Management and Housing Factors Affecting Feet and Leg Soundness in Dairy Cattle

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Modern dairy cattle evolved over the centuries as creatures of the fields and pastures. When cattle were confined, they were kept on dirt or on copius amounts of soft bedding. Under such conditions, the dairy farmer's chief complaint about the feet and legs of cattle was that their hooves did not wear properly. Over the years, a fundamental change in the housing of cattle evolved: the confinement of cows in stanchion barns through the winter months. Adequate bedding was usually available, and cows' hooves did not come into direct contact with the hard, bare concrete much of the time. In summer cows were primarily kept on pasture, and major foot and leg problems were seldom encountered.

A further major change in housing has developed in the past twenty-five years. Free stalls were developed to reduce the dual problems of loose housing: dirty cows and the need for large amounts of bedding. It was only a short time before additional steps were taken: to confine cows year-round on scraped or washed concrete; to give them only free stalls (and often cramped ones at that) with minimum bedding or artificial surfaces to lie on; and to feed them a large amount of grain and other concentrates with little or no pasture and long hay. The floor surfaces also stayed wet almost all the time, and the cow's exercise was minimal. In addition, new concrete, given a rough finish to reduce slipperiness, was extremely abrasive to hooves. Cows moved into a new dairy barn encounter a number of changes: a different diet, more wetness, space less desirable for lying in, less exercise, a harder floor surface. Many cows under these circumstances develop foot and leg problems, and many dairy farmers tend to blame these problems solely on the new, hard floor. We would like to suggest that, while the floor surface must be considered, many other factors contribute significantly to foot and leg disorders and must not be neglected.

Abrasiveness of different surfaces.

The classic experiment on the abrasiveness of different floor surfaces was done by Camara and Gravert (1971). Sixteen different concrete mixtures were tested for abrasiveness on small cubes of hoof tissue taken from feet of slaughtered animals. Results indicated that a mixture containing crushed hard stone of 5mm and smaller was about twice as abrasive as a mixture containing only sand as the aggregate. Wet concrete was an average of 83% more abrasive than a dry surface for the sixteen mixtures. Amount of cement per cubic meter of mix had no effect on abrasiveness.

Hoof tissues treated with a simulated footbath of formalin before testing wore 6% less than untreated material from the same cow (Camara and Gravert, 1971). Exposing hoof tissue to quicklime before testing resulted in 24% lower wear. *In vivo* results with 29 cows were also positive for all tests, but the amounts of wear were somewhat different.

Comparing abrasiveness of surfaces to hooves of live cows.

Early in our research we found that claw length, heel depth, and angle of the claw at the top provide practical measurements that are useful in evaluating the effects of floor surfaces. All the equipment used was quite inexpensive, and labor requirements were not excessive. To measure abrasion, we made small marks on the hoof wall with a soldering iron and measured from this mark to the coronary band and the end of the claw. As the hoof grew, the mark moved toward the end of the claw. Wear and growth rates could be obtained from repeated measurements over time. Gilmore (1978) compared cows from the same herd, some housed in free stalls with scraped alleys, and others in bedded tie stalls. Cows were assigned randomly to the different types of housing and were fed similarly. Group differences are shown in tables 1 and 2. The two housing systems produced differences ($P<.05$) in angles, lengths, growth, and wear of the outside claw of the rear hoof. There was some evidence of higher growth and wear rates for the front hooves of cows in different housing, but overall changes were certainly less than for the rear foot. Gilmore

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also found a significant interaction of age and housing, older cows showing the least hoof wear. He also observed that hooves of cows in free stalls were wet most of the time, while those in tie stalls were dry.

Concavity of the bottom of the hoof was also measured by Gilmore (1978) in four randomly selected pairs of cows. Those in comfort stalls had twice as much area of concavity as those in free stalls (<.01).

The role of the surface in hoof wear is also illustrated in Gilmore's (1978) comparison of 38 Holsteins housed on rubber mats with their 32 herdmates on bedded concrete. Five months after trimming, those on rubber mats had lower hoof angles and longer hoof lengths (P<.05).

Wear of hooves in three herds fed and managed similarly but confined to different surfaces was studied by Hahn (1979). Wear rates of rear hooves increased as animals spent more time per day on bare concrete (Table 3). For the first few months that cows were confined to the new concrete surface, wear rates exceeded hoof growth rates (Hahn, et al. 1978). The results of this study also showed that the higher wear apparently stimulated an increased growth rate (Table 4).

TABLE 1. Changes in rear hooves over 8-mo. period by housing and breed.[a]

Housing system	N	Breed	Trait: Angle	Length	Growth	Wear
			(degree)	(mm)		
Tie stall	17	Holstein	1	17	34	17
	5	Ayrshire	-1	23	41	18
Free stall	18	Holstein	-3	19	38	20
	4	Ayrshire	-10	27	43	17

a Adapted from Gilmore (1978).

TABLE 2. Estimated changes in front hoof measurements during an 8-mo. period by housing type and breed. [a]

Housing system	N	Breed	Trait: Angle	Length	Growth	Wear
			(degree)	(mm)		
Tie stall	17	Holstein	-.5	19	32	12
	5	Ayrshire	-.5	22	34	12
Free stall	18	Holstein	0	18	34	17
	4	Ayrshire	-1.5	22	39	18

a Adapted from Gilmore (1978).

TABLE 3. Wear of the dorsal or toe surface of outside claws of rear hoof.

