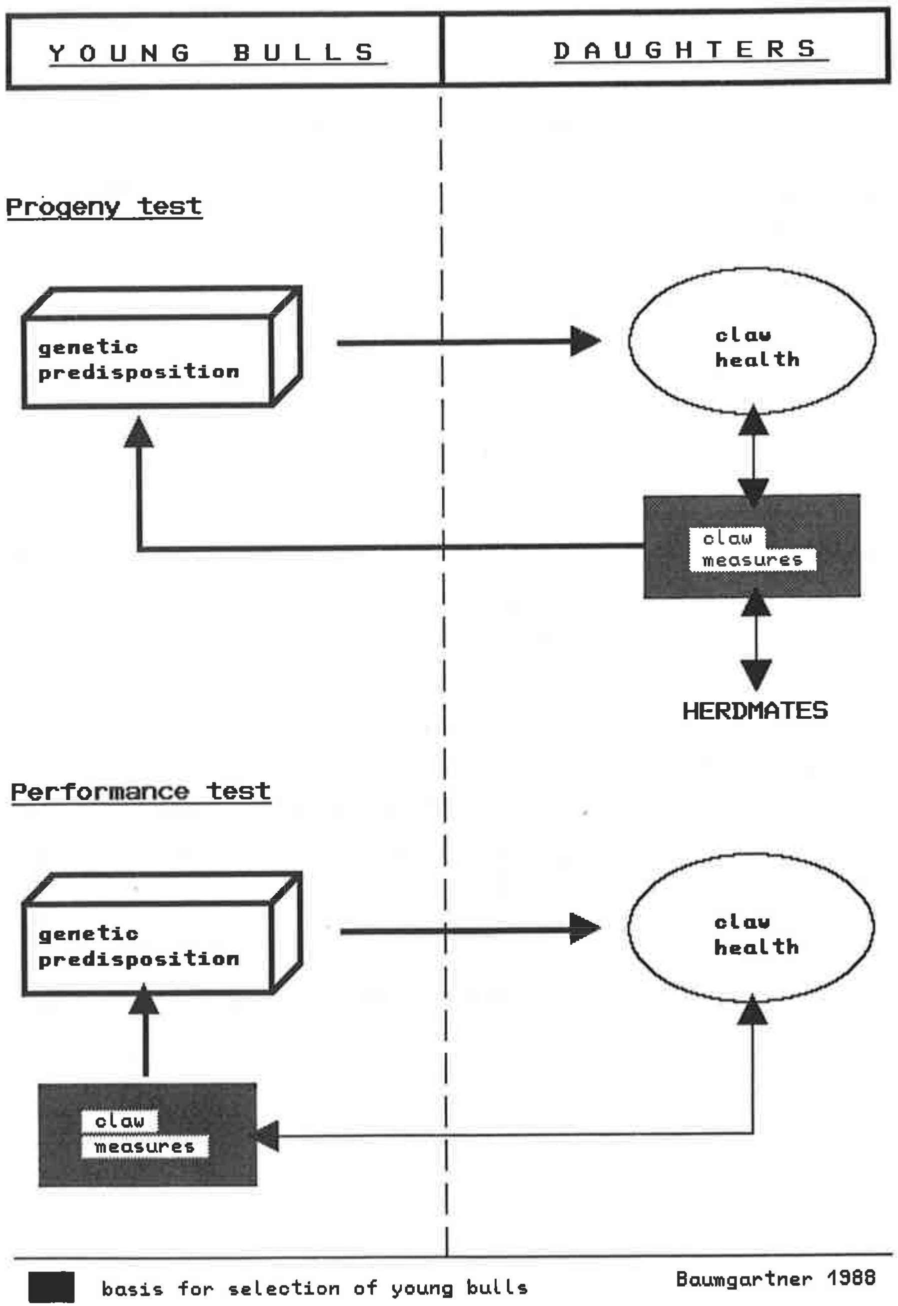
Baumgartner 1989

Figure 3: Material



Baumgartner 1988

Figure 4: Indirect selection pathways



Hoof and Leg Traits in Dairy Cattle

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Abstract

Two studies on hoof measurements and hoof disorders are presented. The first investigation included 119 heifers and dairy cows in first to fifth lactation. Repeatability for objectively measured hoof traits was medium-high to high. The Jersey breed differed significantly from Swedish Red and White, Swedish Friesian, and crosses between these two breeds, as regards several hoof traits.

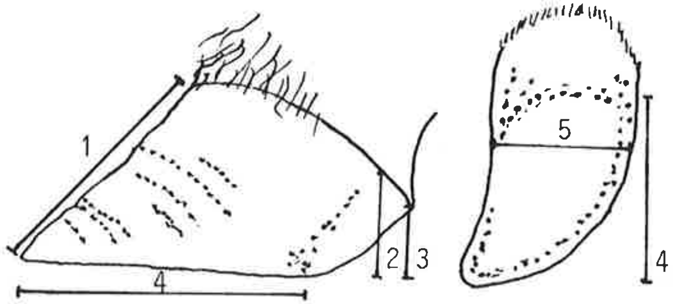
The second investigation comprised 183 young performance tested bulls of two Swedish dual-purpose breeds. Swedish Friesian had more haemorrhages in the sole than Swedish Red and White, while the converse was true for erosio ungulae. Heritability had rather high standard errors due to the small number of animals but was generally high for objectively measured hoof traits, and low for horn content of minerals and amino acids. Bulls having hooves with long toes and soles were more affected by erosio ungulae than other bulls. A high content of proline in the horn signified good resistance to erosio ungulae, whereas a high content of ornithine was unfavourable.

Introduction

Hoof and leg traits are very important in dairy production. In slaughter-house material, Andersson and Lundstrom (1981) found that 74% of the cows were affected by digital diseases. Swedish Friesians (SLB) were more affected (23% free of lesions), than Swedish Red and White (SRB) (28% free of lesions). Four per cent of the animals were very severely affected. In data from the Swedish national milk recording scheme it can be seen that 5.8% of the cows were culled in 1987-88 because of leg and hoof diseases (SRB 5.3% culled and SLB 6.6%) (SHS, 1989). Poor fertility, udder diseases, low production and "other causes" were more common. Low production may be due to several factors, for example various diseases. Disease frequency, i.e. the average no. of veterinary treatments per 100 cows and year during 1988-89, was 3.2 for hoof diseases and laminitis (SHS, 1990). In a study on cows, in herds using crossbreeding between SRB and SLB, made by Ericson (1990), 6.8% of the cows needed veterinary treatment or were culled before third calving, because of hoof and leg diseases. Only the frequency of mastitis exceeded this value.

The purpose of the present paper is to present two Swedish investigations into hoof traits in dairy cattle, and to discuss the usefulness of including hoof traits in the breeding programme. Figure 1 is a schematic drawing of a hoof, including some hoof measures.

Figure 1 Some hoof measures recorded in this paper



1. Toe length
2. Posterior wall height
3. Bulb height
4. Sole length
5. Sole breadth

Swedish Investigations on Hoof Traits

Swedish dairy cows in an experimental herd

The purpose of the study was to identify important hoof traits, which could be measured in dairy cows under field conditions. Variations among breeds were also an important part of the study (Ahlstrom et al., 1986). Thus, hoof and leg traits were periodically studied in 119 heifers and cows in first to fifth lactation. The breeds were Swedish Red and White (SRB-monozygous twins and singletons), Swedish Friesian (SLB), Swedish Jersey (SJB) and SRB x SLB crossbreds. The animals were housed in tie stalls with concrete floors covered with sawdust. Hooves were trimmed on a regular basis twice a year.

The first measurement was made during the first gestation (heifers) and thereafter measurements were taken twice every lactation (cows). Hoof traits (except colour) were objectively measured with a special instrument (Figure 1). This paper presents the following traits: Hoof colour (subjectively judged, five classes 0=light and 4=dark), toe length (mm), Bulb height (mm), ratio toe length/bulb height (calculated), sole area (cm^2), interdigital space width (mm, converted to four classes), toe angle (degree), foot circumference (mm) and pastern length (mm).
In the analysis of the data, Harvey's (1977) LSML 76 program and the Statistical Analysis System (SAS Institute Inc., 1985) were used. In the statistical models the effects of cow, breed, year, age (lactation number), days between measurements and days after calving were considered.

Results

Wide variations among animals were observed for the ratio toe length/bulb height and interdigital space width, while toe length, toe angle, foot circumference and pastern length had rather low coefficients of variation.

A significant influence of the effect of cow was found for all traits (cows). Correlations between repeated measurements in the same individual (repeatabilities), estimated from the variance components between and within animals, are shown in Table 1. Most traits showed medium-high to high repeatabilities. This means that the accuracy of the measurements for these traits are rather good, and only little influenced by temporary environmental circumstances. The ratio toe length/bulb height had the lowest value.

Table 1. Repeatabilities for hoof traits and hoof colour for dairy cows in first to fifth lactation. Standard errors are 0.04-0.05, except for hoof colour: 0.01

Trait	Repeatability
Hoof colour[1]	0.95
Toe length[2]	0.40-0.51
Bulb height[2]	0.30-0.36
Ratio toe/bulb[2]	0.17-0.28
Sole area[2]	0.47-0.67
Interdigital space width[1]	0.32
Toe angle[2]	0.64-0.66
Foot circumference[1]	0.65
Pastern length[2]	0.39-0.53

1 Mean value of front and rear foot.
2 Values on front and rear feet differ.

Effect of breed influenced all traits for cows, and all traits except toe length, bulb height and ratio toe length/bulb height for heifers. Table 2 shows least-squares means for hoof traits of cows in first to fifth lactation of the different breeds. SJB had longer toes than other breeds, but in heifers there were no significant differences between breeds. SJB had shorter pasterns and also the steepest toe angles. In spite of smaller sole area and foot circumference, the pressure per cm^2 on the gro nd was less for SJB than for other breeds, because of lower live weight.

Table 2. Least-squares means for breeds for hoof traits and hoof colour for dairy cows in first to fifth lactation

	Breed				
Trait	SRB twins	SRB singletons	SRBxSLB. crossbreeds	SLB	SJB
Hoof coulour[1] (classes)	2.9	3.6	3.4	1.1	3.9
Toe length[2] (mm)	65.0-72.3	66.1-74.0	65.5-72.9	67.0-73.2	68.4-76.2
Bulb height[2] (mm)	18.2-29.1	20.5-32.0	21.1-31.9	19.0-30.8	18.8-27.8
Ratio toe/bulb[2]	2.3-3.7	2.1-3.4	2.1-3.3	2.3-3.6	2.6-4.0
Sole area[2] (cm^2)	31.4-36.8	31.1-40.0	30.4-39.5	30.6-40.8	27.7-32.9
Interdigital space width[1] (classes)	2.0	2.1	1.9	2.0	1.5
Toe angle[2] (degree)	54.2-55.3	54.7-55.9	54.2-55.5	54.3-56.3	47.2-48.6
Foot circumference[1] (mm)	323.1	330.9	327.8	331.2	289.1
Pastern length[2] (mm)	62.9-64.9	66.4-67.7	66.8-67.5	66.4-67.2	60.3-62.9

[1] Mean value of front and rear foot.
[2] Values on front and rear feet differ.

Age of the heifers at measurement had little influence on the hoof traits, but lactation number influenced some of the traits for the cows. Toe length increased until third lactation. Bulb height showed an increasing trend with higher lactation number, and sole area and foot circumference increased, while pastern length decreased. Using the same material as described above, Ahlstrom et al. (unpublished) made subjective judgements on leg posture. In Germany, Huber (1983) and Baumgartner (1988) made the same kinds of judgements on German Simmental. Huber (1983) studied young bulls and Baumgartner (1988) studied cows in first lactation. Some results are summarised in Table 3.

Table 3. Summary of subjective judgements on leg postures and pastern postures in three different investigations, expressed as percentages of judgements classified as normal.

	Leg posture		Pastern posture	
Reference	front & rear view	side view	front view	rear view
Huber (1983)	30 - 40	about 60	about 70	about 60
Baumgartner (1988)	more than 60	80 -100	about 60	about 20
Ahlstrom et al. (unpublished)	less than 20	80 - 100	about 70	about70

The figures show considerable disparities between the various investigations, one reason being differences in the materials, but another very important reason is that people judge leg posture in different ways. Leg posture is also dependent on how the animals are standing. Ahlstrom et al. (unpublished) found that with increasing age the frequency of knock-kneed and cow-hocked animals increased. There was also a tendency for the frequency of straight front pasterns to increase with increasing age and breed differences were evident.

Performance tested bulls

The purpose of this study was to analyse the genetic variation in hoof traits among young AI-bulls, and to ascertain whether this is a useful strategy to study genetic variations (Andersson et al., 1989).

The material consisted of 82 Swedish Red and White (SRB) bulls and 101 Swedish Friesian (SLB) bulls by 50 sires. They were performance tested at three different stations during 1984 and 1985. Measurements were taken once per animal at a mean age of 439 days (305-603 days) and a mean weight of 412 kg (316-550 kg). Hoof colour was judged subjectively, and hoof disorders (erosio ungulae, pododermatitis circumscripta, haemorrhages in the sole) and deformed hooves were recorded and classified according to degree of seriousness. Before hoof trimming, the four hoof halves were measured objectively (Figure 1) with respect to toe length, posterior wall height, bulb height, and sole area, length and breadth. Hoof horn was analysed with respect to content of calcium (Ca), and magnesium (Mg), zinc (Zn) and different amino acids (cysteine, methionine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine, arginine, hydroxyproline, ornithine).
The analysis of the data was carried out using the method of least-squares as applied in the LSML76 programme by Harvey (1977) and the Statistical Analysis System (SAS

Institute Inc., 1985). In the statistical model the effects of breed, sire, testing station, season and age of the bull at measuring were considered. Despite the limited number of bulls recorded an attempt was made to estimate the heritability of the various hoof and horn traits.

Results

High coefficients of variation were found for minerals and two amino acids (hydroxyproline and orthinine), while toe length, sole length and breadth and most amino acids had low values.

SLB had more haemorrhages in the sole than SRB, which tallies with results published by Andersson and Lundstrom (1981). Only SRB bulls were affected by erosia ungulae and there was only one SRB bull with pododermatitis circumscripta. Deformed hooves were seen in 13% of the SRB and 15% of the SLB bulls.

