HOOF HEALTH: MANAGING COW COMFORT TO REDUCE LAMENESS

James E. Nocek, Ph.D.
Biovance Technology, Omaha, NE

INTRODUCTION

A cow's foot is a unique appendage that has a specific anatomical structure related to a specific function: locomotion. The way in which these structures are organized and/or disorganized can be a barometer to many management practices that either have an internal or external affect on the foot structure. Because of the risks of adverse environmental conditions for several months of the year, confined housing has become a necessary component of properly managing high-producing dairy cows: that means stalls and concrete. Usually there are 10-30% more cows than stalls, and their ability to maximize dry matter is associated with their drive to find limited available bunk space. Offering cows the comfort of their natural habitat without predators and ad libitum access to high quality feed are critical to maximizing profitability. The objective of this paper is to:

1) Characterize the structure and function of the bovine foot,
2) Identify specific cow comfort issues relating to freestalls, stall surfaces, and feedbunks, and
3) Conform housing to fit the cow and her *normal behavior* to maximize cow comfort, performance, and profitability.

FOOT STRUCTURE AND FUNCTION

Lameness could be well defined as a clinical end result of an acute and/or series of subclinical insults, which has negatively influenced hoof structure and therefore, function. However, before we can truly understand the implication of structure, function, and how to better manage the environment to enhance performance, we must first understand the basic structure of the foot.

Basic Structural Components

In its simplest form there are three basic structural components to the foot: bone, corium, and epidermis. The foot is comprised of two digits. The end of each digit is surrounded by a horned capsule often referred to as the claw. Two specific bones within the inside distal digital area are the distal phalanx (pedal bone) and navicular bone. Corium is a tissue that surrounds the bone in each digit. It's comprised of connective tissues, blood vessels, and nerves. There are four specific regions of the corium (dermis) which include the:

1) Perioplic (heel) corium,
2) Coronary corium,
3) Sensitive laminae corium, and
4) Solar corium.

The horn tissue extends beyond the corium and is called the epidermis (Raven 1985).

The epidermis is produced by the dermis (corium). There are four horn producing regions in the corium, which correspond to the four regions of the corium previously mentioned. Each of the specific corium regions produces the specific horn that creates the protection for that area. The epidermis is produced by what are called dermal papillae associated with the corium. The papillae are arranged in a tubular fashion of which the blood supply of the corium enters. These dermal papillae (vascular pegs) then produce the horn cells which are extruded from the dermal papillae and organized into what is called tubular horn (van Amstel and Shearer, 1999). Therefore, the dermal papillae originate from the corium blood supply. The capillary structure that resides within the dermal papillae consists of an arterial and venule. This microvascular structure provides oxygen and nutrients to the developing horn tissue. The degree to which these nutrients are supplied will influence horn cell formation and therefore the quality of the protective tissue component. The epidermis is the skin that actually forms the outer protective layer: this tissue is dead. The inner layer or the germinal layer is alive, however, it does not specifically have a direct blood supply. The corium is the organ which contains the blood supply and nerves. Therefore, damage to the epidermis does not cause pain or bleeding; however, when the corium is affected, both pain and/or bleeding can result. If the epidermis is traumatized (concussion, heat, etc.) it can cause a mechanical breakdown of the corium causing bleeding and pain. The inner most part of the epidermis (horn tissue) is the germinal layer. The corium and the germinal layer of the epidermis is partitioned by a *basement membrane*. Nutrients flow from blood vessels in the dermal papillae through the basement membrane and provide nutrients to the germinal layer, which therefore causes growth of horn.

Keratinization and Cornification

Keratin is a *scleroprotein* that is present largely in structures such as nails and horn. This tissue contains relatively large amounts of sulfur containing amino acids (methionine and cystine). The keratinization process involves forming keratin filaments within the cell that act as *scaffolding,* yielding strength and rigidity to the cell. As the filaments move closer to the surface, strength is further enhanced. The degree of keratinization is different at different regions of the horn. The abaxial wall is harder than the solar and heel regions, with the white line being the softest horn. The substance that cements the horn cells together is a lipoprotein material that renders flexibility yet holds water and is permeable. The relative rate of horn formation varies with different regions of the wall; however, an average rate of 5mm per month in the coronary region is fairly typical. Horn strength is dependent on both internal and external factors. Internal factors include blood and/or nutrient supply as compared to external factors, which are associated with the environment. Horn production is dependent upon a good supply of nutrients and oxygen; therefore, the vascular supply is critical to horn quality. Several key nutrients including protein, carbohydrate, fat, calcium, phosphorous, sulfur, and trace elements like zinc, manganese, and biotin are important to bone structure, epithelial growth and maintenance, and the keratinization process.