	N	1st Lact. Front	1st Lact. Rear	2nd Lact. Front	2nd Lact. Rear
		(mm/mo)			
Principally on dirt	103	4.81	5.13	5.06	4.99
50% on concrete	55	6.38	6.29	5.73	5.30
100% on concrete	81	6.16	6.92	6.82	7.05

TABLE 4. Growth of dorsal or toe surface of outside claws of rear hoof.

	N	1st Lact. Front	1st Lact. Rear	2nd Lact. Front	2nd Lact. Rear
		(mm/mo)			
Principally on dirt	103	5.46	6.20	5.22	5.67
50% on concrete	55	6.43	6.45	6.23	6.45
100% on concrete	81	6.22	7.08	5.91	6.30

The net effects of the varying herd wear rates are illustrated in table 5. The hooves of cows in the herd kept mostly on dirt increased in both first and second lactations. Hooves in the completely confined herd changed little in length during first lactation, but actually wore more than they grew during the second lactation. The effect of concrete surfaces can be seen clearly by comparing growth rates during lactation with rates during the dry period, when all cows in all herds were on dirt or pasture. An obvious conclusion is that cows confined on an abrasive surface during lactation should be placed on dirt or pasture during the dry period to allow for recovery of hoof length.

TABLE 5. Net monthly change (mm/mo.) in claw length for a herd mostly on dirt and one herd completely confined.

	1st lactation	1st dry period	2nd lactation	2nd dry period
	Herd mostly on dirt			
Front	.66	.73	.17	.35
Rear	1.07	.42	.68	.02
	Completely confined			
Front	.07	1.94	-.91	1.51
Rear	.15	.37	-.75	1.00

Data in table 6 show that hoof wear is less than hoof growth in first lactation, but more in second lactation. This rate change may explain the progressive deterioration of feet of older cows housed in confinement. Least squares means for wear and growth by foot and lactation for all cows measured are given in table 7.

Hahn (1979) was also able to measure growth and wear rates on the lateral surface near the rear of the hoof on a

TABLE 6. Comparison of wear and growth (mm/mo.) by lactation in a completely confined herd.

Lactation	Rear Wear	Rear Growth	Front Wear	Front Growth
First	6.93	7.08	6.16	6.23
Second	7.05	6.30	6.82	5.91

TABLE 7. Comparison of toe growth and wear (mm/mo) by hoof and lactation.

Hoof	Wear 1st Lact.	Wear 2nd Lact.	Wear Diff.	Growth 1st Lact.	Growth 2nd Lact.	Growth Diff.
Front	5.78	5.83	ns	6.04	5.78	ns
Rear	6.11	5.77	*	6.58	6.11	**
Diff.	**	ns		**	ns	

*P<.05; **P<.01.

subset of the cows mentioned in earlier tables. His results show that the rear of the hoof is more dynamic than the toe, but he found that data on the rear of the hoof were much harder to obtain because of less precise measurements and loss of reference marks. A comparison of the growth at two sites on the hooves of the confined herd with the herd on dirt (Table 8) shows some interesting interactions. Wear on the toe surface was about 30% greater for cows on concrete than on dirt. On the lateral xxx qces differences were less than 20%. This differential change may be the source of the "turning under" of lateral hoof walls often seen in confined herds. Data for all herds are in Table 8.

Hahn (1979) found that the hoof growth cycle paralleled the hair growth cycle. Rates of hoof growth were highest in spring and summer; they decreased in the fall and became quite low in the winter. These seasonal differences suggest that abrasive surfaces will have more effect on hooves in winter than at other times of the year.

Hoof wear rate is highest in early lactation.

Hahn (1979) found that the wear rates of hooves of cows confined on concrete were highest in early lactation, decreasing linearly with advancing days in milk. Wear rates were higher for cows in early first lactation than for those in the early stages of second lactation.

Effect of housing type on feet and legs.

Reports on the effects of housing types on incidence of foot and leg disorders or hoof deformations are contradictory. In the United States, more problems have been found in free stalls than in tie stalls (Keown and McDaniel, 1979, unpublished; Hahn, 1979; Gilmore, 1979); in Europe free stalls have been reported to be easier on cows' feet and legs than tie stalls (Grommers, 1968; Peterse, 1980; Nygaard, 1979; Gjestang et al., 1979). It is likely that indirect effects such as diet and wetness are responsible for the differences; most herds in Europe with free stalls have not had their rations changed extensively and have slatted rather than scraped floors. Diets in most herds studied in free stalls in the U.S. were based on corn silage and a high percentage of concentrates.

A survey of over 1700 herds in the northeastern United States (Keown and McDaniel, 1978, unpublished) found that more major foot and leg problems were reported in herds having free stalls than in those with tie stalls or stanchions (Table 10).

TABLE 8. Comparison of wear and growth in first lactation at two places on hooves of cows on different surfaces.

Trait	Hoof	Herd On dirt	Herd On concrete	% difference
		Toe Surface		
Wear	Front	4.81	6.16	28**
	Rear	5.13	6.92	35**
Growth	Front	5.46	6.22	14**
	Rear	6.20	7.08	14**
		Lateral surface in front of heel		
Wear	Front	5.70	6.60	16*
	Rear	6.30	7.47	19**
Growth	Front	5.91	7.67	30**
	Rear	6.98	8.34	20**

*P<.05; **P<.01.

TABLE 9. Comparison of wear and growth (mm/mo) at two sites on a hoof in first lactation. [a]

Hoof	Wear Toe	Wear Wall near Heel	Wear Diff.	Growth Toe	Growth Wall near Heel	Growth Diff.
Front	5.78	6.48	**	6.04	7.31	**
Rear	6.11	6.93	**	6.58	7.84	**
Diff.	**	*		**	*	

[a] Tables 3, 4, 5, 6, 7, 8, and 9 adapted from Hahn, (1979).
*P<.05; **P<.01.