The effect of sire influenced many of the objectively measured hoof traits, but had almost no effect on the horn content of minerals and amino acids. Table 4 shows heritabilities for objectively measured hoof traits. The material was small and some values were outside the limits. Nevertheless it could be concluded that hoof measurements show heratabilities high enough to be used in selection. However, they would need to be re-estimated on larger sets of data before any definite conclusions can be drawn.

Table 4 Heritabilities for hoof traits and hoof colour for performance tested bulls. Standard errors are about 0.3

Trait	Heritability
Hoof colour[1]	0.27-0.44
Toe length[1]	0.63-(1.33)
Posterior wall height[1]	0.14-0.78
Ratio toe/posterior wall[1]	0.21-(1.37)
Bulb height[1]	0.23-0.77
Sole area[1]	0.13-(1.16)
Sole length[1]	0.58-0.91
Sole breadth[1]	0.00-0.63

1) Values on front and rear feet differ

Heratabilities for horn content of minerals and amino acids were small, with few exceptions. Heritability for histidine was 0.57 and for ornithine 0.43 (standard errors about 0.4)

Genetic and phenotypic correlations are not presented because of high standard errors. Correlations, corrected for the effects included in the model, between objectively measured hoof traits and horn content of some minerals and amino acids on the one hand and hoof disorders on the other, are shown in Table 5. Correlations with minerals and amino acids not included in the Table were almost nil. Bulls having

hooves with long toes and soles were more affected by erosio ungulae than other bulls. A high value for toe length/posterior wall height was correlated to high frequency of any type of the mentioned hoof disorders and/or hoof deformity. There was a tendency for low posterior wall height to be unfavourable for haemorrhages in the sole.

A high content of proline in the horn was favourable for the frequency of erosio ungulae, and any type of hoof disorder and/or hoof deformity, whereas a high ornithine content was unfavourable for the frequency of erosio ungulae. There was a tendency for high content of hydroxyproline to be correlated to a low frequency of any type of hoof disorder and/or hoof deformity. Tyrosine was significantly positively correlated to toe and sole length and this was also unfavourable for the frequency of erosio ungulae. A weak relationship between high content of several amino acids and high posterior wall height could be seen, which in turn were weakly correlated to lower frequency of haemorrhages in the sole. A high content of amino acids in the horn might indicate harder hoof horn and better hooves, but the results are contradictory as several amino acids were weakly positively correlated to toe length.

These investigations on performance tested bulls are proceeding, so that more reliable genetic parameters can be estimated. Later we also hope to be able to compare the results from the bulls with the health status of their daughters in the field. Information from the daughters will be easy to obtain from the national disease recording scheme (see below).

Breeding Strategies for Hoof and Leg Traits

In order to effectively consider hoof and leg traits in a breeding programme, a number of factors need to be taken into consideration. Possibilities of measuring hoof traits and their variations were discussed earlier. In general the principles of a breeding programme can be outlined as has been done in Figure 2

trait	Hoof disorder erosio ungulae	haemorrhages in the sole	disorder *and/or* deformity[1]
Hoof colour	-0.09	0.02	0.07
Toe length	*0.25*[2]	0.06	0.12
Posterior wall height	0.13	-0.18	-0.13
Ratio toe/posterior wall	0.06	0.16	*0.22*[2]
Bulb height	0.07	-0.06	-0.19
Sole area	0.16	-0.02	0.14
Sole length	*0.25*[2]	0.00	0.14
Sole breadth	0.00	0.01	0.10
Mg	0.16	-0.01	-0.06
Cysteine	-0.04	-0.09	-0.15
Serine	0.15	0.00	0.09
Glutamic acid	-0.06	-0.04	-0.15
Proline	*-0.23*[2]	-0.15	*-0.23*[2]
Glycine	0.15	-0.03	-0.01
Tyrosine	0.16	-0.11	-0.08
Hydroxyproline	-0.09	-0.13	-0.19
Ornithine	*0.22*[2]	-0.08	0.06

1 0 = *no* hoof disorder or hoof deformity
1 = any type of hoof disorder *and/or* hoof deformity
2 Significant at 5% level or higher degree of significance

Table 5. Correlations, corrected for the effects in the model, between hoof traits, hoof colour and horn content of some minerals and amino acids on the one hand and hoof disorders on the other.

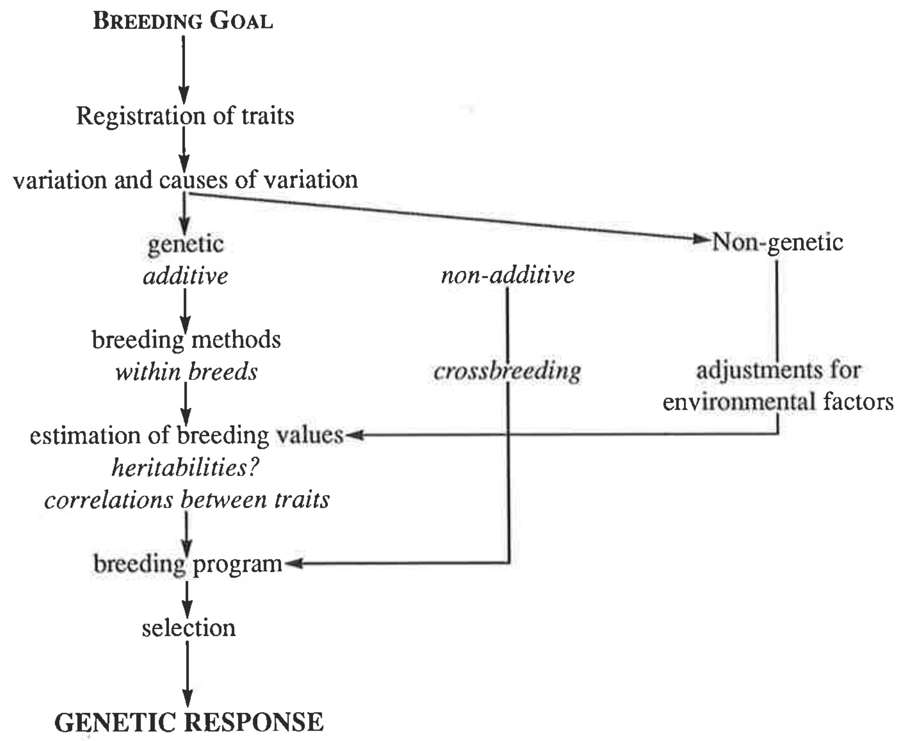


Figure 2. Schematic drawing of the steps in a breeding program.

<u>Breeding goal and registration of traits</u>

The breeding goal for hoof traits in dairy cattle is to produce stock with high hoof quality, defined as a low susceptibility to hoof disorders and a little need of special foot care. Traits to consider are hoof measures strongly related to these objectives, and hoof disorders. From the figures mentioned in the introduction it can be concluded that the hoof and leg traits are of considerable importance.

The recording of different traits may be done through milk recording schemes, progeny testing, performance testing and so on. In Sweden, breeding values for leg posture and quality of legs and hooves are included in a genetic bull index expressing overall merit. Legs and hooves of the daughters are judged subjectively in four classes and a composite score for legs is calculated. Breeding values for legs are published in relative units. In a recent survey, Philipsson (1989) gave a review of international bull evaluations for secondary traits. As many as 18 countries, out of 21, use information on feet and legs in their selection schemes, but only four countries consider disease resistance in a genetic bull index. In Sweden, information about diseases comes from the national animal disease recording scheme, covering the whole of Sweden (Emanuelson 1988). All veterinary treated diseases are recorded and computerised, and integrated with records of the milk recording scheme. Since 1985 this data bank is used in breeding for increased disease resistance. Breeding values for resistance to mastitis and "other diseases" are currently estimated.

Causes of variation

Traits can be registered in different ways. Leg posture is often judged in a few distinct classes, while objectively measured hoof traits often follow a continuous normal scale. Diseases are mostly registered as all-or-none traits, which may cause difficulties. The variation in a trait can be separated into genetic and non-genetic parts. Genetic variation can also be subdivided into additive and non-additive genetic parts. Ahlstrom et al. (1986), found considerable variation among individual cows regarding hoof traits, and Andersson et al. (1989), found the effect of sires to be significant for the same traits. These results indicate that the genetic variation exists for objectively measured hoof traits.

Breeding methods and estimation of breeding values

Crossbreeding is the best breeding method when genetic variation is non-additive. For leg and hoof disorders, Ericson (1990) found positive effects of crossbreeding in Swedish data from the national animal disease recording scheme. When genetic variation is mostly additive, breeding animals are chosen from the pure breeds.

For traits with high heritability, the individual animal's phenotypic measures can be used to estimate breeding values. In a review, Politiek et al. (1986), concluded that heritabilities and additive genetic variation for hoof measures and hoof disorders were high enough to expect genetic improvement. Hoof and leg traits may therefore be measured on bulls at a young age during performance testing. For traits with low heritabilities, information from relatives is also needed. Philipsson et al. (1980), obtained very low heratibilities for feet, legs and locomotory diseases. Nevertheless they concluded that if progeny testing of bulls is based on large daughter groups and the disease shows a reasonably high frequency in early life, improvement might be feasible. Performance testing under carefully controlled conditions is expensive and only a few animals will be tested. On the other hand progeny testing is a lengthy process and sometimes there are practical problems in obtaining reliable information. The value of a measurable trait depends largely on the correlations with those traits that most clearly express the breeding objective. In Swedish dairy cows, Gates (1987) reported some correlations between hooves, legs, disease and survival to 150 days after calving. Hooves and legs were judged subjectively and cows having bad, swollen and lymphatic legs, swollen hocks and deformed hooves were culled earlier than other cows. SRB cows with deformed hooves, and SLB cows with weak pasterns had higher frequencies of veterinary treated diseases than would be expected. Reurink and van Arendonk (1987) and Rogers et al. (1989) also found correlations between hoof

measures and survival. Thus, it appears that hoof and leg traits are important for replacement costs in the herds, among other things.

Breeding programme and choice of traits for selection

Decisions about breeding programmes and selection are made on the farms and within different organisations. Selection is made in four different paths: selection of bulls to sire sons, bulls to sire daughters, selection of bull dams and dams for daughters as new replacements. The most important path, from a genetic point of view, is the path sire-son.

Subjectively assessed leg postures depend on the judge, as mentioned earlier. Baumgartner (1988) observed some relationships between leg postures and hoof forms and hoof disorders, but he concluded that measuring leg posture objectively would give even better results. The way leg posture is judged in Sweden today has relatively moderate influence on frequency of disorders and culling in dairy cattle, according to Gates (1987).

Andersson et al. (1989) deemed the following hoof traits to be of interest: toe and sole length and posterior wall height, toe angle and hardness of horn should be used in the selection, according to Baumgartner (1988). Reurink and van Arendonk (1987) suggested that selection on toe angle and length of diagonal (measured from toe tip to the proximal end of the heel) could reduce susceptibility for hoof diseases. Ahlstrom et al. (1986) also mentioned other criteria for measurements as being useful under field conditions. They must be simple to perform and must not be dangerous (risk of injury). Foot circumference and toe angle fit these criteria, while toe length fits the first but not the second criterion if the cow is standing on the floor and the foot is not fixed (touching sensitive skin). The conclusion is that many authors report toe angle to be an interesting trait for selection, just as is toe length.

References

Ahlstrom G., Ral G., Berglund B. and Swensson C. 1986. Hoof and leg traits of Swedish dairy cattle. I. Objective measurement. J. Vet. Med. A **33**, 561-587

Ahlstrom G., Ral G., Berglund B. and Swensson C. Unpublished. Swedish University of Agricultural Sciences, Department of Clinical Nutrition and Department of Animal Breeding and Genetics, S-750 07 Uppsala, Sweden.

Andersson L.and Lundstrom K. 1981. The influence of breed, age, bodyweight and season on digital diseases and hoof size in dairy cows. Zbl. Vet. Med. A **28,** 141-151.

Andersson L. Ral G. Philipsson J. and Jonsson G. 1989. Variation i olika matt pa klovens exterior och klovhornets innehall av mineraler och aminosyror hos individprovade SRB- och SLB- tjurar. (Swedish University of Agricultural Sciences, Department of Animal Breeding and Genetics, Report 88). 22pp Uppsala.

Baumgartner C.F. 1988. Untersuchungen uber Klauenmasse als Hilfsmerkmale fur die selektion auf Klauengesundheit an Tochtergruppen von Deutschen

Fleckviehbullen. Inaugural-Dissertation zur Erlangung der tiermedizinischen Doktorwurde der Tierarztlichen Fakultat der Ludwig-Maximilians-Universitat Munchen.

Emanuelson U. 1988. The national Swedish animal disease recording system. Acta. Vet. scand. suppl. **84**, 262-264

Ericson K. 1990. Personal communications. Swedish University of Agricultural Sciences, Department of Animal Breeding and Genetics, S-750 07 Uppsala Sweden.

Gates P. 1987. Rapport skriven som en del av praktikarbete pa SHS sommaren 1987. Samband sjukdomar-benexterior. Mimeograph 25 pp. Swedish University of Agricultural Sciences, Department of Animal Breeding and Genetics, S-750 07 Uppsala, Sweden.

Harvey W.R. 1977. User's guide for LSML76. Mixed model least-squares and maximum likelihood programme. Ohio State University, U.S.A.

Huber M. 1983. Untersuchungen uber Klauenparameter an Jungbullen in den Bayerischen Eigenleistungsprufungsanstalten. Inaugural-Dissertation zur Erlangung der tiermedizinischen Doktorwurde der Tierarztlichen Fakultat der Ludwig-Maximilians-Universitat Munchen.

Philipsson J. 1989. An international review of recording and evaluation of secondary traits in bull selection. 40th Annual Meeting of the European association for Animal Production, Dublin, Ireland, 27-31 August 1989. Commission on Cattle Production, Session III : Secondary traits in dairy and dual purpose cattle selection.

Philipsson J. Thafvelin, B. and Hedebro-Velander, I. 1980. Genetic studies on disease recordings in first lactation cows of Swedish dairy breeds. Acta Agric. Scand. **30,** 327-335.

Politiek R.D., Distl O. , Fjeldaas, T., Heeres J., McDaniel B.T., Nielsen E., Peterse D.J., Reurink A. and Strandberg P. 1986. Importance of claw quality in cattle: review and recommendations to achieve genetic improvement. Report of the E.A.A.P. working group on "claw quality in cattle". Livest. Prod. Sci. 15, 133-152.