Two key external factors that influence horn are degree of moisture and concussion. The horn becomes very soft and flexible under conditions of high moisture, however, soft horn is often more susceptible to concussion and penetration of foreign objects. Substances such as manure and urine can destroy the lipoprotein cementing substance around horn cells, which can result in heel erosion.

Weight Bearing

The pedal bone is suspended in the horn capsule by the sensitive lamellae. It is attached mostly at the dorsal and lateral or abaxial wall as opposed to the inside or axial wall. The bovine foot functions to support normal weight bearing. Ideally, the function of weight bearing strives to evenly distribute weight within the claw and equally between claws. The length of the dorsal wall in relation to the thickness of the sole is critical to correct and evenly distributed weight. Possessing a normal dorsal wall length and sole thickness allows the most even distribution of weight bearing forces within the claw; therefore, each stride is evenly cushioned. When the toe becomes long, the sole is thicker, particularly at the toe, thus concentrating more weight towards the heel.

However, when the wall is short and the sole is thin, more weight is borne on the toe, which increases the probability of the formation of toe ulcers. Therefore, the functionally correct foot must bear weight in an evenly distributed manner. This accentuates the need for proper and routine foot trimming. When weight is shifted from one side or the other of the animal, because of injury, concussion, anatomical deformation, etc., the relative internal pressure of the bone on the corium suspended above the solar horn is changed and the opportunity for increased internal destruction of dermal tissue is inevitable. This type of destruction results in hemorrhaging, inflammation, hyperplasia, and hypertrophy of the dermal tissue. This influences horn growth and promotes abnormal epidermal proliferation, further accentuating weight bearing stress. Therefore, environmental factors (including concrete, stall bases, partitions) which cause injury, increase concussion, and/or weight bearing on the digit needs to be minimized.