A higher percentage of herds in stanchions and tie stalls reported no problems with feet and legs. Subjective judgements of mobility (Table 11) suggested more normal mobility for cows in comfort stalls than for those in free stalls (Gilmore, 1979a). Incidence of severe lameness did not differ by housing systems. In another study Gilmore (1979b) found that cows in Vermont in herds having tie stalls had

TABLE 10. Incidence of herds reporting feet and legs to be a major problem by housing type. [a]

Housing Type	Major problems with: Feet	Legs
	(%)	
Free stalls	43	24
Stanchions	29	19
Tie stalls	31	20

[a] Adapted from Keown and McDaniel, 1978, unpublished.

TABLE 11. Percentage of cows showing normal mobility by age and housing system. [a]

	% normal by age		Number scored	
Housing system	Young	Old	Young	Old
Comfort stall	81	64	129	62
Free stall	66	58	293	174

[a] Adapted from Gilmore (1979a).

TABLE 12. Relationships of housing type and sole lesions in Dutch herds. [a]

Housing type	Number of cows	Degree of sole lesions 0	1	2	3
		(%)			
Large samples of herds					
Tie stall	230	30	36	22	12
Tie stall w/ liquid manure	122	30	32	22	16
Free stall	148	23	52	19	6
Early sample of herds					
Tie stall	50	10	42	36	12
Free stall w/ slatted floors	34	0	59	26	15
Free stall w/ solid floors	40	3	60	35	13

[a] Adapted from Peterse, 1980.

deeper heels, claws with steeper angles, and shorter hooves ($P<.05$) than those in neighboring herds having free stalls.

One of the first reports comparing health differences in the traditional tie stalls and loose housing was that of Grommers (1968), who studied Dutch herds. He found that cows in tie stalls had more leg problems, mostly bruised knees and hocks. Foot rot was much more common for cows in loose housing and muddy conditions. It was rare in cows grazed and milked on pasture. Ulceration of the sole and other forms of pododermatitis were most common in the herds tied in stalls. Perhaps Grommer's (1968) most interesting finding was that heifers that had been adapted to hard floors before first calving had fewer foot and leg disorders than those not preadapted. Of those that had been preadapted, only 5% had ulceration of the sole during the early part of the first lactation, as compared to 16% among those not preadapted. This early report on the value of preadaptation to hard surfaces is in agreement with the recent observations of many U.S. dairy farmers.

Peterse's (1980) large study in the Netherlands included an intensive look at two samples of herds. The first sample was based on about ten cows in each of fourteen herds; the second examined 1-3 cows in a sample of about 250 herds. Rear feet were picked up, cleaned, and scored for sole lesions several times during the first lactation. In both samples, the degree of sole lesions (rated from 0 to 3) appeared to be no more severe for cows in free stalls than for those in tie stalls (Table 12). Neither feeding nor age of housing was recorded, and it is possible that these variables are confounded with the results. Data in table 13 show that claw deformation was more common in tie stalls than in free stalls in the Netherlands (Peterse, 1980).

Average measurements of hoof traits in the Cornell Teaching and Research Center herd (McDaniel, Hahn, and Slack, 1978, unpublished) are shown by housing subsystem in table 14. This herd underwent twice-yearly foot trimming and daily footbaths containing a copper sulfate solution for the eighteen months prior to measurement. Values for hoof angles and heel depths were the highest we have ever recorded for an entire herd.

Differences among the various housing types in the Cornell herd (adjusted for age, stage of lactation, and sire) are shown in table 15. Although some trends emerged, few of the differences were large enough to rule out the element of chance. Cows on scraped floors consistently showed the best hooves (i.e., steeper angles and deeper heels with no increase in claw length). Claws of cows in tie stalls tended to be shorter than those on slatted floors. The hooves in this herd were quite healthy, suggesting that an excellent care program can result in healthy feet even among cows in complete confinement.

Effects of housing systems on frequency of lame cows in Scotland are shown in table 16. Cows in free stalls had higher incidence of lameness for both Friesians and Ayrshires. Incidence varied between herds: 1-37% in free stalls and 0-25% in loose housing. "Foul of foot" was the main cause of lameness in both systems—66% in free stalls and 62% in loose housing.

Slippery floors.

Concrete alleys in free stall barns tend to become smooth and slippery after a few years if, as is the common practice, they are scraped several times a week. One consequence of this practice is that cows slip, are seriously injured, and have to be sold (Merrill et al., 1977). At the Miner/Cornell Institute, during the third year the barn was in use, three cows had to be sold because of such injuries; in the fourth year, seven cows had to be sold (Merrill et al., 1977). Floors were then roughened by "scrabbling," and in the following two years no cows were lost to injuries resulting from slipping (Merrill et al., 1977). Grooving slippery concrete is also a common practice. No research is available on the efficacy of grooving in reducing slipperiness, but many dairy farmers have indicated that it did reduce slipping in their herds. Although grooving may be expensive, the cumulative loss of cows to slipping injuries is probably more costly.

Length of confinement and incidence of foot and leg problems.

A survey of about 1700 herds in the northeastern United States (Keown and McDaniel, 1978, unpublished) has shown that the incidence of feet and leg problems is increased as duration of confinement increases (Table 16). Fewer completely confined herds report no problems with feet and legs (Table 16). Only small changes were reported in incidence of major problems with reproduction, udders, or disposition in the same study.