Reurink A. and van Arendonk J. 1987. Relationships of claw disorders and claw measurements with efficiency of production in dairy cattle. 38th Annual Meeting of the European Association for Animal Production, Lisbon, Portugal, September 28-October 1, 1987. Commission on Animal Genetics, Session V: Short contributed papers.

Rogers G.W., McDaniel B.T., Dentine M.R. and Funk D.A. 1989. Genetic correlations between survival and linear type traits measured in first lactation. J. Dairy Sci. **72,** 523-527.

SAS Institute Inc. 1985. SAS user's guide: statistics version 5th ed., Cary, N.C., USA.

SHS. 1989. Arsstatistik fran SHS 1987/88 meddelande nr 159. Swedish Association for Livestock Breeding and Production, Hallsta, S-631 84 Eskilstuna, Sweden.

SHS 1990. Djurhalsovard 88/89. (To be published.) Swedish Association for

Livestock Breeding and Production, Hallsta, S-631 84 Eskilstuna, Sweden.

Lameness and fertility.

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Evidence for association between lameness and fertility.

The phrase 'association between lameness and fertility' is preferred to 'effect of lameness on fertility ' because it is possible that some causes of foot lameness directly impair fertility rather than the lameness itself reducing fertility.

Not many people have studied associations between lameness and fertility. Cobo-Abreu and others (1970) found no significant association, but their study of disease and production in Canadian cattle included only 21 lame cattle . Dohoo and Martin (1984) failed to find and association between diseases of feet or legs and days to conception in 1,315 lactations from 32 Southern Ontario Holstein herds, using the technique of path analysis to identify both direct an indirect effects of disease on production They did not, however, allow for the stage of lactation when lameness occurred.

Dewes (1978) compared the interval from calving to conception in 73 lame heifers or cows in two New Zealand herds, with that of the two-year-old heifer or older cow closest in calving date. In each group in each of the two herds, the lame cows conceived later (11 and 71 days for heifers, 20 and 60 days for cows). More lame heifers were culled or nominated for culling (17 compared with no normal heifers) and more lame cows (8 compared with 2) were so treated. A chi-squared test applied to his data shows that the difference in culling rate was significant at $P<0.001$.
Lucey and others (1986) compared fertility in 770 cows in the Compton herds in Berkshire. The median interval from calving to first service was 45 days and increased by 7 days in cows with lesions of the sole or white line. The interval from calving to conception (median 100 days) increased by 11 days in cows with sole or white line lesions.

Conception rate (pregnancy rate) was 31% during lactations when cows became lame, compared with 40% in control lactations; the statistical significance is not stated but is probably high. They compared conception rate in cows served in the 63 days before and after diagnosis of lameness and found that only in the 63 days before diagnosis of an inter-digital lesion was the conception rate significantly lower. The delay in conception was greatest for sole or white line lesions, and for lesions diagnosed between 36 and 70 days after calving. The interval from calving to conception was increased by 70 days in cows with sole or white line lesions diagnosed in this critical period.

Collick and others (1989) compared 427 cows with foot lameness with the cow nearest in parity and calving date in 17 English dairy herds. The interval from calving to first service was 4 days longer ($P<0.01$) in the lame cows than in the controls, and the interval from calving to conception was 14 days longer ($P<0.001$). More lame cows were culled (67) than control cows (22) ($P<0.001$).

When Collick divided cows into categories, according to the type of lesion, he showed that lameness could sometimes impair fertility drastically. Cows with solar ulcer (pododermatitis circumscripta) for example, had an interval from calving to conception 40 days longer than controls ($P<0.001$). When he divided cows according to the severity and duration of lameness, cows with a high 'clinical effect score' between 71 and 120 days after calving, had an interval from calving to conception 31 days longer than controls ($P<0.01$).

From the findings of Collick and others (1989) and those of Lucey and others (1986) it is clear that lameness in dairy cows can have a marked effect on fertility. The magnitude of the effect depends on the type of lesion, the severity and duration of the lameness, and the time after calving when the cow is lame.

Possible mechanisms causing the association between lameness and fertility.

There are several theoretical reasons why lameness could be associated with reduced fertility.

First, reduced fertility could cause lameness. This seems implausible, though Lucey and others (1986) showed a significant reduction in conception rate before diagnosis of lameness. Occasionally the activity associated with oestrus appears to cause lameness, though this is more often a lesion of the leg than the foot.

Secondly, a common factor could cause both reduced fertility and lameness. The path analysis by Dohoo and Martin (1984) allows for direct and indirect effects of a condition to be calculated. It is possible that small cubicles with inadequate bedding could cause first lactation cows in particular to spend long periods standing (Cermak, 1982; Daelemans and others, 1981; Colam-Ainsworth and others, 1989). There could be damage to the corium of the feet, leading to solar ulcer and white line lesions. At the same time, the stress could interfere with release of luteinising hormone (Nanda and others, 1989) and reduce fertility. Crowding of cattle may lead to sudden movements, as subservient cattle try to avoid being too close to dominant cattle. There is evidence from Bulgaria (Dias and Bodurov, 1986) that prevention of exercise increases the incidence of lameness, and loafing areas which encourage exercise also encourage oestrous behaviour. Crowding, as well as being a stressor, can make observation of oestrous behaviour more difficult.

Slippery floors can cause leg lameness, and it is likely that the sheer forces on the foot can cause damage to the junction of corium and horn, making lesions of the sole and white line more likely. Cows walking on slippery concrete are far less able to show oestrous behaviour and are more likely to suffer stress.

Stock people who drive cows, instead of letting them pick their way through stony areas, cause an increase in lameness (Chesterton, 1988). It is possible that the same people are less able in aspects of caring for stock that affect fertility, for example accurate observation of oestrus.

It is possible that genetic or nutritional effects on lameness could independently affect fertility. So far, we have no direct evidence of factors independently causing lameness and reducing fertility.

Thirdly, lameness could directly reduce fertility. A number of possible mechanisms are proposed.

It is clear that a cow with painful lesions of the hind legs (where 84% of lameness was found by Arkins, 1981) is likely to be more reluctant to stand to be mounted. Oestrus detection rate would then be reduced, with an increased interval from calving to first service. In some cases lame cows are housed separately so that behavioural signs of oestrus will be less likely to be shown.

The pain caused by serious foot lameness is presumably stressful. Evidence of release of corticosteroids in lame cows does not appear to have been published. Transport of cows in a lorry, which appears to be a more mild stressor, blocks the release of luteinising hormone (Nanda and others, 1989) and causes release of corticosteroids. Nanda and others showed that LH was not released while the concentration of cortisol in cows' blood was elevated, during and after transport. It has been shown by Stoebel and Moberg (1982) that cortisol interferes with release of LH in dairy heifers.

A reduction in pregnancy rate would be expected in cows suffering stress at the critical time prior to ovulation when LH is normally released. The magnitude of such an effect could depend on the severity and duration of lameness, and on the time of lameness relative to service.

The observation by Lucey and others (1986) that conception rate was reduced prior to, but not after the diagnosis of lameness could suggest that the lesion in the foot reduced fertility before the cow was sufficiently lame to be noticed.

Recent unpublished observations show that many cows can be lame in a herd for some time before the farmer takes action. The effect of lameness after diagnosis depends presumably on the efficiency of treatment and nursing.

The Importance of the effect of lameness on fertility

Any deterioration in fertility will have an economic cost. The 14 day delay in conception found by Collick and others (1989) costed at £3.00 a day, would amount to £1,050.00 for a herd of 100 cows with 25% incidence of lameness (Whitaker and others 1983). The cost of the increase in culling from 5% to 16%, costed at £300 a cow, amounts to £3,300.

From the cow's point of view, the effect on fertility may be seen as an indication that lameness is a seriously painful and distressing condition. Lucey (1984) found no other disease associated with a reduction in fertility. While we may not prove that the lame cow is suffering greatly, neither can we prove to the contrary. Veterinary surgeons might be advised to take cattle lameness more seriously as a welfare problem

than in the past.

Prevention of reduction in fertility in lame cows

Since the cause of the association between lameness and fertility is uncertain, methods of prevention of the reduction in fertility in lame cows cannot be guaranteed. Proposals are made on the basis of observations and published evidence.

First, improvement of conditions that could cause lameness and independently reduce fertility are considered. Buildings with large, well-bedded cubicles will encourage lying (Daelemans and others, 1981; Cermak, 1982) and may reduce trauma to feet and hence lameness while at the same time reducing stress and hence helping fertility. Provision of loafing areas could encourage exercise and hence reduce lameness and also improve oestrus detection. Scabbling or re-laying of slippery floors could reduce damage to feet and encourage oestrus behaviour. Education, or replacement, of stock people who drive cows through stony areas could, at the same time, lead to cows' oestrus behaviour being more closely observed.

Secondly, methods of prevention of lameness itself, which could in turn affect fertility, are listed. The factors already mentioned will also apply here.
In addition, the following are considered important:

(a) The selection of bulls (and dams) with no lameness in their own feet, nor in those of their relatives, has been found to work. It depends on accurate recording of cases of lameness, and on waiting for progeny to reach an age when foot lameness is likely to be manifested.

(b) Replacement of stony roads and broken concrete will reduce the risk of penetration of the sole and white line.

(c) Feeding less readily fermentable carbohydrate and feeding that amount in small meals close in time to or mixed with fibrous food, will reduce the risk of acidosis and damage to the laminae.

(d) Formalin boot baths will reduce the incidence of foul-in-the-foot (interdigital phlegmon) and will probably reduce the incidence or severity of heel from erosion (slurry heel, erosio ungulae).

Thirdly, effects of lameness on fertility could be reduced by care of those cows that do suffer foot lameness. Prompt treatment by appropriate means depends on detection. Locomotion scoring of whole herds as they emerge from the milking parlour shows that a high proportion of cows can be clinically lame (score 3 or more) without the stock people having noticed.

Treatment which quickly reduces pain would be expected to reduce any effect on fertility. For example, systemic antibiotic for foul, paring the outer claw to relieve overloading, application of a block to a sound inner claw or transfer of a cow to a straw yard with food, water and milking machine within easy walking distance could all quickly reduce pain and, hence, stress.

After treatment of a lame cow that is not yet served, regular assay of progesterone in milk would permit detection of oestrus without the need for observations of oestrus behaviour. One or two injections of prostaglandins, followed by insemination two or three days later, could similarly be effective.

References

Arkins, S. (1981) Lameness in dairy cows. Irish Veterinary Journal, **35**, 135-140, 163-170.

Cermak, J (1982) Zoocentric approach to definition of cubicle length and width for Friesian dairy cows. British Cattle Veterinary Association. Proceedings for 1981 -82, 41-48.

Chesterton , R.N. (1988) Understanding and dealing with the lame dairy herd. Proceedings of the 5th seminar of the dairy cattle society of the New Zealand Veterinary Association, Auckland, p. 115-125.

Cobo-Arbreu, R., Martin, S.W., Willoughby, R.A., Stone, J.B. (1970) The association between disease, production and culling in a university dairy herd. Canadian veterinary journal **20**, 191-195.

Colam-Ainsworth, P., Lunn, G.A., Thomas, R.C., Eddy, R.G. (1989) Behaviour of cows in cubicles and its possible relationship with laminitis in replacement dairy heifers. The veterinary Record, **125**, 573-575.

Collick, D.W., Ward, W.R.,Dobson, H. (1989) Associations between types of lameness and fertility. The Veterinary Record; **125**, 103-106.

Daelemans, J., Maton, I., Lambrecht, J. (1981) The appraisal of some cubicle floors by cows. In: Modeling, design and evaluation of agricultural buildings. J. A. D. McCormack (ed) CIGR Section 2 Seminar, Aberdeen. Scottish farm Buildings Investigation Unit, Bucksburn, Aberdeen.

Dewes, H.F. (1978) Some aspects of lameness in dairy herds. New Zealand veterinary journal **26**, 147-148, 157-159.

Dias, J.G., Bodurov, W. (1986) Incidence of hoof diseases in cows raised using new technologies. Veterinarno Meditsinski, Nauki, **23**, 67-71.

Dohoo, I.R., Martin, S.W. (1984) Disease, production and culling in Holstein-Friesian cows. IV. Effects of disease on production. Preventive Veterinary Medicine, **2**, 755-770.

Lucey, S. (1984) Ph.D. thesis, University of Reading.

Lucey, s., Rowlands, G.J., Russell, A.M. (1986) The association between lameness and fertility in dairy cows. The Veterinary Record, **118**, 628-631.

Nanda, A.S., Ward, W.R., Dobson, H. (1989) Effects of naloxone on oestradiol-induced LH surge in transported cows. Journal of Reproduction and Fertility **87**, 803-807.

Stoebel, D.P., Moberg, G.P. (1982) Effect of adrenocorticotropin and cortisol on luteinising hormone surge and oestrus behaviour in cows. Journal of dairy science, **65**, 1016-1024

Whittaker, D. A. ,Kelly, J. M. ,Smith, E. J. (1983) Incidence of lameness in dairy cows. Veterinary Record **113** 60-62.

The Costs of Lameness in Dairy Herds

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Introduction

Lameness affects the economic performance of dairy cows in a variety of ways. Cows contribute to farm profits through the volume of milk produced, it's quality, the value of cull cows and of calves.

Lameness affects the farm output by reducing yield through stress, lower appetite and extending calving intervals. A lower cow weight through lameness affects the value of the cull at sale. Milk from lame cows treated with antibiotics may have to be discarded for some days. As lame cows are culled at a greater rate than healthy stock, the overall herd culling rate rises with lameness. To produce the extra replacement heifers, more cows than necessary must be put in calf to dairy semen instead of to beef bulls. Hence the total calf income is reduced. It should also be said that enforced extra culling will reduce the genetic level in the herd as the selection pressure will be reduced.

The costs of milk production are also affected by lameness. Lame cows need veterinary attention and treatments, extra time from the herdsman, more services, more concentrates per litre of milk, and often have to be replaced with more expensive replacements. If reared at home, the extra replacements use up land that could be put to more profitable use by, for instance, producing more forage for the milking cows or for growing other crops and livestock. As in all businesses, the farmer makes his profit from the narrow margin between income and costs (Table 1). With lameness, the rise in costs of say £50 per cow and a reduction in income of say £40 per cow will lead to a loss of £88 instead of the profit in the example of £2 per cow. This example reflects a position above average. The costs in this case do contain an allowance for unpaid family labour. Farm profits depend upon herd size and stocking intensity. The latest year end results from the MMB (for farmers that use their consultancy services)farmers with about 120 cows show a profit of around £28.000. In this case the profit would be £31,000 for a similar sized herd.

