DISSERTATION

# SURVEY OF HUSBANDRY, MANAGEMENT, HOUSING, LEG LESIONS, HYGIENE, PRODUCTION, ECONOMICS, AND COW BEHAVIOR, ON 113 COMMERCIAL U.S. DAIRIES

Submitted by:

Wendy K. Fulwider

Department of Animal Sciences

In partial fulfillment of the requirements

for the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall 2007

UMI Number: 3299769

INFORMATION TO USERS

COLORADO STATE UNIVERSITY

August 27, 2007

WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY WENDY K. FULWIDER ENTITLED SURVEY OF HUSBANDRY, MANAGEMENT, HOUSING, LEG LESIONS, HYGIENE, PRODUCTION, ECONOMICS, AND COW BEHAVIOR ON 113 COMMERCIAL U.S. DAIRIES BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

Dorian J. Garrick

Norman L. Dalsted

Bernard E. Rollin

Temple Grandin
Adviser

William Wailes
Department Head

ABSTRACT OF DISSERTATION

SURVEY OF HUSBANDRY, MANAGEMENT, HOUSING, LEG LESIONS, HYGIENE, PRODUCTION, ECONOMICS, AND COW BEHAVIOR ON 113 COMMERCIAL U.S. DAIRIES

Dairy cattle should be kept clean, dry and comfortable. There are economic and welfare advantages for providing housing for dairy cows during the winter months instead of leaving them outside in harsh climates. To improve overall health and well-being, cows should be moved from indoor stalls into the barnyard, where they can groom themselves and one another. Cows should be able to stretch, sun themselves, exhibit estrus behavior, and exercise. To decrease the incidence of leg problems, mastitis, bloat, and calving-related disorders cows should be allowed generous access to outdoor pastures or exercise yards.

In the first essay, dairy cow behavior, needs, and preferences for housing and milking centers is discussed. Current recommendations for stall size and management practices are reviewed. The social needs of dairy cattle and the benefits of positive human-animal interactions were reported. Recommendations for transport were also included.

In the second essay, dairy cow hygiene, leg lesion incidence and location for cows on 113 dairies were recorded and analyzed. Stall bed types reviewed included compost pack, rubber filled mattresses, sand, and waterbeds. Results indicated that stall bed type was a good predictor for leg lesion incidence and location of wound, as well as level of hygiene. The numbers of mature cows present on a dairy were also related to bed type, as well as bed length in sand stalls. Severe lesions were associated with higher somatic cell counts. There were correlations between high somatic cell counts and the percentage

of cows reported lame by the producer and the neck rail height. High leg lesion rates were correlated with somatic cell count, death loss, and percentage of herd reported lame.

The third essay evaluates diiferent stall bed types for culling rate, percentage of mature cows in herd, bedding cost and frequency. Producer satisfaction for cow comfort, manure management, and cow longevity, by base type were reported. This data indicated that waterbeds were a viable option for cows and producers when good quality sand is unavailable or handling sand-laden manure is not feasible.

Wendy K. Fulwider
Animal Sciences Department
Colorado State University
Fort Collins, CO 80523
Fall 2007

ACKNOWLEDGMENTS

I would like to thank the faculty, staff, and graduate students, in the Department of Animal Sciences for their support and assistance. I would also like to thank my advisor, Dr. Teple Grandin, for her encouragement and guidance while working on my dissertation and doctoral studies. My committee members, Dr. Bernard Rollin, Dr. Norman Dalsted, and Dr. Dorian Garrick are appreciated for their comments, suggestions, and guidance.