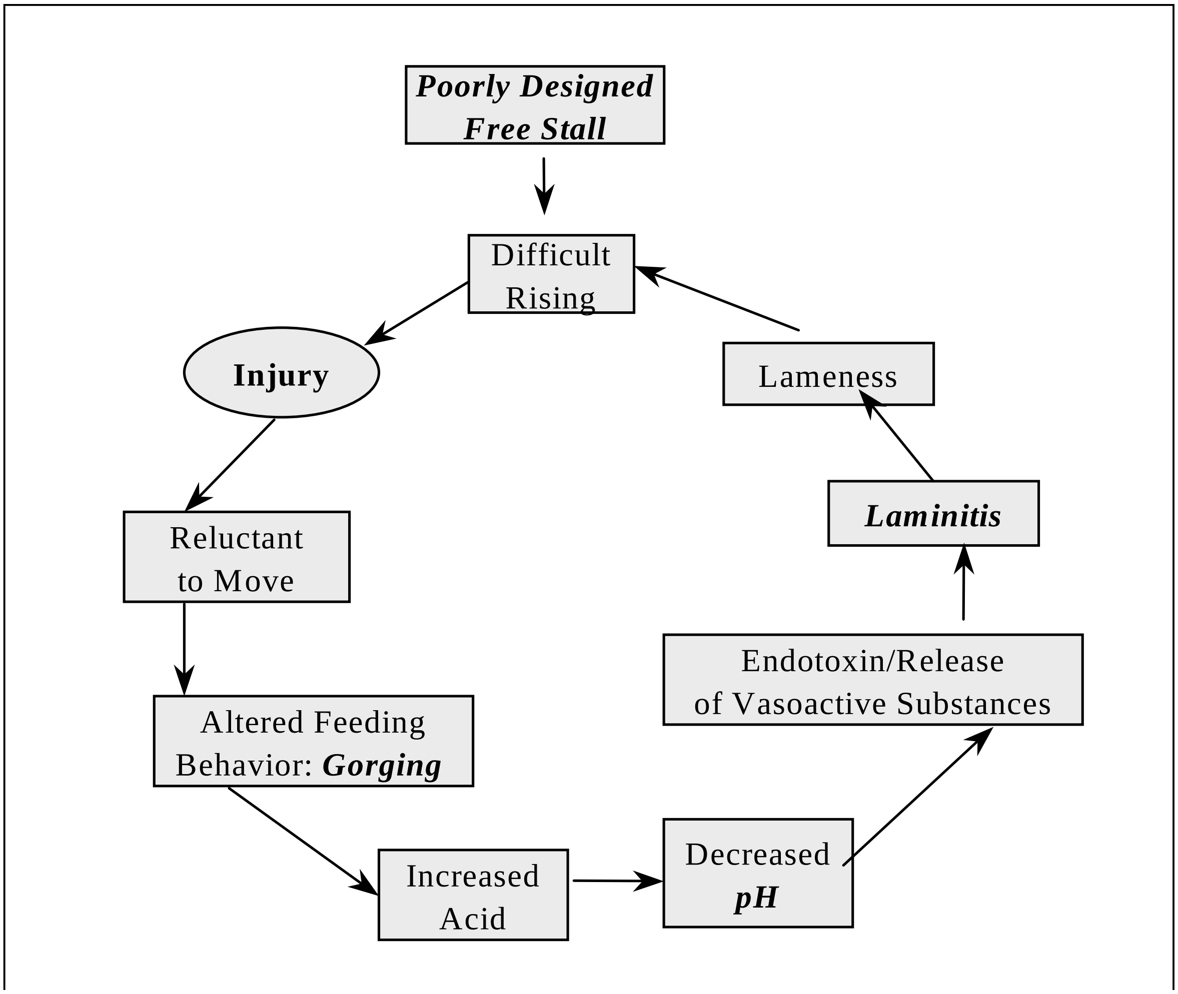

Figure 1: Implication of Free Stall Design on Lameness

FREESTALL DESIGN

Partitions

Key considerations in the design of a freestall are to study and understand the behavior of the cow in relation to her rising and lying behaviors. The partition should allow very little interference with the animal and her activities and should promote cleanliness. The animal must:

1) Enter and leave the stall easily,
2) Lay down and rise without interference from the partitions and other animals, and
3) Stand or lie in the stall comfortably.

The natural rising behavior of a cow was studied by Irish and Merrill, 1986. During the initial stages, the cow transfers her weight forward, or lunges to facilitate shifting her weight. This weight transfer then allows her to use her knees to act as a fulcrum. Less weight is placed on the hindquarters, which allows her to rise rear first. When stable on her back legs she then stands on each front leg separately. There are two general types of problems associated with freestall designs which have significant implications on the animal: 1) mechanical-physical (injuries and traumatization) and 2) animal behavior: her ability to position herself in the stall.

Typical injuries and trauma associated with an improper stall design effect several parts of the anatomy. Bruised ribs can develop from the cow striking the lower part of the partition when lying down. Hooks and pins can be severely injured and/or swollen in the same way. Knee injuries result from hard or unbedded brisket boards or stall surfaces. Teat injuries can result from narrow stalls or having a short neck rail with no bedding. Swollen hocks are the result of little and/or abrasive bedding as well as short stalls with the hocks lying on the curb with pressure of the animal on the hocks.

The various types of behaviors associated with improper stall design are related to animal positioning in the stall. There are a variety of positions the cow assumes which suggest that the stall design is not conducive to fitting the cow's behavior. When the cow has limited space to lunge, she generally jerks her head up in an attempt to place most of her weight on her forelimbs. She then finds a place to lunge. As you can imagine, it takes much more effort to raise the hindquarters from a forelimb standing position vs. a kneeling position. The result is greater potential for injury. Other abnormal behaviors include lying diagonally in the stall, which usually is associated with a short neck rail. The cow can lie half in the alley and half in the freestall and/or lie completely in the alley, which generally suggests that it is impossible for that animal to utilize the stall. When the stall is too wide, oftentimes cows will turn around in the stall. Standing or lying in the stall for prolonged periods of time is another abnormal behavior which suggests either the stall is too narrow or short.