Savoir faire
English - no nonsense, throw him out
Italian - stand still, say carry off
Dutch - . . . . — to be able to carry on = savoir faire

Table 1:
The Income and Costs of a Typical Dairy Herd

Per Cow		
Gross output		**£**
Milk 6000 litres@ 17.2p per litre		1032
Calf		115
Herd depreciation		60
Total gross output		*1207*
Variable costs		
Concentrates 0.28/litre @ £146 per tonne		247
Purchased feed		15
Vet and Med		20
AI and recording		20
Bedding		10
Sundries		22
Forage variable costs0.5 hectares @ £170/hect.		85
Total variable costs		*417*
Gross margin per cow		**670**
Fixed costs per cow @ 2 cows per hectare		
Labour (including an allowance for unpaid labour)		120
Machinery	Depreciation	55
	Repairs	31
	Fuel and electricity	23
	General	9
Rent and rates		68
Land maintenance		9
Fixed costs sundries		20
Interest		70
Total fixed costs		*405*
Profit per cow		**670-405 = £265**

Calculating the Costs

The approach taken in this assessment is to use the rates of occurrence of various types of lameness already known, to assess their effects on performance and to attach costs. Patterns of lameness are "inflicted" upon a herd of one hundred cows at different rates of intensity so a herd cost of the disease can be determined.

On average, in well recorded herds, lameness appears to affect about 15% to

17% of cows. (Esslemont and Wassell 1990, Collick Ward and Dobson 1989). There is a range in the rate of lameness in the literature from as low as 4% (Leech 1960) to 28% (Collick, Ward and Dobson 1989). Generally, the higher rates of around 25% are, of course, found in the studies that include the herdsman's treatments as well as those of the veterinarian. (Prentice and Neal 1972, Arkins 1981). Collick (1990) has found rates are rising and suggests that up to 55% of cows are affected with lameness in each lactation.

The culling rates for lameness that we do have show only 1.4 to 1.6% of cows culled are sold for this reason (Benyon and Howe 1974, Gartner 1980; Whittaker, Kelly and Smith 1983). Farmers' reasons for culling are generally very poorly defined.

Rowlands, Russell and Williams (1985) described the incidence of lameness in terms of type and stage of lactation with foul, white line abscess and sole ulcer all broadly rising and falling in incidence post partum.(Table 2)

Table 2 :
Cases of Lameness by Stage of Lactation and by Type (8404 cases)

	No. of Cases of Lameness by Days Before and After Calving						
	< -60	-60 - 0	1 - 30	31 - 60	61 - 120	121 -210	>210
	525	672	1239	1085	1936	1822	1125
	Percentage of above cases by type of finding						
L	27	13	20	12	9	9	7
F	18	14	18	18	16	15	14
W	12	14	11	15	14	14	20
S	8	11	8	14	15	15	12
P	10	11	8	8	9	10	11

Key
L = Leg Lesions F = Foul W = White Line Disease S = Sole Ulcer P = Puncture/pus
Rowlands, Russell and Williams (1985)

Collick et al (1989) studied 17 farms with a lameness incidence of 17% (range 8 - 25%) and found that of the 427 cases studied, lameness could be categorised into three types; sole ulcer (31%), digital disorder (47%, defined as white line separation or abscessation, foreign bodies in the sole and a pricked or punctured sole), and interdigital disease (22%, all lesions involving the skin between the clefts and the heel - foul in the foot, interdigital granulosa and dermititis). The same author also split the lameness into two levels of severity as it affected the cows' weight and condition. By comparing the lame cow with a control animal in the same herd, Collick was able to show the affect, according to the stage post partum at which the disease first stuck, of the three types of lameness, on conception rate, services per conception and culling.

Table 3

Effect on Fertility and Culling of Lameness in Cows, Depending on Stage post partum First Affected.

Type	Stage Post Partum 0-35	36-74	75-120	>127	Serves/conception S/C A	C	Culling Rate % Culling A	C
	Days lost calving to conception							
sole Ulcer	19	24.9	40	4.9	2.45	1.73	22	4
Digital Disease	12	19.2	19.8	9.2	2.11	1.72	17	6
Inter Digital Disease	17	-1.0	-5.1	1.4	1.81	1.61	4	5
"High Score"	30	15.3	31.7	10.8				
"Low Score"	7	12.6	14.7	2.9				

S/C denotes the services per conception for A -- affected cattle and B -- the controls.
Culling shows the percentage of the cows culled in that lactation, A affected, C controls .

The affect of lameness on milk yield varies widely depending on the severity of the condition, the promptness of treatment, the yield level and the management. The range appears to be from 1 to 20% yield reduction in the lactation though little detailed information is available. In case study work, yield losses of 3 to 5 litres a day for 3 to 7 weeks were noted in lame cows with weekly milk records.

To calculate the costs of lameness, it is necessary to know the costs of factors such as,

a day's delay in conception,
an extra cull,
a service,
treatments for the different diseases,
the herdsman's time,
the cost of any reduction in yield.

It is necessary to include the cost of withdrawing milk of cows treated with certain antibiotics. As lame cows generally need to be treated more than once it is also important to add the extra costs involved for repeat cases. The rate of treatments per affected cow ranges between 1.4 (Esslemont and Wassell 1989) and 1.7 (Collick 1990).

The costs involved will also depend on whether any milk that would be produced if the lameness was not present could be sold within the farmers present quota. One case is taken where the yield produced has no effect on the quota position so leading to the chance for considerable extra profits, if lameness is reduced, or losses if lameness occurs. (Case 1, which leads to an extra 14.85p margin of milk sales less feed costs per litre). If the effect of improving the output of a herd by cutting down the incidence of lameness is to raise production of milk over the quota the farmer will take action in order to reduce the penal level of levy payable. This action can be taken either to cut down on cow numbers, releasing the land for another crop - say wheat - (Table 4) or to

cut the herd size easing the stocking rate to spread the remaining cows over the unchanged forage area. In the examples illustrated the extra litres per cow due to reducing lameness is taken to lead to a profit of 7.9 p per litre (Case 2) or only 3.9p per litre (Case 3 Table 5). If the farmer is assumed to simply lease quota to allow him to produce the extra milk then a quota leasing charge of 7p per litre would be involved. If this had the effect of reducing the margin per litre in Case 1 from 14.85p to 7.85, it makes the quota leasing example similar in effect to Case 2.

Table 4

Partial Budget to Show Within Quota Benefit of Producing 60,000 litres from 10 Cows Fewer Releasing 10 Acres for Wheat (Case 2)

	£		£
Costs forgone		Income forgone	
Less Variable Costs (Non food)			
10 Cows @ £322	3220	10 calves @£100	1000
2 Less replacements		2 culls @ £350	700
2 @ £700	1400		
Lower Interest on Cows			
15% on £600 x 10 cows	900	Extra Costs	
Less Labour		Variable cost Wheat	
25 hrs @ £4.50 x 10	1125	10 acres @ £230	2300
		Labour 8hrs x 10	
Extra Incom		80 x £4	320
Gross output Wheat			
10 acres @ 2.5t/acre x £95	2375		
Total	9020		4320

Difference £4700

The benefit is worked out using figures that refer to 10 cows at 6,000 litres per cow for ease of calculation. For a herd improvement in performance through a lower rate of lameness giving, say, 60,000 litres from 10 fewer cows, this uses up 10 acres less for dairying which are put down to wheat. This amounts to £4,700 net or 7.86p per litre produced this way (Case 2).

In the case of releasing 10 cows, at 6,000 litres per cow, using the 10 acres of forage released for a herd now with 10 fewer cows, the saving is in the reduced maintenance requirement. This is 250,000 MJ per year. The 60,000 litres can be produced partly from the forage from these 10 acres. This should reduce the concentrate bill by 8.1 tonnes at £140/tonne which is £1136 (Case 3 Table 5).

Table 5
Partial Budget to Show Within Quota Improvement of Yield per Cow, Cutting Herd Size by 10 Cows,Releasing Forage Acres to Supply More of Feed from Home Grown Resources.
case 3

Costs Forgone	£	Income Forgone	£
Maintenance Costs (part)			
10 Cows @ £50	500	10 Calves @ £100	1000
		2 Culls @ £350	700
Replacements			
2 Heifers @ £750	1500		
Interest			
10 Cows £600 @ 15%	900		
Concentrates Saved			
8.1 tonnes @ £140/tonne	1136		
Total	4036		1700
Difference	£2340		

The benefit is £2340 which at 60,000 Litres is 3.9p per Litre

The cost of a day's delay in conception is taken to be the effect of the "putting off" of a day's yield (say 25 litres) in the early stage of the next lactation, less the small amount of milk produced in the extra half day of the lactation extended by the delay (say, 5 litres, leading to a net loss of 20 litres). There is also the cost of producing fewer calves (Table 6).

Table 6
The Cost of a Delay in Conception (Cases 1,2 and 3)

	Case 1	Case 2	Case3
20 Litres @ 18.75p per Litre	£3.75		
Less concentrate, 20 Litres @ 0.28 Kg/Litre			
5.6 Kg @ £140/tonne	£0.78		
Net loss per day	£2.97	£1.57	£0.78
(pence per litre)	(14.85)	(7.9)	(3.9)
Plus			
Loss of calf income/day extra			
One 365th of £120	£0.30	£0.30	£0.30
Total	£3.27	£1.87	£1.08

A cull cow weighing say 550 kg sells for about 67p per kilo and the replacement heifer costs at least £750 to rear or to purchase. The new animal produces some 1,000 litres less milk in her first lactation than the (fit) cow being culled would normally have achieved. At a margin over purchased feed of 14p per litre this adds £140 to the cost.

The heifer also produces a smaller calf from a smaller sire, for example, Aberdeen Angus (at, say, £50) instead of the calf from the cull cow, crossed with an exotic breed, which would have been worth, say, £120.

Table 7
Cost of an Extra Cull

Cull Sale	£370
Heifer Cost £750	
Difference	£380
Lower Margin from Heifer Lactation	£140
Lower Value of Calf from Heifer	£70
Total Cost	£590

An extra insemination costs about £15 to £40 depending on the bull used. Farmers may economise on service fees for lame cows by using less expensive semen. An average of £18 is used here. The choice of bull may also have significant effects on the breeding programme in the long term.

The treatments for the different types of lameness depends on the type of disease, it's severity, the practitioner involved, the farmer's attitude and the degree of success achieved in earlier attempts. A severe case of sole ulcer may require 20 to 25 minutes of the practitioner's time which at £45 per hour, may amount to over £20. The bandage, medication, and block may amount to £22 worth of treatment. The herdsman may take up to 5 hours attending to, or caring for, the affected cow. The withdrawal of milk may be for up to 7 days. The disease may reduce the yield of the cow by 3% for the whole lactation. As the cow may continue to be fed for her or her group's potential yield, there may not be any saving in concentrates. Similar calculations can be made for the other two main types of lameness (Table 8)

Table 8
Veterinary and Other Costs of a Case of Lameness

1. Severe Case Sole Ulcer	
Time - 25 mins @ £45 per hour	£18.75
Share of turnout fee	£5
Medication, bandage, treatment	£12
Further treatment	£10
Sub Total	£45.75
Herdsman's Time (5hrs @ £3.5)	£17.5
Withdrawl of milk (7 days) yield 30 litres/day	£35.91
Effect on yield 3% of lactation	£30.70
Total	£129.86
2. Severe case of Digital Disease	
Veterinary Costs	
Time @ £45 per hour	£15
Medication, bandages, treatment	£15
Sub total	£30
Herdsman's time (3hrs @ £3.50/hr)	£10.50
Withdrawl of Milk (3 days)	£15.39
Effect on yield 2% of lactation	£20.60
Total	£76.49
3. A Severe case of Inter-digital disease	
Veterinary Costs	
Time 10 minutes	£7.5
Medication, treatment	£7
Sub total	£14.5
Herdsman's time	£3.50
Effect on yield (1%)	£10.30
Nil milk withdrawal	
Total	£42.80

The herdsman's time is involved in coping with lameness whether it is spent helping the veterinary surgeon, treating the cow himself, or in getting the slow moving animal to come in for milking or feeding. While the herdsman may be paid no more

for this work, his time does have an "opportunity cost", that is, he could be better employed elsewhere, whether it is spotting bulling cows or getting some extra rest. This is costed at the average rate of pay of £3.50 per hour.

When a lame cow loses yield the farmer may not cut down on feeding her concentrates. Of course it would be sensible if he didn't as the cow is unlikely to be able to reach her forage supply anyway and she requires the concentrates to maintain herself. Yield loss should be costed, at the most in Case 1, at the full value of the milk not produced. In cases where the yield if obtained, would put the farm over the quota, the loss of milk is only 7.9p (Case 2) and 3.9p (Case 3)

The effect of lameness on services to conception and the chances of culling, compared with paired animals without the disease, can be drawn and summarised from the study by Collick et al (1989) (Tables 3 and 9)

Table 9
The Effects of Lameness on Fertility and Culling

Type	Stage of lactation (days)	Services per conception	Calving to conception	Chance of culling (increase)
		2.45 v 1.73	Days	Per Cent
Sole ulcer occurring	0-35	0.72	19	18
	36-74	0.72	25	18
	75-120	0.72	40	18
	>120	0.72	4.9	18
		2.11 v 1.72		
Digital diseases occurring	0-35	0.39	12	11
	36-74	0.39	9	11
	75-120	0.39	20	11
	>120	0.39	9.2	11
		1.81 v 1.61		
Interdigital disease occurring	0-35	0.2	17	0
	36-74	0.2	0	0
	75-120	0.2	0	0
	>120	0.2	1.4	0

Collick et al 1989

As an example, taking the case of a sole ulcer occurring to a cow at 75 to 120 days post partum, (Table 10) the effect is to increase the services per conception by 0.72, to lengthen the interval to conception by 40 days, and to increase the chances of the cow being culled by 18 percentage points (from 4% to 22%).