TABLE OF CONTENTS

Abstract of Dissertation .......... iii
Acknowledgments .......... v
Table of Contents .......... vi
List of Tables .......... ix
List of Figures .......... xi

CHAPTER 1: OVERVIEW OF DISSERTATION 1
Introduction .......... 1
Overview of Problems Addressed .......... 2
Leg Lesions and Hygiene in Dairy Cows .......... 2
Producer Satisfaction with Stall Base and Effects on Herd Health .......... 3
Discussion .......... 3
References .......... 5

CHAPTER 2: DAIRY CATTLE BEHAVIOR, FACILITIES, HANDLING, HUSBANDRY, AND WELFARE .......... 6
Introduction .......... 6
Housing and Facilities .......... 6
Bedding .......... 12
Milking Center Design .......... 17
Automation and Robotic Milking .......... 21
Behavior and Management .......... 22
Tail Docking .......... 25
Stray Voltage .......... 26
Social Environment .......... 28
Cow and Calf Handling .......... 31
Bull Handling .......... 34
Threat Postures .......... 35
Other Dairy Animals .......... 36
Transport Developments .......... 37
Human – Animal Interactions .......... 38
The Behavior of the Cow Person .......... 39
The Behavior of the Cow .......... 40
Establishing the Relationship .......... 43
The Implications for Animal Welfare .......... 43
Husbandry Procedures .......... 44
Conclusions .......... 45
References .......... 47

CHAPTER 3: INFLUENCE OF FREE-STALL BASE ON TARSAL JOINT LESIONS AND HYGIENE IN DAIRY COWS .......... 55
Introduction .......... 55
Materials and Methods .......... 57

Leg Lesion Measurements 59
Cow Hygiene Measurements 59
Production Information 60
Statistical Analysis 60
Results and Discussion 61
Tarsal Lesions 61
Knee Lesions 63
Cow Hygiene 63
Best and Worst Practices 66
Base Type details 69
Rubber filled mattresses 69
Sand 69
Waterbeds 69
Compost Pack 69
Conclusions 70
References 72

CHAPTER 4: EFFECT OF STALL BASE ON HERD HEALTH, COSTS, AND PRODUCER SATISFACTION 74
Introduction 74
Materials and Methods 75
Stall Dimensions 76
Leg Lesion Measurements 77
Cow hygiene Measurements 77
Production Information 78
Producer Satisfaction 78
Stall Base Purchase and Maintenance Costs 78
Statistical Analysis 78
Results and Discussion 79
Tarsal Lesions 79
Knee and Thigh Lesions 79
Herd Characteristics 80
Stall Dimensions: Lameness, Lesions, and Somatic Cell Count 80
Cow Hygiene 82
Producer Satisfaction 84
Conclusions 86
References 87

LIST OF TABLES

Table 2.1: Free-stall Design: Recommended Dimensions for Cows (from McFarland, 2003 ........ 8

Table 2.2: Daily Time Budget for Typical Cow in Milk (Courtesy R. Grant, Miner Agricultural Research Institute, Chazy, NY) ........ 11

Table 2.3: General Response of Animals Under Different Handling Treatments (Seabrook, 1991) ........ 41

Table 3.1: Farms Visited and Cows Recorded for Tarsal Joint Lesions and Hygiene by Free-stall Bed Type Included in the Analysis ........ 58

Table 3.2: Influence of Free-stall Bed Type on Percent of Cows with Various Lesion Scores ........ 61

Table 3.3: Influence of Free-stall Bed Type on Percent of Affected Cows and Lesion Location ........ 62

Table 3.4: Influence of Stall Bed Type on Percent of Cows and Hygiene Score ........ 64

Table 3.5: Associations of Bed Type with Percent Mature Cows Somatic Cell Count, Percent Culled and Weekly Winter Bedding Frequency ........ 64

Table 4.1: Total Herd Cow Numbers, Number of Cows Scored, Average Stocking Density, and Number of Stall Rows per Barn by Bed Type ........ 80

Table 4.2: Stall Width, Length, and Neck Rail Height by Bed Type ........ 81

Table 4.3: Times Manure is Removed per Day; Percent Culled Annually, Died Annually, and Reported Lame on the Day of Visit by Bed Type ........ 82

Table 4.4: Percent Mature Cows, Somatic Cell Count, Bedding Frequency per Week, and Bedding Cost per Week by Bed Type ........ 83

Table 4.5: Producer Satisfaction with Cow Longevity, Lameness Hock Injury, Teat Injury, Mastitis, Somatic Cell Count, Udder Health, and Hygiene ........ 84

Table 4.6: Producer Satisfaction with Cow Comfort, Bedding Cost and Use, Manure Management, Labor, and Base Life ........ 84