The survey showed that the length of confinement was more important for herds in free stalls than for those in other types of housing (Table 18). In the other types of housing, lengthier confinement showed a tendency to create a higher percentage of problems. This trend suggests that the negative effect of hard floor surfaces is cumulative and can be reduced by putting cows on dirt for a few months each year.

TABLE 13. Influence of housing system on claw shape deformations of the hoof (modified from Peterse, p. 83).

Degree of claw deformation	Tie stall	Free stall[a]
	%	
0	33	57
1	37	33
2	29	8
3	3	2

[a] Primarily slatted floors.
P $(X^2) < .01$.

TABLE 14. Unadjusted averages for hoof traits of cows in the Cornell herd on different types of floor surface where hoof trimming and footbaths were routine. [a]

Floor surface	N	Angles	Heel depth	Lengths
		(degrees)	(mm)	(mm)
	First lactation			
Tie stalls	17	55	42	83
Scraped	89	56	48	83
Slatted	16	54	48	84
	Second lactation			
Tie stalls	40	57	45	83
Scraped	16	55	47	85
Slatted	22	53	45	85
	Third lactation			
Tie stalls	39	56	45	84
Scraped	12	56	53	87
Slatted	23	55	46	85

[a] Adapted from McDaniel, Hahn and Slack, 1978, unpublished.

TABLE 15. Least squares differences among rear hooves of cows on different floor surfaces in the Cornell herd. [a]

Housing type	Claw angles, lateral	Heel depth	Claw lengths, lateral
	(degrees)	(mm)	
	First lactation		
Tie stalls	1.8	-5.6*	-3.1
Scraped	2.7	.6	-3.0
Slatted	0	0	0
	Second lactation		
Tie stalls	3.1[b]	.7	- .6
Scraped	1.5	2.7	.1
Slatted	0	0	0
	Third lactation		
Tie stalls	.7	-1.5	-1.0
Scraped	1.1	6.7*	2.1
Slatted	0	0	0

[a] Adapted from McDaniel, Hahn and Slack, 1978, unpublished.
[b] $P<.10$; $*P<.05$.

TABLE 16. Percentage of cows lame by housing system in Scotland [a]

Housing	Numbers: Herds	Numbers: Cows	Breed: Friesian	Breed: Ayshire
Free stall	16	1859	9.3%	4.0%
Loose housing	14	1585	4.2	2.4
Difference			5.1%	1.6%

[a] Modified from: Lameness in Cattle (Bell & Miller 1977).

TABLE 17 Association of length of confinement and degree of reported foot and leg problems. [a]

Degree of confinement	No problem	Major problems
	(%)	
Winter only	14	30
All year	8	44

[a] Table 17 and following table 18 adapted from Keown and McDaniel, 1978, unpublished.

New concrete is especially abrasive

Hahn et al. (1978) found that hooves of all cows confined on a new concrete surface wore more than they grew for the first two months on the new concrete. Owners of the herd studied had not done any special preparation of the surface after the contractor completed it. Observations in England (Eddy, 1977) have also shown a high incidence of lameness in the first two years cows are on new concrete. More recent experiences have shown that dragging a flat concrete block over a new surface for 40 to 50 hours removes a significant amount of the early abrasiveness, which results from the formation of very small projectile-like structures formed during the curing process (H. G. Mullen, personal communication, 1977). The abrasiveness of concrete is reduced over time by scraping and by the freezing-thawing cycle. There is a fine line between concrete that is too abrasive and that which is too slick.

Just looking at the top of hooves is not enough to judge the effect of different floor surfaces.

Many people judge the effect of floor surfaces on feet and legs by simply observing cows as they stand or walk. Our findings and those of Gilmore (1979) are that many short, steeply-angled feet are very worn on the bottom and are completely flat, rather than showing normal concavity. Peterse's (1980) conclusion was that just looking at the side of a hoof was not a substitute for inspecting the bottom for sole lesions. He found a correlation of only .2 between photos of the side and top of hooves and the severity of lesions on the bottom.

Confounding of hard floors, wet hooves, feeding, time lying down, disease and other things.

It is our opinion that hard floors are just one part of many managemental and environmental factors in confinement housing that put high stress on feet and legs. We think that reducing the stresses described below will alleviate (but not eliminate) foot and leg problems for cows spending several hours per day on concrete.

Manage to keep hooves as clean and dry as practical.

Wetness softens the hoof horn and makes it wear more when cows are on concrete which allows organisms causing foot rot to penetrate the horn and thereby weaken it.

Ulcerated sole is rarely seen in animals on pasture or in loose housing. Separation of the effects of wetness and hard surfaces is impossible, as dry concrete is a rarity in most of the U.S. Evidence that the rates of sole ulceration is higher in winter is confounded with less growth of the horn at this time (Hahn 1979).

Ulceration of the sole is more common in cows seen standing with their front feet in the free stall and their rear feet in the alley. Whether this is cause or effect is debatable. Some think such posture is a cause, while others think it occurs after the ulceration. We have verified (Hahn, Wilk, McDaniel, unpublished) Touissant Raven's comment (1973) that such standing is a way a cow can reduce the weight on the rear feet.

Many foot problems start in the first 100 days of the first lactation. Up to 40% of 2-yr olds are so affected. Wear on the sole of the feet of these young cows from wet concrete has been cited as the major cause by some, while others blame heavy feeding of concentrates. Certainly feeding of concentrates is not the entire cause, as up to 40% of 2-yr old Friesians in New Zealand, who do not get concentrates, are affected (Dawes, 1978). Management practices that may reduce this problem are preconditioning heifers to concrete and using a footbath to harden the hoof.