The relationship between lameness and improperly designed freestalls is obvious when an injury occurs. However, there are other subtle types of subclinical problems that result. Figure 1 illustrates events linking poorly designed freestalls to laminitis and lameness. Initially, the poorly designed freestall caused difficulty in rising, which may result in subtle injuries. The perpetuation of these injuries results in a reluctance of the animal to move. These behaviors alter her feeding behavior, which encourages more *gorging* feeding activity (eating 2 to 3 times per day vs. 10 to 14 times per day). Injured cows generally have prolonged periods of lying and fewer trips to the feedbunk to consume more meals. This type of feeding behavior oftentimes results in increased acid production, which decreases ruminal pH. Decreased ruminal pH results in death of certain types of bacteria which release endotoxins upon their death, ultimately causing release of vaso-active substances such as: histamine and certain types of hormones, etc. It is thought that the vaso-dilation and constriction ultimately results in rupturing of blood vessels, causing lack of oxygen and nutrients to reach the lower extremities of the foot causing a deadening of tissue ultimately resulting in subclinical laminitis (Nocek, 1997). This process over time will cause further lameness, which ultimately accentuates difficulty in rising and standing. Observing these types of injuries, behaviors, and activities need to be part of the daily management program on each farm.

Freestall Length

A cow needs approximately 30% of her body length as a lunge space in order to rise properly. For a mature cow lying down, approximately 27 to 40 inches is required in front of her knees. Therefore, the stall length is proportional to body length (body length + 30%). Since all cows are not equal in body length, it is difficult to identify exactly what the lunge area should be for the average stall. If the largest cow was used as a model, then stalls usually are too big for most. A general rule of thumb is to take the average of the largest 25% of the cows in your herd. For a mature cow, length from the rear of the curb step to the neckrail should be approximately 66 inches, and going to the wall (assuming stalls are not shared head to head), 90 inches is usually adequate.

Freestall Width

When cows are observed lying without partitions, they maintain a minimum space between them. This should be kept in mind when evaluating the width of a freestall design. Minimum space must be kept between cows when lying down at the same time. A study conducted by Matton et al. (1978) indicated that as stall width increased from 41 to 47 inches, lying time within the stall also increased. For a mature cow, approximately 48 inches facilitates lying and rising movements and provides sufficient comfort during normal behavior.

Freestall Curbs

Any type of *slope in* curb or a stall surface that slopes toward the front will force the cow forward. This can reduce lunge space and cause extra effort in rising. The cow should stand on a flat, hard surface in the stall. Even if the curb is sloped in, adequate bedding and/or an appropriate stall surface must provide a flat platform. Otherwise, undue stress is placed on internal aspects of hooves in relationship to the weight-bearing surface. The pins and tailhead should just be over the curb when the cow is lying down. This will enhance cleanliness of the stall. Bedding keepers on the curb are a point of debate. Some feel that it allows the accumulation of manure and organic mater, which serves as a place for pathogens to grow contributing to mastitis. Others have had good success with utilizing bedding keepers in maintaining bedding thickness to reduce hock and hindleg injuries. If they are used, attachment bolts should be rounded and/or sunken so they will not cause additional abrasion to the animals' legs or bottom of the feet.

Freestall Partitions

A critical point of concern on the freestall partition is the dimensions between the stall bed and the lower bar of the partition. If there is too little space or the partition is too low, the cows can lie under the partition and hit their backs. The bottom of the partition should be at the proper height, such that it does not strike the ribs, backbone, or hooks when the cow is lying down. It also should allow for adequate side lunging. The height of the top bar on the platform also dictates the relative height of the neck rail. For a mature cow, the height should be approximately 48 inches. Neck rails restrict forward movement into the stall. If the partition is too low, then the neck rail is a hindrance to cows during the rising movement. The distance from the neck rail to the front of the stall should be approximately 22 to 24 inches. Sometimes, brisket boards are utilized and serve the same purpose as neck rails. The brisket boards should make up approximately 25% of the stall length from the front of the stall.

Freestall Surface Materials

When planning freestall surfaces there are several critical factors that must be considered. The surface must be durable and easily maintained. They must be well drained and/or resilient to water. It should not be slippery, and footing should be adequate to prevent potential injury. The flooring should be soft and comfortable, not hard, cold, and damp. The surface should be made of inert material, if possible, so pathogenic organisms will not grow. Finally, the cost of the surface has to be considered in relation to the potential of reducing or increasing animal injuries.