LIST OF FIGURES

Fig. 2.1: Fair Oaks cows. Given the opportunity, cows will seek their level of comfort in well-designed stalls that have plenty of space for a cow to stretch out and relax, as on this well-managed dairy ........ 10

Fig. 2.2: Rotary milking center, Turlock, CA. These California Jerseys take a turn on the rotary. Cattle are easy to train to enter and exit the rotating platform: training often takes only 3 days ........ 18

Fig. 2.3: Herringbone rapid-exit brisket bar. The straight, rapid-exit brisket bar in a herringbone allows cows and heifers of various sizes to be milked together with ease and maximum comfort. Longer cows slide along the bar. Heifers may adapt more easily to being milked in a herringbone. Cows of varying age, size and infirmity may have difficulty making the sharp turn into a parallel milking center (photograph courtesy of DeLaval, Inc.) ........ 20

Fig. 2.4: Motorized brush. Cows seek out this brush to groom themselves. It is well-worn, and less than 1 year old. This motorized brush is located in the walkway and accessible to 400 cows as they enter and exit the milking center. Producers who have provided motorized brushes for their cows report that cows spend the bulk of their free time for days at the brush if they have been previously kept in a pen without one (e.g. during the dry period) (photo courtesy of DeLaval, Inc.) ........ 23

# CHAPTER 1

# OVERVIEW OF DISSERTATION

## Introduction

As the numbers of dairy farms have declined the number of cows per dairy has increased. This has lead to increased confinement of dairy animals. The use of technology has been implemented to improve housing, milking centers, management, nutrition, cattle transportation, and veterinary medicine. Milk production has increased as the industry has become more specialized and efficient.

Modern housing has moved away from the traditional straw bedding as producers grow higher yielding, more profitable crops. This has led to the use of mattresses or deep sand free-stall barns. These stall beds provide increased comfort for the cow and reduce the need for straw or other bedding material such as sawdust. Lack of bedding or infrequent bedding of mattresses may result in tarsal lesions or poor hygiene. There is a wide array of stall mattresses available to producers, some of which are comprised of foam, rubber crumbs, or water.

Cow preference tests allow cows to vote for which stall bed they prefer. Generally, cows prefer the softest available bed (Fulwider and Palmer, 2004a). In the coldest period of winter, cows preferred waterbeds over foam or rubber filled mattresses for lying. During other times of the year, cows preferred rubber or foam filled mattresses (Fulwider and Palmer, 2004b). Ruud and Østerås (2007) found that softer stall mattresses were associated with higher milk yields and reduced mastitis incidence.

## Overview of Problems Addressed

Producers with free stall barns often keep cows indoors year-round. Stall bed type was found to have an impact on weekly bedding cost, culling rate, and cow longevity. There were differences between bed types for producer satisfaction with regard to cow comfort, cow longevity, manure mangement, and stall bed life (Fulwider et al., 2007a). Lesion incidence and hygiene was impacted by stall bed type (Fulwider et al., 2007b).

### Leg Lesions and Hygiene in Dairy Cows

Traditional animal care was based in the absence of illness, injury, or pain. Sick animals were treated promptly. The focus of modern animal care has been with intensive techniques where space is limited and cows have been confined on concrete. This has resulted in higher rates of lameness. Many people in the industry believe that high levels of production indicate good conditions for cows. This is not always the case, as the third of dairies with the most combined score 2 and 3 tarsal joint swellings with cows maintained on rubber-filled mattresses had the highest milk production of any third, regardless of bed type (Fulwider et al., 2007b).

Hygiene is important for of dairy cows as related to somatic cell counts (Schreiner and Ruegg, 2003; Ward et al., 2002) and the comfort of the people who milk them. A relationship between cow hygiene and subclinical mastitis was reported by Schreiner and Ruegg (2003). Relationships between udder and leg hygiene and somatic cell count and the rate of intramammary infection were quantified. Udders described as dirty were more likely to be infected by a major pathogen.