Calculating and adding up all the component costs of sole ulcer lameness for this cow the cost in Case 1 terms is £401.30 for a single case and £492 for the average cow with 1.6 cases.

Table 10
The Total Costs of Single Case of Sole Ulcer Lameness

	Case 1	Case 2	Case3
Cost of treatments	£	£	£
(1 @ £23.80, 1@ £12, 2 @ £5)	45.80	45.80	45.80
Herdsman's time (5hrs)	17.50	17.50	17.50
Cost of culling - 18% of £590	106	106	106
Cost of longer calving to conception (40 days)	131	74.70	43.3
Cost of extra services 0.72 @ £18	13	13	13
Yeild reduction (3% of lactation)	30.70	14	7.01
Milk withdrawal (7 days)	57.30	26	13.10
Single case Total	401.30	297	246
Cost of extra 0.6 repeat	90.80	62.10	50
Cost of 1.6 cases per cow	492	359	296

The same type of calculation can be made for the cost of each of the three types of lameness (Table 11 Digital Disease; Table 12 Interdigital Disease); some of the more expensive examples are shown.The costs vary according to the stage post partum at which the disease first strikes. In addition, if the rate at which a case has to be retreated is taken as 1.6 cases per affected cow, the costs will rise further, because of the four components that vary with the chronic condition - extra treatments, yield loss, milk withdrawal and the herdsman's time. These extras are calculated at the rate of 0.6 of the cost of the first case.

Table 11.
Cost of a Single Case Digital Disease Occurring at 50 days Post Partum.

	Case 1	Case 2	Case3
Cost of treatments	£	£	£
(1 @ £15, 2 @ £7.50)	30	30	30
Herdsman's time (3hrs)	10.50	10.50	10.50
Cost of culling - 11% of £590	64.90	64.90	64.90
Cost of longer calving to conception (9days)	29.50	16.80	9.75
Cost of extra services 0.39 @ £18	7.02	7.02	7.02
Yeild reduction (2% of lactation)	20.60	15	7.48
Milk withdrawal (3 days)	15.40	15	5.6
Single case Total	178	146	130
Cost of 1.6 cases per cow	224	180	160

Table 12
Cost of a Single Case Interdigital Disease Lameness at 20 days postpartum, Cost of 1.6 cases.

	Case 1	Case 2	Case3
Cost of treatments	£	£	£
(1@ £7.50, 1@£7)	14.50	14.50	14.50
Herdsman's time (1hr)	3.50	3.50	3.50
Cost of culling (no effect)	0	0	0
Cost of longer calving to conception (17days)	55	31.80	18.40
Cost of extra services 0.2 @ £18	3.60	3.60	3.60
Yield reduction (1% of lactation)	10.26	4.67	2.33
Milk withdrawal	0	0	0
Single case Total	87	58	42
Cost of 1.6 cases per cow	104	72	54.6

Table 13 Cost (£) of a case of lameness in an individual cow, according to Type and Stage of lactation.
(Assuming 1 and 1.6 cases per affected cow, covering cases 1,2 and, 3)

		Stage (days)			
		0-35	36-74	75-120	>120
		£	£	£	£
Sole ulcer	Case 1	328/381	326/379	401/492	276/329
	case 2	256/301	257/302	297/359	227/272
	case 3	222/263	224/265	246/296	205/247
Digital disease	case1	177/232	178/224	192/254	163/222
	case 2	147/185	146/180	153/194	139/179
	case 3	131/163	130/160	133/166	127/159
Interdigital disease	case 1	87/104	27/49	48/65	36/53
	case 2	58/72	24/40	36/49	29/42
	case 3	42/55	23/36	29/42	25/38

87/104 signifies £87 cost of first treatment, £104 cost of 1.6 cases total.

Costs in a Herd

To estimate the cost of lameness in a whole dairy herd, it is possible to allocate a pattern of the three types of lameness to a notional 100 cow herd, according to the findings of Rowlands et al (1985). These patterns can be set to reflect the rate of incidence of the disease (from 8% to 56% in steps).

Table 14

The rate of occurrence of a three different types of lameness in a 100 cow herd, by Stage Postpartum according to per cent of heard affected overall

	Rate (%) 8	12	16*	20*	24*	28*
	Number of cases					
Sole ulcer						
0-35 days	0	1	1	1	2	2
36-70 days	1	1	1	2	1	2
71-120 days	1	1	2	1	2	2
>120 days	1	1	1	2	2	2
Digital disease						
0-35 days	1	1	2	2	2	3
36-70 days	1	2	2	2	3	3
71-120 days	1	1	2	3	2	3
>120 days	1	2	2	2	4	4
Interdigital desease						
0-35 days	0	0	1	2	1	1
36-70 days	0	0	0	1	1	2
71-120 days	0	1	1	1	2	2
>120 days	1	1	1	1	2	2

*The rates of 32%, 40% and 56% are simply taken as double the relavent rates shown above.

The total cost of lameness in these 10 "herds" ranges from £1,494 to £13,783 depending on the rate of incidence and the case dealt with.

Table 15

Cost of lameness per herd, per lame cow in the herd and in England and Wales, depending on rate of lameness, at 1.6 cases per affected cow. Disease involves the three types of lameness at the incidence and spread shown in table 14. Cases indicate the cost of lost margin per litreshown in table 6

Per cent (%) rate of incidence of lameness	8	12	16	20	24	28	32	40	48	56
Cost in 100 cow herd										
Case 1 (£)	2185	3077	4341	4964	5886	6891	8683	9928	11774	13783
Case 2 (£)	1673	2342	3152	3673	4314	5035	6304	7346	8628	10070
Case 3 (£)	1493	2117	2796	3269	3900	4530	5593	6539	7801	9060
Cost per Cow lame										
Case 1 (£)	273	256	260	239	238	236	260	239	238	236
Case 2 (£)	209	195	197	183	179	179	197	183	179	179
Case 3 (£)	186	176	174	163	162	162	175	163	162	161
Number of cows (M) 2.83										
Cost of lameness (£M) @ given rate lame										
Case 2	47.3	66.3	89.2	103.9	122.1	142.5	178	208	244	284
Case 3	42.2	59.9	79.1	92.5	110.4	128.2	158	185	221	256

At the higher costs for lost milk, in a herd reflecting an average rate with 24% of the cows affected by lameness, the cost is £5,886 or £238 per lame cow. If the ideal rate of no cows lame is possible, and if 8% is about the lowest practical rate (Collick et al 1989) to expect, then the difference in losses between the herd with 24% lameness and the herd with 8% is £3,701 (using the Case 1 Values). At values which reflect the true value of extra milk production under a quota regime, the cost in a herd with 24% lameness is £4,314 (case 2) and £3,900 (case 3) representing a cost over 8% lameness of £2,641 (case 2) and £2,407 (case 3).

Nationally in England and Wales this multiplies up, in 2.83 million cows, to total costs of lameness (if say 16% of the herd is affected) of £89.2 million. However this simple multiplication implies that the extra products, calves, wheat etc. produced could all be sold at present market prices. This is not likely to be the case as there are not only quotas for milk production but limited demand for other products.

Discussion

On the basis of Case 2, the costs for the first incidence of the three types of lameness in a typical cow are between £227 and £297 for sole ulcer, £139 to £153 for

digital disease and £24 to £58 for interdigital disease.
Table 16
Proportions of Costs of the Three Types of Lameness

	75 days Sole Ulcer	50 days Digital Disease	20 days Interdigital Disease
Costs of Treatment	11.4	16.8	16.6
Herdsman's Time	4.3	5.9	4.0
Cost of Culling	26.4	36.4	0
Cost of Longer Calving to Conception Interval	32.6	16.5	63.2
Cost of Extra Services	3.2	3.9	4.1
Yield Reduction	7.6	11.5	11.7
Milk Withdrawal	14.3	8.6	0
Fertility Costs %	62.2	56.8	67.3

It is clear (Table 16) that cost of the veterinarian's time and treatment is a small proportion of the total costs in the three examples taken from Tables 10, 11and 12 when these costs do not exceed 17%. The major items are the cost of culling extra cows (26.4 and 36.4% where it applies) and the cost of the delay in conception (16.5 to 63.2%). Added together these two and the cost of services total over 55% and up to 67% of the total costs. As many of those involved in extension work may not have had this information brought together this way, it may provide more material to use in urging the farmer to take preventive action against the disease.

These costings are only estimates. Each farm and veterinarian will treat lame cows in different ways. These days there are "No Withdrawal" antibiotics available and these are becoming more widely used. While these antibiotics cost around £7 per injection and two such courses may be necessary, they remain cheaper , by about £20, than discarding 70 to 100 litre of milk.

These figures do not take account of the sub-clinical cases of lameness occurring in all herds; in many the cost of this aspect of lameness will be much greater than the cost of clinical cases. The figures do not take account of the welfare aspects. If one could score or cost the apparent pain and suffering born by lame cows a new type of scale would be needed for the purpose. As good preventive management and husbandry has been shown to be one of the main ways of keeping lameness well under control, maybe farmers who scored too high a score on such a scale should not be allowed a licence to keep cows however much money the disease might be costing them.

References

Arkins S. (1981) Lameness in Dairy Cows. Irish Veterinary Journal, **35**, 135-140.

Benyon V.H. and Howe K.S. (1974) The disposal of Dairy Cows in England and Wales,

1972-73. Report No. 192. University of Exeter, Agricultural Economics Unit.

Collick, D. W. (1990) Personal communication

Collick D.W., Ward R. and Dobson H. (1989). Associations between different types of lameness and fertility. Vet. Rec. **125**,103-106.

Esslemont R.J. and Wassell B.R. (1990) Incidence of Lameness in Herds using the University of Reading DAISY database. Internal Report, Department of Agriculture, University of Reading.

Gartner J.A. (1980) Replacement Policy in Dairy Herds. Unpublished Ph.D. Thesis, University of Reading.

Leech, F. B. Davis, M. E. MCrae, W. D. Withers, F. W. (1960) Report of National Survey, 1957-58 pp. 62 London HMSO

Prentice, D. E. ,Neal, P. A. (1972) Veterinary Record **91** 1-6

Rowlands G.J., Russell A.M. and Williams L.A. (1985). Effect of Stage of Lactation, Month, Age, Origin and Heart Girth on Lameness in Dairy Cattle. Vet. Rec. **117** p576-580.

Whittaker D.A., Kelly J.M. and Smith E.J. (1983) Incidence of Lameness in Dairy Cows. Vet. Rec. **113**, 60-62.

Bovine Contagious Interdigital Dermatitis: A review and critique of the literature

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Bovine contagious interdigital dermatitis (BCID) was first documented as a specific disease condition of cattle when *Bacteroides nodosus* was isolated in 1966 from foot lesions of cattle that had been grazed with sheep, suffering from ovine contagious foot rot (OCFR). Subsequent reports have suggested that the etiologic agents and transmission of BCID are similar to OCFR, caused by a synergistic infection of *B.nodosus* and *Fusobacterium necrophorum*. Natural transmission of BCID has been demonstrated following environmental contact between affected and non-affected cattle.

Experimentally, pure cultures of *B. nodosus* isolated from the cattle and sheep have been successfully transferred to the interdigital skin of cattle, provided that prior maceration and invasion by *F.necrophorum* had occurred. Cattle and sheep are readily infected with their respective *B.nodosus* isolates. Sheep isolates, however, do not readily infect cattle, and cattle isolates cause only transient interdigital skin infections in sheep. Although the etiologic agents and transmission of BCID and OCFR are similar, the pathogenesis, pathology, and clinical features of the two conditions vary markedly. In both diseases, the primary site of infection is the epidermal cells of the interdigital skin.

In OCFR, the pathogenesis of the interdigital and hoof lesions has been well documented, but studies of BCID are limited; much of that information has been extrapolated from OCFR. In the early hoof lesions of OCFR, *B.nodosus* is the predominant and often the only bacterial invader of the skin and cornified epithelium of the hoof and precedes *F.necrophorum* into the matrix of the horn. The pili of *B.nodosus* help maintain the commensalism of the bacterium, while it's proteases damage the horn. *F.necrophorum*, which subsequently penetrates the epidermal matrix of the horn, is largely responsible for the necrosis and purulent exudate in the infected horn.

Gross lesions of chronic OCFR are characterised by undermining of the heal and sole horn with purulent exudate, whereas BCID lesions are frequently confined to the interdigital skin. Undermining of the heel and sole with subsequent necrotic laminitis that is so characteristic of chronic OCFR is only occasionally observed with BCID. The lesions and severity of BCID and OCFR have been attributed to differences in the piliation and protease production by the *B.nodosus* isolates from cattle and those from sheep.

Although BCID has been described as causing serious economic losses in many countries, the pathogenesis of BCID in cattle and the epidemiologic relationship between BCID and OCFR have not been clearly delineated. A brief review of the published literature will be presented with a subsequent critique by the symposium participants.

The Effect of Supplementary Dietary Biotin on Hoof Hardness and Hoof Growth and Wear Rates of Dairy Cows

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Summary

The effects of Biotin supplementation on hoof hardness, and hoof growth and wear rates in dairy cows were assessed in an on-farm feeding trial at Seale-Hayne Faculty from October 1984 to February 1985

.The faculty herd was housed in cubicle accommodation bedded with shavings. The floors were solid concrete scraped twice daily. The cows were bunker-fed silage and received concentrates according to yield.

36 British Friesian cows were selected from the herd. They were paired according to date of calving, parity and previous yield, and then randomly allocated to treatment (Biotin-supplemented) or control groups. The treatment group received 20 mg Biotin per day (Rovimix H 2% type S - Roche products). This was sprayed onto their in-parlour feed as an aqueous solution.

Hoof hardness was measured using a Shore Type A Durometer. Biotin supplementation produced significantly harder hoof tissue ($p<0.001$) in the centre of the abaxial wall and increased the hardness of heel horn tissue ($p<0.05$) after 13 -15 weeks,

Hoof growth and wear was assessed by measuring the rate of descent of a branded mark in the abaxial hoof wall, with respect to the coronet.

There was no effect of treatment on hoof growth rates. Non-supplemented animals only underwent a negative change in hoof height in weeks 5 - 8 of the trial. There was also a general trend ($p<0.1$) for Biotin supplemented animals to have larger net gains in hoof height during weeks 5 - 11 of the trial.