Types of Freestall Surfaces

For years earthen filled stalls have been a popular freestall surface. Relatively inexpensive however, they require a significant amount of maintenance. Cows tend to burrow holes in the front of the freestall and this throws the cow forward. Animals can be easily lodged in the front part of stalls with earthen surfaces. Concrete is another commonly used surface; however, it is more expensive and can be cold, wet, and abrasive if adequate bedding is not utilized. Rubber mats embedded into the concrete can offer a softer surface than concrete; however, they can be slippery and expensive. Whole rubber tires embedded into earthen filled stalls offer an inexpensive means of providing a shock absorptive surface, however, they are very difficult to maintain. Cows tend to burrow holes between the tires, and they can accumulate significant amounts of organic matter. Wooden planks can work well as a bedding surface; however, they are relatively expensive, and they will rot over a period of time. The most attractive bedding is sand. It meets all the requirements that should be considered in appropriate freestall surfaces. However, a major challenge associated with sand is its negative effect on many manure systems. In addition, if the sand contains small stones, it can cause stone bruises and actually puncture the bottom of the cow's foot. In the past 10 years, woven polyethylene or polypropylene material has become a popular surface. It can be purchased in long sheets or individual stall dimensions. They are attached to the front of the freestall, and several stalls are filled with either shredded tire material or sawdust to provide a mattress cushion. Individual cow mattresses are also available, which can be filled with a bedding material. The mattresses become easily displaced as cows search for adequate footing. Water mattresses have been used and offer a soft surface, however their cost and longevity have yet to be evaluated.

Criteria for Bedding Materials

Bedding materials must provide comfort and be as inert as possible, non-toxic, non-abrasive, absorptive, dry, readily available, adaptable to manure systems, and cost-effective. The use of no bedding (utilizes the stall surface alone) works well for some stall surfaces (sand). Other surfaces, including rubber mats, may pose a slipping problem. Woven polyethylene has also been utilized with no bedding, with relatively good success; however, it too can be abrasive and slippery. Long or chopped straw is used but is less popular than in the past because it is less absorptive and does not handle well in manure systems. Sawdust is still the major source of bedding material, and comes in the form of dust, chips, and shavings. Sawdust can be kiln dried or green. Shavings and chips can be very abrasive. Green (wet) sawdust can cause mastitis challenges if not handled properly. Composted manure has become increasingly popular. People have used both composted (heated to > 140° F) and non-composted material. Composted manure is non-abrasive and can be an excellent alternative to sawdust if managed properly. Paper products that are shredded, ground, or pulped have increased in popularity as freestall bedding. Shredded paper is generally utilized in maternity and sick-pen areas. Paper pulp material is very soft, inexpensive, and absorbent. When used properly in a freestall, it is an excellent source of bedding. Some people have experienced mastitis challenges with this material. It can become quite saturated quickly if not managed properly.

Feedbunk Design

The most critical objective of any feedbunk design is to aid in maximizing intake. The cow must be comfortable while eating and must not be concerned about slipping. The design must increase accessibility to the feed and should reduce or minimize wastage. When observed in her natural habitat, the cow had been adapted to eating in a grazing position, as in pasture. Studies have shown that cows will eat longer and produce more saliva during the eating process when they are consuming food in a grazing vs. a more horizontal position. However, no indication of how much the cow would eat in these different positions was indicated. When given a choice between ground level or elevated type of feedbunk, cows generally choose the ground level. Ground level feeding also reduces feed tossing and wastage. A bunk surface 4-10 inches higher than the alley surface (foot height) is recommended to increase reach.

Feed Barriers

Feed barriers are designed to restrain the animal from the feed and allow comfortable access to the feed. Also, they should reduce wastage. The types of barriers that have been used in the past include: tombstone barriers, diagonal bar barriers, headlocks, and post and rails. The post and rail barrier is generally the most economical, especially if there is no need to frequently restrain a large number of animals in a given area. If this is an objective, headlocks may be a more feasible alternative, although they are considerably more expensive. If the rail is located on the outside of the post, this can allow cows to reach further into the feed area with less force on the barrier and their necks. Cables can be used quite effectively as barriers; however, if cables are too low they may irritate the cow’s neck.

Other Issues Regarding Feedbunks

Open front, drive through, or fence line feeders are very popular; however, feed must be pushed up to the cows often during the day. Pushing up of the feed redistributes and may stimulate intake and trigger cows to migrate to the feedbunk. The eating surface of the manger should be smooth and easy to clean. High-strength concrete, tile, or vinyl sheets have been used quite effectively for surfaces. Concrete or inlaid tile works best for mechanical push up.