Producer Satisfaction with Stall Base and Effects on Herd Health

A wide variety of stall base types have been available to producers. Fulwider and Palmer (2004b) compared cow preference for 13 different stall bases. Types included were foam, solid rubber, rubber crumbs, crumbled cork, waterbeds, a foam mattress encased in a rubber mat, and a layer of foam over rubber crumbs. Producers have to weigh many factors before a decision can be made regarding which stall base would be the best for a particular dairy. These factors include:

- Which bed would be most beneficial to cows
- The best investment over time
- The effect it will have on manure handling
- How often bedding must be applied
- Bedding availability

## Discussion

The objective of this dissertation was to determine management practices used dairies, how cows have been affected by housing and management, and the level of producer satisfaction with current practices. Producers have been challenged by fluctuations in milk prices and the management changes required as the number of cows per dairy increase.

The image of the dairy industry has changed immensely in recent years. Dairies have increased in size and efficiency. The geographic location of dairies has also changed (Garry, 2004). Cows use to be pastured in summer and housed over the winter. Free stall barns gained popularity due to decreased bedding and labor requirements. An open dirt lot in the warmer, drier western U.S. has been the common housing choice for many producers in that region of the country. Larger dairies and different environmental conditions in which cows are kept have driven the need for cow comfort research.

Much research has been done with regard to cow preference for different stall beds, stall components and dimensions. It should be beneficial to producers to have information regarding the effect of bed type on cows, as well as the satisfaction level of producers with the different management requirements of each stall bed type.

## References

Drissler, M., M. Gaworski, C.B. Tucker, and D.M. Weary. 2005. Freestall maintenance: effects on lying behavior of dairy cattle. J. Dairy Sci. 88:2381-2387.

Fulwider, W.K., T. Grandin, D.J. Garrick, T.E. Engle, W.D. Lamm, N.L. Dalsted, and B.E. Rollin. 2007a. Effect of stall base type on herd health, costs, and producer satisfaction. Proc. of the 6th Int'l. Dairy Housing Conf. Am. Soc. Ag. Bio. Eng. , St. Joseph, MI.

Fulwider, W.K., T. Grandin, D.J. Garrick, T.E. Engle, W.D. Lamm, N.L. Dalsted, and B.E. Rollin. 2007b. Influence of free-stall base on tarsal joint lesions and hygiene in dairy cows. J. Dairy Sci. 90:3559-3566.

Fulwider, W.K. and R.W. Palmer. 2004a. Use of impact testing to predict softness, cow preference, and hardening over time of stall bases. J. Dairy Sci. 87:3080-3088.

Fulwider, W.K. and R.W. Palmer. 2004b. Stall usage differences of thirteen different freestall base types. Prof. Anim. Sci. 20(6):470-482.

Garry, F.B. 2004. Animal well-being in the U.S. dairy industry. In The Well-Being of Farm Animals : Challenges and Solutions. G.J. Benson and B.E. Rollin, eds. Blackwell Publishing, pages 207-240.

Ruud, L.E. and O. Østerås. 2007. The effect of lying surfaces on milk yield and udder health in Norwegian free stalled dairy herds. Proc. of the 6th Int'l. Dairy Housing Conf. Am. Soc. Ag. Bio. Eng. , St. Joseph, MI.

# CHAPTER 2

## DAIRY CATTLE BEHAVIOR, FACILITIES, HANDLING, HUSBANDRY, AND WELFARE

**Jack .L. Albright[1] and Wendy Fulwider[2]**
*[1]Purdue University, West Lafayette, Indiana 47907, USA*
*[2]Colorado State University, Fort Collins, Co 80523, USA*

### Introduction

Dairy cattle should be kept clean, dry and comfortable. Early Indiana research showed economic and welfare advantages for providing housing for dairy cows during the winter months instead of leaving them outside (Plumb, 1893). To enrich their environment and to improve overall health and well-being, whenever possible cows should be moved from indoor stalls into the barnyard, where they can groom themselves and one another (Wood, 1977; Bolinger et al., 1997), stretch, sun themselves, exhibit estrus behavior, and exercise (Albright et al., 1999). Exercise decreases the incidence of leg problems, mastitis, bloat, and calving-related disorders (Gustafson, 1993).