It has been shown by Peterse (1980) and Anderson and Lundstrom (1981) that foot rot decreases the longer cows are on pasture after being confined. Although the agents causing the decrease are not known, we have observed that hooves of cows on pasture are both clean and dry most of the time. The hoof bottom is exposed to the sun some of the time. Getting cows off concrete for several hours each day has reduced foot problems for many farmers.

In free stalls, the use of bedding materials such as fine agricultural limestone has also been reported to help. The problem with limestone is that it will clog up most, if not all, liquid manure systems. It clogged our system in less than 6 months. Farmers with systems designed for scraping and hauling may want to consider limestone for bedding.

Many farmers have reported that simply putting cows on pasture during the dry period resulted in a noticeable reduction in foot problems. Others have reduced problems by coupling this practice with careful inspection, trimming, and treatment of hooves just before cows are placed on pasture after drying off.

Feed to reduce laminitis.

Laminitis is a disease that is not well understood, but it can devastate the feet of cows. The resulting damage is apparently irreversible. Cows seem most subject to its ravages in early lactation. Diets that are low in fiber and high in acidity have been reported to increase laminitis. Cows kept on dirt seem to tolerate low-level laminitis without serious hoof problems; however, many foot problems become evident in cows with laminitis in herds completely confined on concrete. We surmise that fresh cows, and especially heifers, will have less laminitis if they are gradually placed on high-energy rations, rather than being placed suddenly on full feed. To our knowledge, research on this hypothesis is not available.

There is a need for sound research on the relation of feeding and foot problems. Many observations are based on herds that have poor housing as well as poor feeding. The high incidence of foot problems in the early part of the first lactation have been blamed on high levels of concentrates.

Yet, similar kinds of foot disorders have been reported from herds in New Zealand (Dawes, 1978) that do not feed concentrates. What is needed to settle this question is to feed a group of first calvers low levels of concentrates for the first 150 days of lactation and compare their hooves to those receiving higher levels of energy.

Hooves of cows can be affected by levels of sulphur or sulphur-bearing amino acids in the ration. Clark and Rakes (1982) found that hooves of cows whose rations were supplemented with methionine hydroxy analog grew faster in the spring and were softer than those of controls. Amino acid composition of the hoof was also changed. Long-term effects of such changes were not reported.

Hooves that show roughening of the wall of the toe or side have probably been affected by some type of laminitis. A single deep groove is more likely the consequence of a health problem than of feeding.

Disease

Foot and leg problems and laminitis have been reported as a consequence of viral diseases such as BVD (Newman, 1976) and Blue tongue (L. Coggins, 1982, personal communication). Many dairy farmers expand their herds by buying cattle when they move into new confinement facilities; perhaps disease problems which are endemic to mixing cows from different herds have contributed to foot and leg problems. The development of a preventive vaccination program in consultation with a veterinarian is mandatory for reducing foot and leg problems.

Time spent lying down.

It is common knowledge that cows will spend more time lying down if a satisfactory area is provided. Some think that less rest predisposes cows to foot problems. Cows apparently lie down more in loose housing than in free stalls. Schmisseur et al. (1966) found that cows spent 12 hr 21 min per day lying if in loose housing compared to 10:40 in free stalls. They also preferred loose housing if given the opportunity (Table 19). Cows preferred semi-open, partitioned stalls facing other cows ($P<.05$). They also preferred 7.5 ft stalls to 6.5 ft stalls. Perhaps reduced cow comfort is one cause of more foot problems in many herds with free stalls.

One early sign of a sore-footed cow is that she is frequently found in the free stall. When turned out on dirt, she also tends to lie down almost immediately. In our visits to herds reporting serious foot problems, we have consistently observed that free stalls were poorly maintained or were not used much by the cows.

Foot baths for cows on hard or abrasive surfaces.

Routine use of foot baths in herbs with a high incidence of foot rot has long been recommended by many researchers.

TABLE 18. Interaction of length of confinement, housing type and incidence of foot and leg problems.

Housing type	Length of confinement	Feet: No problem	Feet: Major problems	Legs: No problem	Legs: Major problems	N
		(%)				
Free stalls	Winter only	16	35	33	18	225
	All year	7	48*	17	29*	249
Stanchions	Winter only	15	28	29	18	477
	All year	8	38ns	33	28ns	40
Tie stalls	Winter only	12	31	27	19	612
	All year	16	35ns	25	22ns	84

*$P<.05$; ns=$P>.05$.

TABLE 19. Preference of cows for loose housing and free stalls.

Previous housing	Preference when had opportunity: Free stall	Loose
Loose housing	2	22
Free stall	10*	10

*7 were observed only once in 14 observations over 10 days.

Studies by Camara and Gravert (1971) indicated that foot baths containing formalin hardened the hoof and made it less subject to abrasion. The same result was obtained by walking cows through quicklime. Casual observation would seem to recommend highly the use of foot baths, but sound research on their effectiveness is quite limited. Table 20 shows the incidence of foot rot in Dutch herds with and without a foot bath. Incidence of foot rot increased with increased time in confinement, despite the use of a foot bath.

We compared two small groups of cows completely confined to concrete for about one year (McDaniel, 1981, unpublished). One group has no foot bath; the other walked through a bath containing copper sulfate after each milking. At the end of the year, four of the original twelve cows without foot baths were still in the herd, and all showed severe foot rot. In the group with foot baths, six cows remained at the end of the year; none showed severe foot rot and three were completely clear. Hoof infection rates did not differ more than could be expected by chance. We now walk all cows through a foot bath after each milking as a routine management procedure.