Feedbunk Space

Primary objective is to have adequate feedbunk space so that the cow can conveniently consume 10 to 14 meals per day while she is in the freestall area. If your objective is to have all cows eat at one time; for example, in a four-row freestall barn the plan should include approximately 24 inches per cow at the feedbunk. If your plan is not to have all cows eat at one time, and if you have a six-row barn, the general recommendation is 18 inches per cow. In this type of situation it is particularly important to ensure that edible feed is in the bunk and in front of the cows 24 hours a day. This type of situation also requires increased feed push-up management.

Alley Surfaces

The area on which the cows walk is extremely critical to cow comfort and foot health. Floors should be etched or grooved, and the grooves should be either diamond or square shaped patterns (6 x 6”). The grooves themselves should not be too deep or wide (about .5 inches). Depending upon whether the grooves are placed in at the time concrete is poured or whether they are re-etched, edges should be smooth and caution must be taken to observe the unevenness of the concrete, especially if grooves are made while the concrete is curing. Placement of grooves while the concrete is still wet can cause subtle mounding of concrete. This causes unevenness and potential pressure points on the bottom of the cow's feet. Total implication of this is not fully realized and may be a significant contributor to mechanical lameness, especially after animals have just been trimmed. The use of rubber matting in alleys where cows have to walk and/or stand for long periods of time may help alleviate some concussion to the leg. In feed alleys, four-foot sheets of rubber matting can be placed against the feed alley itself so that all four feet can stand on the matting while eating, or they can be placed approximately two feet away so front feet will be on a concrete surface. The latter situation may help reduce slipping associated with the rubber mats. The best installation procedure is to embed the rubber mat into the concrete as it is being poured. You must continually observe for slipping in matted areas.

Although slatted floors have become quite popular in certain areas of the country and have been utilized quite successfully, I am not convinced that they are the best floor surface for foot health. In observing cows walking on slatted floors, I often notice toes becoming caught in slats, and manure buildup in the wintertime is sometimes difficult to manage. Newly poured concrete can be quite abrasive, as previously mentioned, especially if grooves are being placed during the curing process. There has been some suggestion that curing concrete releases certain chemicals which may have a negative influence on hoof texture. More information is needed to clarify this issue.

Other alley surfaces need to be developed and tested as an alternative to concrete for dairy cattle. They need to provide cushion (shock absorption) and a non-slippery, yet non-abrasive and cost effective surface (i.e. track surfaces, concrete impregnated with certain flexible material).

CONCLUSION

- Observe cows daily and record lameness codes and cow comfort indexes.
- Observe area and stalls where cows *are* and *are not* lying down.
- Critically evaluate the stalls where cows are not lying down and make changes.
- Watch for cow injury patterns.
- Consistent back injuries, hook injuries, and pin injuries can provide significant information regarding stall design.
- Provide plenty of soft, dry bedding!
- Watch for floors with excessive abrasiveness.
- Use of rubber mats in walk alleys may be advantageous to absorb shock; watch for slipping!
- A fence line or drive-through feedbunk with the eating surface at ground level or up to 10 inches above the feet alley is recommended. Ensure that the throat height and neck-rail height are adequate for the cow size that you are feeding.

LITERATURE CITED

Bickert, W. G. 1990. Feed manager and bunk design in dairy feeding systems. Proceedings from the Dairy Feeding Systems Symposium, Harrisburg, Pa., Jan. 10-12, 1990. Northeast Regional Agricultural Engineering of Service-38. pg. 199.

Irish, W. W., and Merrill W. G. 1986. Design parameters for freestalls. Proceedings from the Dairy Freestall Housing Symposium, Harrisburg, Pa., Jan. 15-16, 1986 pg. 45.

Matton, Daelenans, and Lambrecth. 1978. Regional Agricultural Station for Agriculture. Zoological aspects of housing associated with lactating dairy cows.

Nocek, J. E. 1997. Bovine acidosis: implications of laminitis. J. Dairy Sci. 80:1005.

Raven, E.T. 1985. Cattle foot care and claw trimming. Farming Press Books, UK ISBN 0-85236-149-1

van Amstel, S.R. and J.K. Shearer. 1999. Anatomy and Physiology of the Bovine Foot. Hoof Health Conference, Modesto, CA.