Aetiopathogenesis of Interdigital Lesions in Cattle

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Summary

Nomenclature, definition and aetiopathogenesis of interdigital disorders are considered, except the evolution of interdigital hyperplasia. These include hygiene (4,10,20,21,22), trauma (1,4,6), hereditary influences (7,8,11,17), bacterial (3,5,9,12,13,16,18,19,23,25,26,27), and viral (24) infections, often all interrelated.

Material and Methods

For a three year period , the frequency in 1,341 cattle;430 were bulls and 911 were either heifers or dairy cows, morphoclinical and evolutive characters of the interdigital disorders were studied. The aetiological factors and pathogenesis of lesions were studied by examining the dynamics of claw development previously described by Bolte and others (4). Samples from 140 cases were taken for the isolation of *Bacteroides nodosus* by culture on the Egerton 79 medium. Granulation tissue was taken from 22 bulls and 14 cows with chronic interdigital hyperplasia in different stages of development; material was innoculated onto solid medium with brain-extract and Sabouraud medium; tissue was also examined histologically.

Results and Discussions

Pathological lesions were associated with the abnormal growth of untrimmed claws. Interdigital lesions shared a frequency of 52-85% in cattle housed in intensive systems with permanent housing; age, sex, floor type and the length of bed all had an influence.

Acute interdigital dermatitis was frequently diagnosed; lesions were similar to those described in the literature (3,12,13,14,15,18,19,26) and affected the interdigital skin around the heel bulbs. Initially the skin was tumefied and very sensitive; after 2-4 days, a purulent exudate developed that was foul-smelling. Gradually, as a result of keratolytic processes, caused epidermal maceration leaving the papillary layer uncovered, thereby producing typical ulcerating, necrotic lesion. In the absence of therapy, the process extends to the horn wall and underlying lamina to produce pododermatitis septica suppurativa and the phlegmona interdigitalis. This form is found almost exclusively in heifers and cows maintained in a housing system on short beds or on slats, without a protective litter and mostly affect the hind limbs.

Chronic interdigital dermatitis was found more frequently in cattle maintained on stalls with straw litter. From 8-12 months of age hyperkeratinisation of the skin from the dorsal interdigital region, accompanied by a light inflammatory reaction, could persist. In all the cases the interdigital space was narrowed and preventing free passage of dung and litter through the space. A higher frequency was recorded in bulls

compared with dairy cattle.

In all cases interdigital hyperplasia appear to have evolved from a form of chronic dermatitis. It may affect up to 85% of sire bulls and 38% of cows. The frequency increases with age, becoming maximal at 5-6 years of age. The hyperplasic process gradually forms from skin from the axial coronary region spreading the two digits, appearing as a pseudotumorous, fibrous formation covered by hyperkeratinised epidermis which is barely sensitive to pain. In advanced forms, we have observed more proliferative centres with disquamation of epidermis and open ulcerative, necrotic lesions, brought about by trauma and the large size of the lesion. On histological section, we found highly vascularised fibrous tissue containing granulomata. The lesions have a diameter of 0.5-1.5mm, present as yellow-orange or dirty-white colour and are surrounded by a capsule. A caseous, purulent exudate is often present. The granulomata involved hair follicles in a few cases, characteristic of folliculitis.

Mycelia filaments were found on microscopic examination of sections in the centre of the lesions. Microbial cultures from the granulomata or exudate grew *Monosporium apiospermum* (the imperfect form of the fungus *Allescheria boydii)* and other fungi or actinomycetes in the process of identification.

The results of the bacteriological examination show that *Bacteroides nodosus* was isolated in 72% of the cases featuring acute, incipient dermatitis; the organism has also been recorded in cattle without lesions (30%) or with lesions of hyperplasia (45%).Correlating these results with the dynamic formation of the lesion, we propose that the aetiopathogenesis of acute dermatitis is associated with *Bacteroides nodosus* infection, a fact noted also by other authors (3,12,13,16,19,25). In chronic forms of disease other organisms are present, notably, mycetes and actinomycetes; lesions resemble those associated with mycetomas or granosis described in man (2).

Conclusions

1. Two forms of dermatitis have been identified:

   i) acute, with a frequency going up to 37% in dairy cattle, characterised by exudative-ulcerative-necrotic lesions found in the skin of the posterior interdigital space:

   ii) chronic, with a frequency of over 44% in bulls aged up to four years, where hyperkeratinisation and hyperplasia are predominant and found in the dorsal interdigital area.

2. Interdigital hyperplasia is a form of chronic dermatitis, affecting between 16-85% of bulls and between3-38% of the cows, frequency increasing with age.

3. Infection with *Bacteroides nodosus* can be associated with acute dermatitis, but in the case of chronic dermatitis and interdigital hyperplasia mycetes and actinomycetes were isolated; the significance of this finding is currently being investigated

References
1. Amstutz H. E. (1986). Dis. of Ruminant Digit- Fifth Inter. Symp., Dublin, 101-106.
2. Avram A. 1969). Micetoamele in Romania, Ed. Acad. R.S.R. Bucuresti.
3. Berg J.N. (1978) Sympos. Bov. Digit Dis., Skara.
4. Bolte s. si colab (1987). Rev. de zoot. si med. vet., **11**, 23-26.
5. Borisevich V.B.(1985). Vet. Moscov,USSR,**4**, 52-54.
6. Cheli R. si Mortellaro C.M. (1986). Dis. of the Ruminant Digit, 5th Inter. Symp., Dublin, **8**-13.
7. Cirlan M. (1982). Al IV lea Simp. Inter. as. tulb. deget. rumeg., Alfort.
8. Cirlan M. (1982) Rev. de crest. anim., **10**, 36-42.
9. Clark B.L. si col. (1982). Congr.mondial al XXII-lea Med.Vet.,Perth,Australia, 145.
10. Demertzis P.N. (1978). Rep. Sec. Simp. Bov. Digit. Dis., Skara.
11. Dietz O. si col. (1978.) Mh. f. Vet. Med., **33**, **22**, 850-855.
12. Egerton J.R. si Leing E.A. (1978). Al II lea Simp. boli. deget. bov Skara.
13. Egerton J.R. si Laing E.A. (1982). Al IV lea Simp, tulb deget. rumeg., Alfort.
14. Espinasse J., Savey M. Thorley C.M., Toussaint-Raven E.,Weaver A.D.(1982.) Atlas en couleur des affections du pied des bovins et des ovins, Ed, Point Veterinaire Soc.Francaise de Buiatrie, 12-18.
15. Greenough P.R., MacCallum F.J., Weaver A.D.(1983). Les boiteries des bovins, Le Pont Veterinaire, 160-185.
16. Gupta R.B. si col. (1964.) Cornell Vet., **54**, 66.
17. Lukyanovskii V.A. si Filippov Yu. I. (1984). Sbor. N., Trud. Moskov. Vet. Acad.. 96-97.
18. Moga-Minzat R. si col.(1984.) Pododermatitele infectioase ale rumegatoarelor, Ed. Ceres, Bucuresti.
19. Moldovan M. si colab. (1986). Lucr.st. I.A.T., XXI, 99-102.
20. Moldovan M. si colab. (1988.) Rev. de zoot. si med. vet., **2**, 46-52.
21. Moldovan M., Bolte, S. (1988) Rev. de. zoot. si med. vet., **2**, 46-52
22. Moldovan M., Bolte S. 1988. Rev. de zoot. si med. vet., **5**, 49-57.
23. Morosanu N. (1969). Teza de doctorat, F.M.V. Bucuresti.
24. Rebhun W.C. si col.(1980.) J.A.V.M.A., **177** (5) 437-440.
25. Thorley C.M. si col. (1977). Vet. Res., 100, 387.
26. Toussaint-Raven E. si Cornelisse J. L. (1971). Vet. Med. Rev., 2-3, 223-247.
27. Weaver si col.(1981). J.A.V.M.A., **178** (4) 375-377.

The Economic Importance of Lameness in Imported Dairy Cattle in Tanzania

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ABSTRACT

The economic importance of lameness in a farm with 200 imported cattle managed semi-intensively was studied. During a period of one year, clinical examinations for lameness coupled with analysis of health and breeding records from the previous 5 years were used to study the association between lameness and fertility. Rectal examination and progesterone assays were done to assess the reproductive activity and the level of feeding was assessed by determination of blood glucose. The herd had a high incidence of lameness mainly caused by laminitis, sole ulcers, white line disease and dermatitis interdigitalis. Ovarian cyclicity, rate, and energy levels between lame and sound animals were not different. Lameness was associated with long calving interval (465 days), low pregnancy rate (0.50), decreased milk production, high costs of medication and high culling rates consequently causing a negative net profit income.

The Way to Healthy Hooves

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Good animal management directed to high production requires healthy hooves on healthy animals. The requisites for healthy legs and hooves are a good environment and proper care.

The shape of the cow's hoof has been adapted to stand up to varying environments. The hoof horn of cows which walk long distances for their daily feed wear down at the same rate as it grows.

Today, cattle hooves become insufficiently worn. This applies especially during the stall-feeding period. Therefore hooves require special attention and care. Cows with overgrown feet or poor hoof health in other respects have difficulty in rising. They are stiff in their movements and often lame. The risk of decubital injuries and teat-tramp increases. Unhealthy hooves may also lead to reduced appetite and poor milk production.

With a normal hoof the wall consists of toe and posterior wall. The soft tissue is protected by the wall, the sole and the bulb. Inside we find the corium and the third phalanx.

The hoof horn grows an average of six centimetres per year. When the toe becomes longer the load on the sole is moved backwards. Over-loading of the rear parts increases the risk for injuries in the corium.

Feet do not grow only in length. In due course the outer claws of the hindfeet almost always become higher than the inner claws. This, too, may cause serious changes of load. Compare the wheels of a tractor-drawn cart; if any wheel is overloaded, the risk of puncture increases. Overloaded outer claws are related to solar ulcer. Trimming is therefore most needed on the outer claws of such hindfeet to evenly distribute the load.

In cattle which have overgrown feet a wide hindleg stance is often adopted as she attempts to relieve the load on the outer claws. She moves with abnormal gait.
A cow is most simply trimmed in a foot trimming crush. There are many types, all with slight differences, based on the principle that the cow is fixed in position and supported under the belly. When the feet have been raised with ropes or chains the hoof trimmer can work safely and snugly.
The commonest trimming tools are a club, blade and hoof knife. In the trimming operation the toes are shortened and the two claws are made equally high. The trimmed hoof has a smooth sole with cavity, bevelled wall, and equally high claws and

short accessory claws.

When trimmed the cow now stands and puts her weight on both hind feet in a more correct manner. The toe length is now twice the height of the posterior wall.
A hoof miller can also be used for trimming. It requires a special technique and, in particular, a sound basic knowledge of hooves and trimming principles.
An important element in routine hoof trimming is to observe and rectify changes in hoof horn and interdigital skin.

Hoof lesions can be seen even when the cow is standing in the stall. There, an accustomed eye can see signs in cows which exhibit pain. Cows which shuffle to relieve the weight on both hindfeet often have pain in both feet. The placing of their hooves in the manure-gutter may also be an attempt to relieve pain by standing on a softer foundation.

Other cows stand on the edge of the concrete cubicle bed. This is seldom due to the size of the cow or the length of the stall, but usually to some disease in the rear part of the feet. Such cows need immediate care even if the hooves are not long. The disease is aggravated if they do not receive proper attention. Nearly all forms of lameness in cows derive from the feet and it is usually the outer claws of the hindfeet that are affected.

The commonest hoof diseases found during the housed period are hoof ulcer, horn erosion and laminitis. Interdigital phlegmon often occurs during the grazing period. Several diseases may be present simultaneously. Typical hoof ulcers appear in the transition between the central and rear third of the sole. They arise due to overloading of the rear outer claws or laminitis. A hoof ulcer is formed when haemorrhage in the corium causes defective horn formation. This produces a tract, originating from the corium, through the sole. This offers a direct entry for bacteria, which can cause serious infections in the hoof. This is treated by trimming the entire hoof to produce the proper distribution of load. The horn is cut clean round the ulcer to relieve the load on the area. Bandaging is sometimes necessary.
Horn erosion is seen as fissures and pockets at the heel in a typical V-shaped pattern. The chief causes are poor stall environment, bacterial infection, and bad horn quality caused by defective hoof care. The treatment consists of first trimming the sole. All undermined horn is then cleared away so that the pockets disappear. Sometimes local treatment with a suitable dressing should also be given.

Acute laminitis leads to quick onset of stiffness and tender feet caused by inflammation and haemorrhage in the corium. The cow attempts to relieve the load on the painful hooves by abnormal stance. It is a metabolic disorder and usually occurs in newly calved heifers and cows who have experienced a change to an intensive concentrate diet. The inflammation and haemorrhage in the corium cause poor keratinisation, manifested as haemorrhage in the sole. This is sometimes the origin of hoof ulcer. The lesions are aggravated if the cow stands on a hard surface.
So-called laminitic rings in the hoof wall indicate that the cow has previously experienced laminitis. To avoid the risk of laminitis, cows should be given a smooth

change of feed around calving and extreme amounts of concentrate fed should be avoided.

Interdigital phlegmon - or, as it is also called, acute foot-rot - is the commonest digital disease during the grazing period. Severe lameness is usual, but as a rule only one leg is affected. The cow has fever and the affected foot is swollen from the coronary matrix.

It is caused by bacteria which are normally present in faeces and thus always on the ground. The fact that not all cows develop interdigital phlegmon is due partly to the varying resistance of different animals and to the bacteria challenge. Animals with good resistance keep healthy even in bad, bacteria-rich environments. In a good environment even poorly equipped animals can avoid disease.

If the environment is poor and the animal has poor resistance because of a number of small abrasive injuries in the interdigital skin there is a greater risk of interdigital phlegmon. It is usually treated with antibiotics.

In herds with horn erosion and interdigital phlegmon, footbaths may be used with good result. They can be used both in cow-sheds and out of doors and be prepared from copper sulphate

To prevent problems with hoof health the best and most important measure is trimming twice a year. Hoof health is thus regularly checked and faulty load conditions and diseases are corrected and treated in time. The cost of trimming twice a year corresponds actually only to the gross income of a few tens of kilos of the annual milk production per cow.

In many herds control and care are necessary between trimmings. The possession of a foot trimming crush is important for this purpose.

A good local environment and management technique help to keep feet healthy. A clean and dry stall with plenty of litter is an important health-promoting factor.