Gravert (personal communication, 1980) stated that he had not continued research with foot problems because he had observed that daily use of a foot bath containing formalin reduced morbidity to negligibly low levels. The data of Peterse (1980) in Table 20 illustrate the widespread use of foot baths in herds having free stalls in northwestern Europe.

Other researchers are not completely convinced of the benefits of foot baths. In 1980 an experiment was started at the National Institute for Research on Animal Diseases (Compton, Berkshire, U.K.) to test their value (A.M. Russell, personal communication, 1980). A unique aspect of this experiment was that two feet (one front and one rear) of each cow were treated and the other two served as untreated controls, so any differences should be due unquestionably to the foot bath. No results have been published to date. Further evidence favoring foot baths is given in table 21 (McDaniel et al., 1979). Cows in New York herds that routinely used foot baths had deeper heels. Figures showing steeper claw angles and shorter claws are arguable because the herds using foot baths also routinely had their cow's hooves trimmed.

Research on the effectiveness of foot baths containing copper sulphate, formalin, or other agents for cows in confinement is needed under American conditions, as regards both disease control and benefit-cost ratio.

TABLE 20. Effectiveness of a formalin foot bath in preventing foot rot. [a]

Housing	Category	Degree of infection 0	1	2	3	Number of Cows
		(%)				
Tie stall	Foot bath	71	19	10	0	52
	None	49	12	16	3	292
Free stall	Foot Bath	63	35	12	0	133
	None	40	33	27	0	15

[a] Adapted from Peterse (1980), p. 111.

TABLE 21. Averages and ranges between herds that routinely used foot baths and those that did not.

	With copper sulphate $\bar{X}$	Range [a]	No foot bath $\bar{X}$	Range [a]	%Diff.
Heel depth (mm)	48	(46-50)	41	(37-45)	+17%
Angles (degrees)					
Medial	53	(45-57)	40	(33-49)	+33%
Lateral	52	(45-55)	39	(32-48)	+33%
Lengths (mm)					
Medial	84	(82-86)	90	(81-97)	+ 7%
Lateral	86	(84-89)	91	(82-101)	+ 6%

[a] Range between herd averages.

TABLE 22. Incidence of sole lesions by trimming status on 14 commercial farms. [a]

Degree of sole lesion	Trimmed in first lactation 1st lact.	2nd lact.	Not trimmed 1st lact.	2nd lact.
	(%)			
0	5	10	8	14
1	47	50	45	34
2	35	35	33	31
3	13	5	14	22
N	76	59	83	59

[a] Adapted from Peterse (1980), p. 113.
P (χ^2) .05.

Role of hoof trimmings in reducing foot and leg disorders.

Trimming is a widespread practice, but research on quantifying its benefits is very limited. Results of a survey by Peterse (1980) are given in table 22. His evidence shows a beneficial effect of trimming in reducing sole lesions, especially in the second lactation. Rund and Mardon (1981) found a statistically significant positive association between frequency of hoof trimming and milk yield in a large sample of Norwegian herds. Only herd feeding level, sire's breeding value, and relative producing ability of cows culled had more effect on herd average than hoof trimming. Reproduction and milking machine maintenance were less important.

One thing that may help get better hoof management is making farmers more aware of the financial losses from lameness, which are primarily due to:

1. loss of milk yield
2. loss in body weight
3. decreased feet efficiency
4. premature culling
5. costs of treatment by farmer and veterinarian
6. secondary losses such as undetected estrus and subsequent delayed conception.

Also the salvage value of lame cattle is 25% less than that of normal cows (Weaver, 1964).

Recommendations on managerial procedures that will reduce foot leg problems in confinement.

These recommendations are based on our personal opinions formed from visiting a large number of dairy herds, reviewing the available literature, and many discussions with other researchers in the area. They may or may not be correct, but they are used in our research herds. We would greatly appreciate hearing of any research or experience that proves or even suggests that any of them should be reevaluated.