Neglected hoof care causes:

i) faulty hooves and affects the cow's manner of moving, thereby increasing the risk of teat tramp and inflammation of the udder.

ii) pain in the hooves and hoof diseases. This causes the cow to eat and produce less milk.

iii) increased costs of veterinary treatment and of antibiotic-rejected milk.

iv) premature slaughter; replacement of such cows substantially increases costs.

v) unnecessary and lengthy suffering

The way to healthy hooves is : well trimmed hooves, good stall environment, concreted gateways and successive adaption to a concentrated feed.

Cows with healthy hooves which can walk, stand and move in a correct way can more easily meet todays high demands for economical production.

Risk Factors for Pododermatitis in Bulls for AI

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Introduction

In Artificial Insemination (AI) centres digital diseases represent an important cause of economic losses because it is impossible to collect semen from lame bulls. Three forms of pododermatitis; pododermatitis septica, pododermatitis circumscripta and pododermatitis aseptica diffusa associated with interdigital hyperplasia, are the most common foot conditions in bulls (Smedegaard, 1962; Modrakowski, 1978; Cirlan, 1982a).

Numerous endogenous and exogenous factors contribute to the pathological lesions, particularly pododermatitis (Toussaint Raven, 1973; Martig et al., 1980; Andersson and Lundstrom, 1981)

The aim of the present paper is to assess the risks associated with some of these factors in AI centres.

Materials and Methods

The investigations were carried out at an AI centre near Iasi, Romania, and involved all the Holstein-Friesian and Brown Swiss bulls living in the centre for a period of 6 years.

The conditions of housing and exercise of the bulls, as well as the methods used for the study of risk factors, have been presented elsewhere (Cirlan, 1982b).

Results

1. Breed influence

In bulls of Holstein-Friesian breed the incidence of pododermatitis was similar with that in Brown Swiss bulls, as is illustrated in Table 1

2. Influence of age

Table 2 shows that the risk of pododermatitis is positively correlated with age, both in Holstein-Friesian and in Brown Swiss bulls.

Table 1:
Influence of breed on the frequency of pododermatitis in bulls.

Breed	Number of bulls	Pododermitites Non-affected No	Affected No	Affected %
Brown Swiss	170	129	41	24.1
Holstein-Friesian	571	458	154	19.8
Total	741	587	154	20.7

$Chi^2 = 1.5$; f = 1; P = NS

Table 2:
Influence of age on the the frequency of pododermatitis in bulls.

Group of Age (years)	Holstein-Friesians Total No	Affected No	%	Brown Swiss Total No	Affected No	%
- 3	729	47	6.4	205	9	4.3
3 - 5	213	22	10.3	75	13	17.3
5 - 7	146	24	16.4	50	13	26.0
7 -	101	20	19.8	34	6	17.6
	Chi^2=29.2;f=3 P<0.001			Chi^2=29.2;f=3 P<0.001		

Table 3:
Influence of body weight on the the frequency of pododermatitis in bulls.

Group of Body weight (Kg)	Holstein-Friesians Total No	Affected No	%	Brown Swiss Total No	Affected No	%
<500	369	7	1.9	101	-	-
501-600	228	12	5.2	77	-	-
601-700	112	19	16.9	15	5	33.3
701-800	83	12	14.4	17	4	23.5
801-900	195	26	13.3	90	18	20.0
901-1000	157	25	15.9	51	11	21.5
1001-1100	45	12	26.6	13	3	23.0
	Chi^2=60.9;f=6;P<0.001 r=+0.94			Chi^2=60.9;f=6;P<0.001 r=+0.61		

3. Influence of body weight

In Holstein-Friesian bulls the frequence of pododermatitis is significantly higher with increasing body weight from 700 kg upwards while in Brown Swiss bulls it is seen from 800 kg upwards. An important risk is present in bulls of both breeds under 500 kg.(Table 3).

4. Influence of season

Table 4 shows that the incidence of pododermatitis is higher in Holstein-Friesian bulls during the summer. This relationship is even greater in Brown Swiss bulls.

Table 4:
Influence of season on the frequency of pododermatitis in bulls.

	Surgical interventions			
	Holstein-Fresian		Brown Swiss	
Season	No	%	No	%
Spring	56	22.5	19	25.3
Summer	76	30.6	33	44.0
Autum	73	29.4	15	20.0
Winter	43	17.3	8	10.6

5. Influence of butterfat yield of the dam

In Holstein-Friesians the frequence of pododermatitis is significantly higher in bulls bred from dams with a butterfat yield of 250-300 kg and over 400 kg. In Brown Swiss bulls, the risk of pododermatitis developing increases with rising butterfat yield of their dams (Table 5).

Table 5:
Influence of butterfat yield of the dam on the frequency of pododermatitis in bulls.

	Butterfat Yield of dam (Kg)	Total Bulls No	Affected No	Affected %
Holstein-Friesian	<250	425	72	16.9
	201-300	111	29	26.1
	301-350	20	7	35.0
	351-400	10	4	40.0
	>400	5	2	40.0
(Chi^2=18.0;f=4;P<0.001	r =+0.95)			
Swiss Brown	<200	96	19	19.7
	201-250	58	15	25.8
	251-300	12	4	33.3
	>300	4	3	75.0
(Chi^2=78.2;f=4;P<0.001	r =+89)			

6. Influence of sire and of interdigital hyperplasia.

Table 6 shows the influence of the sire on the frequency of pododermatitis in male offspring. From the same table, the presence of interdigital hyperplasia can be seen to influence the development of pododermatitis.

Table 6:

Influence of sires on the frequency of pododermatitis in the male descendents and association between interdigital hyperplasia and pododermatitis.

		Total descendents in centre.	Affected by pododermatitis.		Of which affected by pododermatitis and interdigital hyperplasia.	
Sires	Breed	No	No	%	No	%
Alexander 38818+	HF	9	6	66.6	5	83.3
Bj. Frans 10369+	HF	24	11	45.8	9	81.8
Fortunatus 710453+	HF	5	1	20.0	1	100.0
More 200668+	B	16	3	18.7	2	66.6
Total		54	21	37.0	17	80.9
Idol 750018 -	HF	22	1	4.5	-	-
Sk. Stefan 9246 -	HF	11	-	-	-	-
Total		33	1	3.0	-	-

$Chi^2 = 14.0$; f=1 $p<0.001$

+ = Present in centre and affected by pododermatitis.

- = Present in centre and not affected by pododermatitis.

HF = Holstein-Friesian breed.

B = Brown-Swiss breed.

Discussion

The results demonstrate that the frequency of pododermatitis is similar between Holstein Friesian and Brown Swiss breeds, although a breed difference in susceptibility for digital diseases has been described in dairy cows by Berger (1977), Andersson and Lundstrom (1980, 1981).

A higher rate of pododermatitis is associated with increasing age. This is probably caused by biochemical changes in digital horn, which create a favourable environment for microbial invasion and growth. At the same time, the use of AI bulls increases with maturity and age because reproductive activity is optimal at 6-8 years of age when there is a greater risk of pododermatitis. This correlation between age and pododermatitis was reported by Modraskowski, (1978), Andersson and Lundstrom (1980;1981).

In both breeds body weight is a risk factor. It increases from 50% to 100% in the animals over 900 kg body weight. It seems that over-loading of the sole, caused by compression mostly at the heel adversely affects the local blood circulation to cause ischaemia which depresses the rate of keratogenesis; necrosis develops in respective

zones of the sole. These results are in accord with those reported by Smedegaard (1962), who observed that in Danish bulls there is a direct correlation between the incidence of pododermatitis circumscripta and increasing body weight. The same results were shown by Modrakowski (1970) in Polish bulls, but this correlation could not be demonstrated in Swedish dairy cows by Andersson and Lundstrom (1981).

The season of the year is an important environmental factor influencing the frequency of pododermatitis. In Holstein-Friesian bulls, a higher rate of pododermatitis is observed in summer and at the beginning of autumn, when the warmer weather favours the development of a bacterial flora and enzymatic process of keratolysis. In Brown Swiss bulls, the summer season increases the appearance of pododermatitis; it's seasonal incidence must be an important primary environmental effect.

The results on the influence of butterfat yield of dams which bred bulls show that selection of bulls based on milk yield of dams in the Brown Swiss breed is a risk factor in their male descendants as the butterfat yield of their dams increases to 300 kg. In Holstein-Friesian bulls this relation is not linear, maximum risk occurring in dams with a 250-300 kg butterfat yield; however the number of dams with butterfat yield over 400 kg is too small for statistical analysis.

The sire selection for all AI bulls represents a risk factor for producing pododermatitis, shown by high incidents in bulls under 3 years of age and with the body weight under 500 kg. It is clear from Table 6 that hyperplasia interdigitalis is a risk factor, 80% of affected bulls having interdigital hyperplasia in their antecedency. Probably, the bacterial flora associated with macerated and infected lesions of hyperplasia interdigitalis as well as their toxins absorbed into the local blood circulation of the feet, are favourable factors for the development of lesions characteristic of pododermatitis.

Several authors have identified factors in the etiology of pododermatitis circumscripta:

1) circulatory and metabolic disturbances from pododermatitis aseptica diffusa that precedes the pododermatitis circumscripta;

2) local ischaemia;

3) local haematoma followed by necrosis and infection with *Fusebacterium necrophorum* or *Corynebacterium pyogenes* interrupting the continuity of the sole horn (Weaver, 1975; Nilsson, 1978; Toussaint Raven, 1978).

Conclusions

In those bulls studied, the appearance of pododermatitis is favoured by factors as: age, body weight, season, coexistence of interdigital hyperplasia, the butterfat yield of the dam and the presence of pododermatitis lesions in the sire.

References

1.Andersson L. , Lundstrom K. (1980) The influence of breed, age and season on digital diseases in diseases in Swedish dairy cows. Third International Symposium on Disorders of the Ruminant Digit, Vienna, 62-75.

2.Andersson L., Lundstrom K. (1981) The influence of breed, age, body weight and season on digital diseases and hoof size in dairy cows. Zbl. Vet. Med. A **28**, 141-151.
3.Berger G. (1977) Gliedmasson und Klauengesundheit von Rindern unterschiedlicher Herkunft in industremassig produzerenden Milchviehalangen. Mh. Vet. Med. **32**, 683-684.
4.Cirlan M. (1982a) Influenta facteriler genetici si epizootologici asupra incidentei ficului interdigital la taurii felesiti pentru insamintari artificiale. Rev. Crest. Anim. **10**, 36-42.
5.Cirlan M. (1982b) Occurrence of surgical affections in a bull centre for artificial inseminations. Fourth International Symposium on Ruminant Digital Diseases, Alfert, France.
6.Martig J., Levenberger W.P., Dozzi M. (1980) Quality and alterations of bovine claws as a function of different variables. Third International Symposium on Disorders of the Ruminant Digit, Vienna, 40-45.
7.Modrakowski A. (1978) Some aspects of the incidence of pododermatitis circumscripta in bulls kept at insemination centres. Second Symposium on Bovine Digital Diseases, Skara, 96-102.
8.Nilsson S.A. (1978) Bovine laminitis and sequellae of it. Second Symposium on Bovine Digital Disease, Skara, 75-83.
9.Smedegaard H.H. (1962) Ulceration of the sole in the bull and it's relation to the circumference of the shin bone. Proc. Nord. Vet. Cong., 385-392.
10.Toussaint Raven E. (1973) Lameness in cattle and foot care. Neth. J. Vet. Sci. **5**, 105-111.
11.Toussaint Raven E. (1978) Influence of bacterial invasion into the epidermis on horn formation. Second Symposium on Bovine Digital Diseases, Skara, 29-30.
12.Weaver A.D. (1975) Ulceration of the sole in cattle, Vet. Rec. **96**, 381-382.

Radiological Researches on the Phalangeal Changes in Pododermatitis Circumscripta in Cattle

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Introduction

Pododermatitis circumscripta (Rusterholz ulcer) is an important disorder of the digit in cattle, because of its frequency of occurrence and progressive nature of the pathology (1,3,4,7,8,9,11,15). Controversy remains regarding the part played by alterations in bone structure of the hind phalanx and deep flexor tendon, despite papers being published about its aetiopathogenesis (5,6,10,12,13,14,15,16,17).

This paper presents results of a radiological investigation into cows with solar ulcer (pododermatitis circumscripta) where dynamic bone structure was altered.

Materials and method

Solar ulcer (pododermatitis circumscripta) was diagnosed in the early stage of disease in 30 Holstein-Friesian cows. Every case was followed up for a period of three years using clinical and radiological examination.

Lateral radiographs were taken with a TUR D-36 X-ray machine using Azoix Safety Film, placed in the interdigital space; consecutive films taken after different periods of time were compared with those taken of the normal digit.

Foot trimming and correct surgical treatment was carried out on all the cows before the radiological examination. In two cases with necrosis of the plantar aponeurosis, tendon resection was performed.

Results and Discussion

Radiological examinations showed early lesions of solar ulceration that are not preceded or accompanied by alterations in bone structure of the hind phalanx. Analysis of the evolution of these cases and correlation of the lesions with radiographic changes show that the bone lesions, characterised by periostal reaction, osteolysis and osteophitosis develop progressively; this is due, either to the persistence of the external lesion, or as a result of the extension of aseptic and septic complications, described in Table 1.

Table 1:
Radiographic changes in phalanges and correlation with development of lesions associated with pododermititis circumscripta.

Evolutive stage	Number of cases	Bone alteration of the third phalanx at the radiological examination.	Figure
Incipient pododermitis circumscripta.	30	missing	2A &2C
From which: with primary healing in 3-4 weeks after the treatment.	6	missing at two years from the beginning.	2B
with tardy healing in 2-3 months and alteration of the horn of the sole.	12	moderate periostal reaction at two years from the beginning.	2D
with recurrence at 6-12 months.	5	reduced exostosis at the insertion of the plantar aponeurosis at 1-2 years from the beginning.	5A
		voluminous exostosis discovered at 3 years from the beginning.	5B
with chronic evolution.	4	moderate osteolysis of the posterior limit of the phalanx and of the distal sesamoid at 2 years from the beginning.	3A & 3B
with chronic evolution and necrosis of the plantar aponeurosis.	1	pronounced osteolysis with calcification (reformed animal) at 2 years from the beginning.	6A & 6B
	2	exostosis at the insertion of the plantar aponeurosis, ossifying of the adjacent scar structures at 2 years after the surgical treatment of resection of the plantar aponeurosis.	7A & 7B

After considering previous descriptions of the aetiopathogenesis of pododermatitis circumscripta (2,3,4,5,8,10,12,16,17) we consider that the main lesion is caused by overloading of the central zone of the sole; this originates from turning up of the solar edge of the abaxial wall, because growth rate exceeds the spontaneous abrasion rate. The effective support surface on the sole is reduced, limiting itself to a circumscribed zone in the centre, compressing the vascularised, deep tissues (corium) and thereby causing ischaemia that, in time, will lead to the cessation of keratogenesis on this well-circumscribed area and the appearance of the pododermatitis circumscripta.