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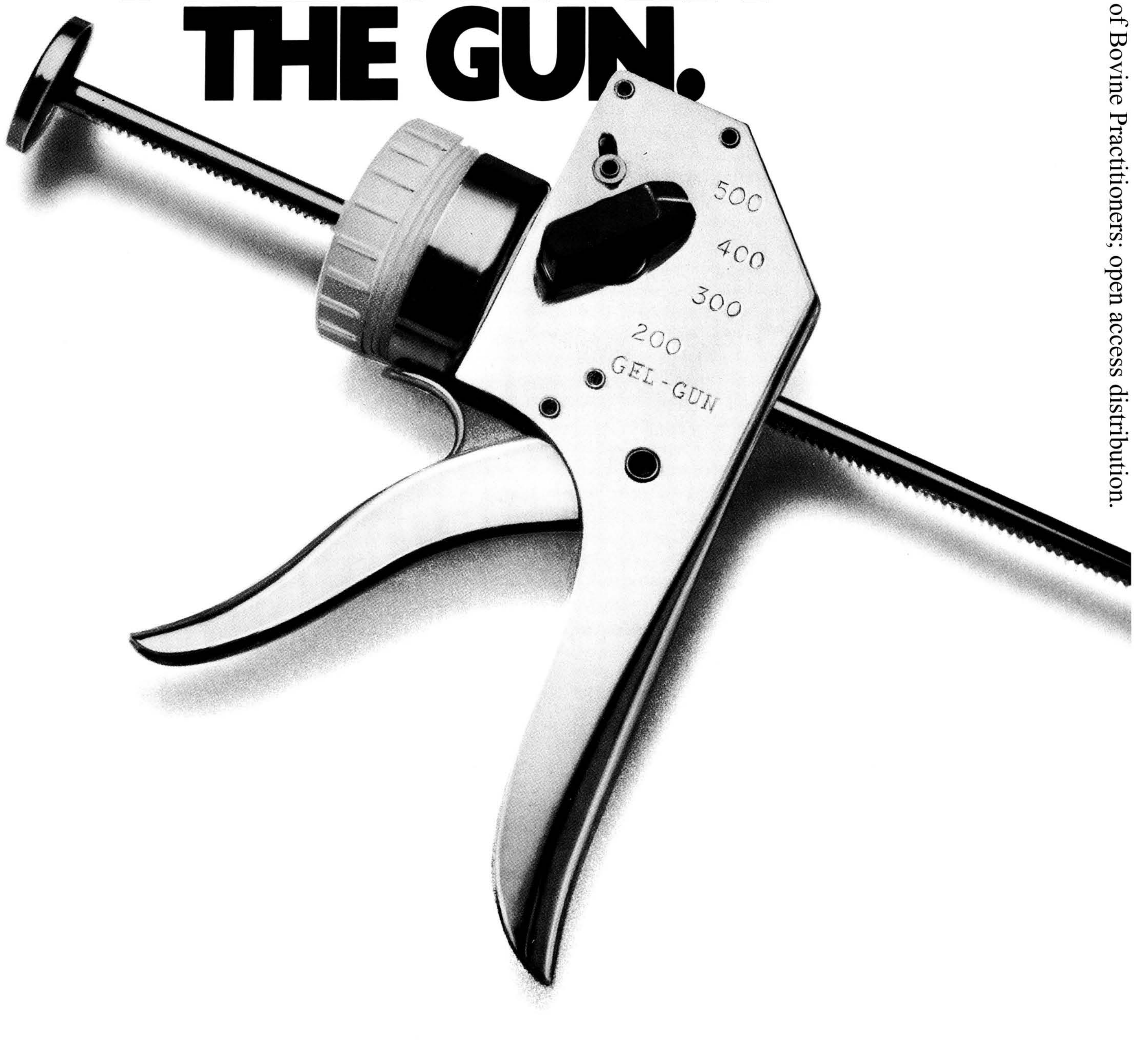

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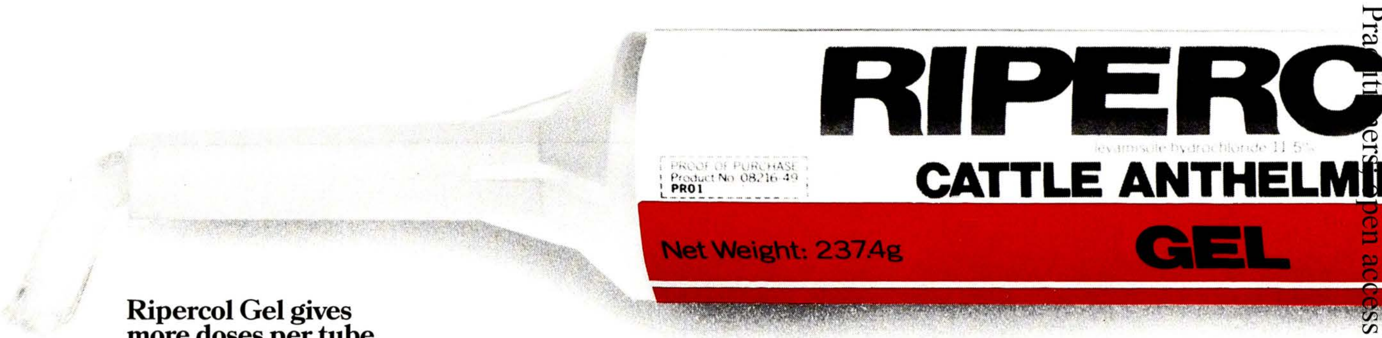