This opinion is based on the fact that in cases of incipient pododermatitis circumscripta, where excess horn has been removed by corrective trimming, and extending the support area over the whole sole, so that pressure is evenly distributed between the two digits, healing occurs despite the permanent radiological changes to the periosteum of the hind phalanx (Fig. 2a and B). This fact refutes the theory that position of the limbs (3,4,15) and exostoses (3,5,12,13,14,15) are important factors in the aetiopathogenesis of pododermatitis circumscripta.

In conclusion the radiological researches undertaken in 30 cows with pododermatitis circumscripta show that changes in bone appear late and are characterised by periostitis in the case of late healing (Fig. 2d and 4b) and by osteolysis with calcification and osteophysis (Fig. 5b, 6b and 7b) in the case of the chronic evolutive forms.

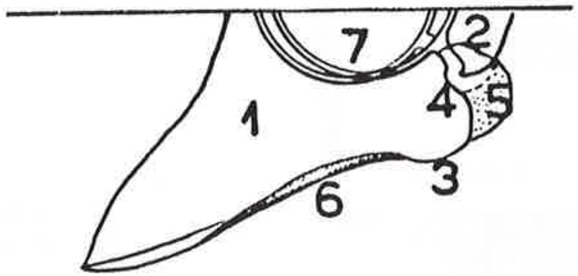

Figure 1. The explanatory sketch of the normal radiographical images.
1. the third phalanx;
2. the distal sesamoid;
3. The plantar tuberosity;
4. the plantar limit of the third phalanx;
5. the volar process ;
6. the plantar arch;
7. the second phalanx.

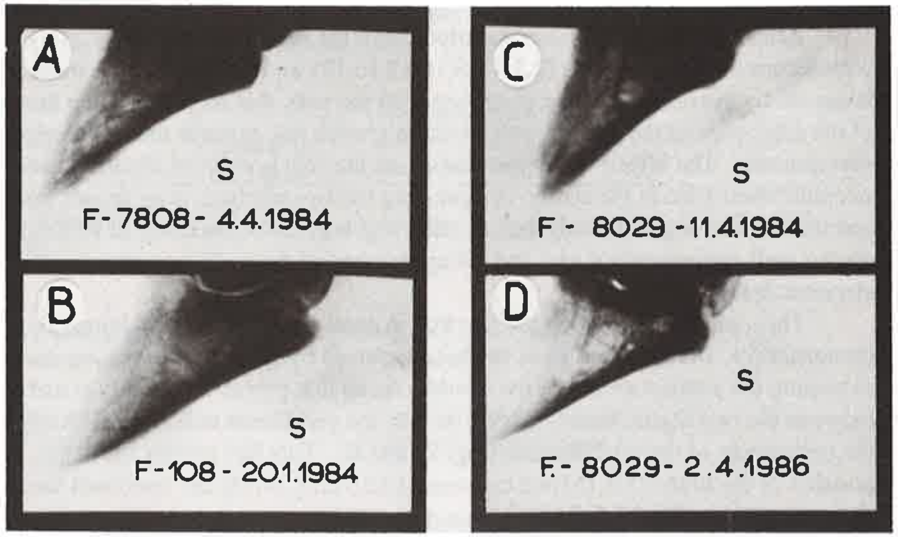

Figure 2. Radiological aspects of the phalanx in incipient pododermatis circumscripta (A and B) and after primary (C) and late (D) healing

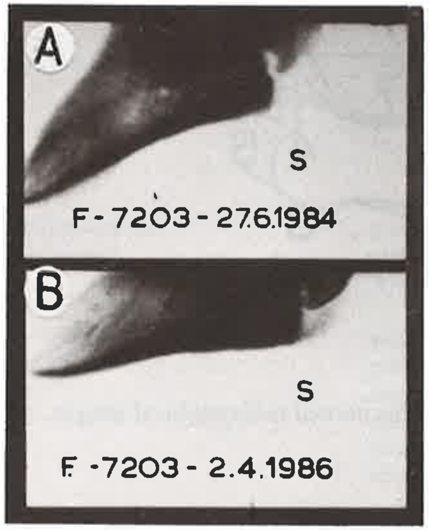

Figure 3.
Moderate osteolysis of the posterior edge of the phalanx and of the distal sesamoid (A-at two years from the beginning; B-at four years from the beginning) in pododermatitis circumscripta with chronic evolution without complications.

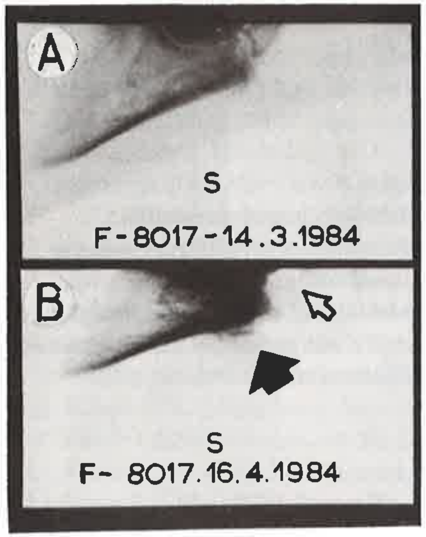

Figure 4.
Bone alterations in the chronic recurrent pododermatits (A-after apparent healing, with scar rests of the horn of the sole; B-reduced exostosis at the insertion of the plantar aponeurosis at one year from the beginning and at one month from recurrence).

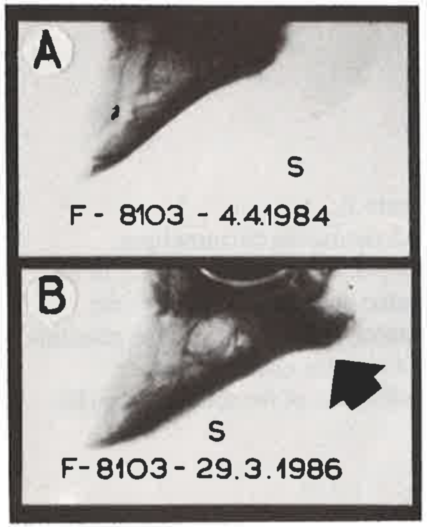

Figure 5
Reduced exostosis at the insertion of the plantar aponeurosis in the recurrent pododermatitis circumscripta after one year after the beginning (A) with the forming at three years of a voluminous exostosis.

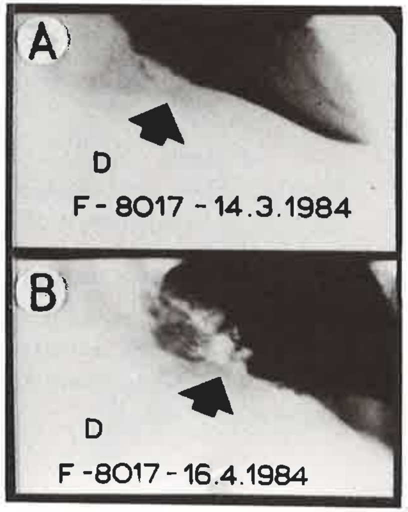

Figure 6
Osteolysis in pododermatitis circumscripta complicated with the necrosis of the plantar aponeurosis (A) evolving with severe osteolysis of the phalanx and of the distal sesamoid (B) after a month.

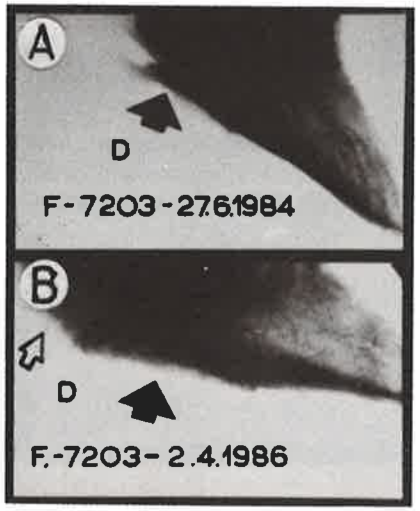

Figure 7.
Pododermatitis circumscripta complicated with the necrosis of the plantar aponeurosis (A) with the forming after two years after resection of a massive exostosis and ossification of the solar surface (B).

References

1. Arkins S. (1981) Irish Vet. J., 35, 135, 163.
2. Bolte S.,et al (1987) Rev. Zoot si Med. Vet., 11, 23.
3. Cristea I. (1983) Bolile aparatului locomotor la animalele de ferma, Ed. Ceres, Bucuresti, 156-162.
4. Greenough P.R., MacCallum F.J., Weaver A.D. (1983) Les boiteries des bovins, Ed. Le Point Veterinaire, 177-185.
5. Gunther M. (1979) Klauenkrankheiten, Ed. Gustav Fischer, Jena, 70-77.
6. Koch L. (1978) Inaugural dissert., Fachbereich Tiermedizin Munchen. 48.
7. Modrakowski A. (1978) Individual dissertation, Skara.
9. Moga M.R., Moldovan M., Vintila Cornelia (1984) Pododermatitele infectiose ale rumegatoarelor, Ed. Ceres, Bucuresti, 104-105.
10. Nilson S.A. (1966) Nord. Med. Vet., 18, 241.
11. Prolic I. (1969) Veterinaria 18, 2, 145.
12. Roztocil V. (1961) Veterinarstvi, 16, 6, 450.
13. Russell A.M. (1978) Anim. Dis. Rep., 2, 3, 5, 8.
14. Rusterholz a. (1920) Schw. Arch. Tierheilk., 62, 421.
15. Silbersiepe P. si col. (1965) Lehrbuch der speziellen Chirurgie fur Tierarzte und Studierende, Enke, Stuttgart.
16. Weaver A.D. (1975) Vet. Rec. 96, 381.
17. Zantiga J.W. (1973) Neth. Sci. Journal , 5 88.

The Cow and her Cubicle

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When cubicles were first introduced during the early sixties as a way of loose housing cows, they were known as "comfort stalls". Since that time, design has been influenced by factors of cost, slurry control, and labour economy to produce what might better be described as "convenience stalls". Cubicles are now a cheap means of loose housing high density herds often with scant regard for comfort or welfare. It is suggested that the majority of cows merely tolerate them, and many suffer stress and injury as a result of being confined to them. Abnormal lying, rising and standing positions can be observed in most cubicle sheds. Resultant veterinary conditions which manifest themselves in the cow include stiffness, lameness, enlarged infected hocks, swollen knees and damaged hips. In addition, once cows lie down in cubicles their body movement is so restricted that rumen hypomotility occurs and normal rumination cannot proceed. Forced by discomfort, the cow is forced to stand up.

What has happened to the original comfort stalls and why are we having these problems? First we must accept that cows have become much bigger through change of breed and breeding policy during the last 25 years. The average Holstein/Friesian now measures 2.4m (8ft) from nose to tail. The majority of cubicles are only 2.1m (7ft) in length. The relationship between cow and cubicle size is often aggravated by the imposition of head rails, which further reduce the space available. It is virtually impossible for large cows to stand normally with four feet on the cubicle bed. Lying and rising become difficult and it is often in the effort of rising that litter is removed from concrete beds. It is the absence or paucity of bedding which causes the big hocks. They are virtually bed sores which become infected.

Short cubicles can be acceptable if they are formed with box manure topped with straw, as happened in the early days. Unfortunately the increasing incidence of environmental mastitis has forced many farmers to reduce the challenge of infection by replacing the soft bedding with concrete. At first a lip was provided to retain some measure of bedding but it was soon discovered that this also retained urine and milk and aggravated infection. The lip was consequently abandoned.

Old railway sleepers were often used as a base to construct the solid concrete beds. This resulted in 25 5 cm (10") heel steps. To save labour and also reduce the challenge of infection from dirty passageways, automatic slurry scrapers gained popularity and because they could not cope with straw the term "minimal bedding" came into use. Scrapers demanded sawdust or limited quantities of chopped straw. Thus we have arrived with our current welfare problems. What is the answer? Briefly we must accept that the modern cow demands a larger bed. This means a cubicle 1.2m

(4ft) wide and at last 2.4m (8ft) long with a brisket board to position her correctly on the bed. The cow also demands and has a right to a soft, clean bed which will not cause her injury or distress. In most cases this means using larger quantities of bedding than is in current practice. This is particularly true where straw is used on a flat concrete base. In order to prevent unnecessary pressure being exerted on the back feet the step onto the beds should never exceed 15 cm (6")

The basic needs of the cow are

i) to be able to lie down and rest comfortably for as long as she wishes

ii) to get up and stand without stress or difficulty.

They ought to be the deciding factors when designing cubicle accommodation. All too often cubicle construction has been determined by cost, size of the building available, and bedding by the type of slurry system used. The cow's welfare and comfort have come a poor second despite the fact that it is she who generates the capital.

Laminitis in Dairy Cows

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The investigations were directed to the exploration of frequency, etiopathogeny and symptomatology of cow laminitis. Four farms with a total of 1,520 Holstein-Friesian and Brown Swiss dairy cows ageing between 3-8 years were studied. Out of these, 1,130 cows were permanently tied by the neck and 390 were turned out at pasture 4 hours daily from June to October.

The highest incidence of laminitis occurred in cows with permanent neck ties. Localisation was most frequently in the medial hind claw.

In the etiopathogeny of laminitis the authors established that a most important cause is nutrition. The nutrition factors can be listed - overeating of cereals, low crude fibre proportion, unmatured barley, cereals, hay infested by fungi and pesticides, sudden access to abundant vegetation and an abrupt change of rations. Other factors such as gestation, trauma and infections are also important.

Authors ascertained that etiopathogenetically the laminitis might be classified as - traumatic, alimentary, toxic, pregnancy and symptomatic.

The authors described four clinical forms of laminitis - acute, subacute, subclinic and chronic.