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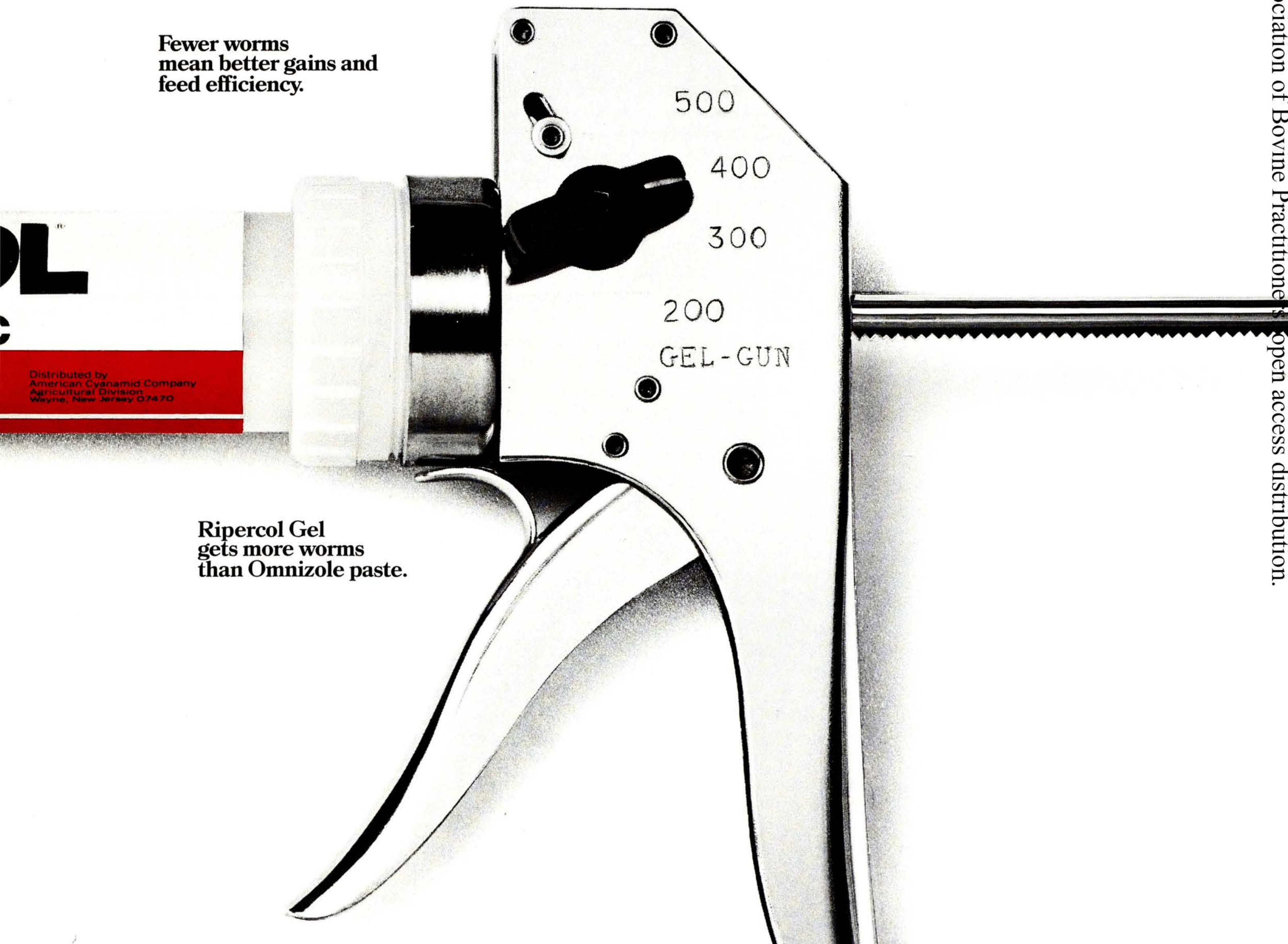

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1. Reduce abrasiveness of new concrete before placing cows on it.
2. Reduce slipperiness of old concrete by "scrabbling" or grooving. Move cows slowly on wet concrete to minimize slipping and falling.
3. Keep cows on dirt as much as practical, preferably some time every day.
4. Keep dry cows on pasture or dirt lots and separate them from the milking herd.
5. Preadapt heifers to concrete and use of free stalls before they calve, preferably at breeding age and again in late dry period.
6. Use a **clean** foot bath containing a copper sulphate or formalin solution daily.
7. Feed all cows a ration balanced for all nutrients and fiber based on feed analysis.
8. Practice preventive medicine to reduce viral diseases.
9. Have free stalls that cows **like** to lie in and keep the stalls dry and smooth.
10. Change cows gradually from a low-energy dry cow ration to a high-energy milking cow ration.
11. Handle first calvers carefully during the first 60 days after calving.
12. Routinely trim, inspect, or treat problem feet or lame cows.
13. Practice a routine inspection of each cow's feet about twice a year when foot problems are present.
14. Inspect feet of cows when they are dried off, especially any that have had foot or leg problems during the lactation or have abnormally shaped feet.
15. Inspect the bottom of hooves closely. Upon picking up the feet, many "normal-looking" hooves are found to have bad spots, heel erosion, or severe wear.
16. Where practicable, move into new facilities in the spring, since hoof growth rates are highest then.

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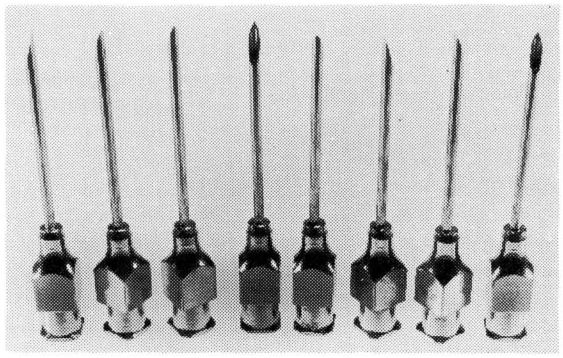

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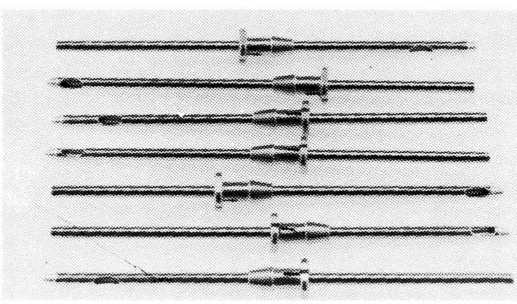

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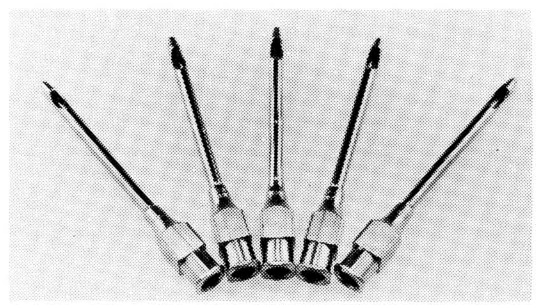

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