Housing and Facilities

Housing systems vary widely from fenced pastures, corrals, and exercise yards with shelters to insulated and ventilated barns with special equipment to restrain, isolate, and treat cattle. Generally, self-locking stanchions/headlocks (one per cow), corrals, and sunshades are used in warm semi-arid regions. Pastures and shelters are common in warm humid areas, naturally ventilated barns with free stalls are used widely in cool humid climatic regions, and insulated and ventilated barns with tie stalls are common in colder climates (Albright et al., 1999). Free stall housing with open sides (or no side walls) is common in hot-humid areas with rainfall over 64 cm or 25 to 30 cm in a 6 mo period e.g. San Joaquin Valley in California (D.V. Armstrong, Arizona, 1999, personal communication). The range of effective dimensions for pens and stalls for calves, heifers, dry cows, maternity or isolation, special needs, milking cows and mature bulls have been published in the 'Ag Guide' (Albright et al., 1999). Recommended sizes of free stalls and tie stalls as related to weights of Holstein female dairy cows were revised (McFarland, 2003; Table 2.1).

Maintaining high standards of hygiene may increase productivity while minimizing the incidence of mastitis, endoparasitic, and foot infections. Two studies (Reneau J.K. et al., 2005; Schreiner D.A. and Ruegg, P.L., 2003) found hygiene of the hind leg and udder to be associated with somatic cell scores. In addition, Hughes (2001) further notes that it is unacceptable to present parlor operators with cows requiring extensive cleaning. He also states that it would be wise for the dairy industry to remain free from reproach, since abattoirs have set cleanliness standards for animals sent to slaughter since the *Escherichia coli* 0157 outbreak in the mid-1990s.

Table 2.1: Free-stall design: recommended dimensions for cows (from McFarland, 2003).

| Dimension[1] | Weight of cow (kg) | | |
|---|---|---|---|
| | 550 | 650 | 750 |
| $L_S$ = total stall length[2] (mm) | OF: 2030-2185<br>CF: 2335-2490 | OF: 2135-2285<br>CF: 2440-2590 | OF: 2285-2490<br>CF: 2590-2745 |
| $L_H$ = head space length (mm) | 430 | 455 | 480 |
| $L_L$ = lunge space length (mm) | 355 | 380 | 405 |
| $L_N$ = length to neck rail (mm) | 1575 – 1625 | 1675-1725 | 1775 - 1825 |
| $L_B$ = length to brisket board (mm) | 1575 – 1625 | 1675 - 1725 | 1775 - 1825 |
| $L_P$ = stall partition length (mm) | (Ls – 355) to Ls | (Ls – 355) to Ls | (Ls – 355) to Ls |
| $H_N$ = height to neck rail (mm) | 1065 -1170 | 1120 - 1220 | 1170 - 1270 |
| $H_P$ = stall partition height (mm) | 1065 -1170 | 1120 -1220 | 1170 -1270 |
| $H_B$ = brisket board height (mm) | 10 -15 | 10 -15 | 10 -15 |
| $H_C$ = stall curb height (mm) | 150 -250 | 150 -250 | 150 -250 |
| $H_E$ =stall entry height (mm) | 300 | 300 | 300 |
| $H_{L1}$ = lunge clearance lower (mm, max.) | 280 | 280 | 280 |
| $H_{L2}$ = lunge clearance upper (mm, min.) | 815 | 815 | 815 |
| $W_S$ = stall width, center to center (mm) | 1090 – 1145 | 1145 - 1220 | 1220 - 1320 |
| $S_B$ = stall base slope (%) | 1 – 4 | 1 - 4 | 1 – 4 |

[1]Outer edge of the curb to the brisket board
[2]OF = open-front stall; closed front stall

Current trends and recommendations favor keeping dairy cows on unpaved dirt lots in the western USA and on concrete or pasture in the North USA throughout their reproductive lifetimes. Concrete floors should be grooved to provide good footing and to reduce injury (Albright, 1994, 1995; Jarrett, 1995). The concrete surface should be rough but not abrasive, and the micro surface should be smooth enough to avoid abrading the feet of cattle (Telezhenko, E. and Bergsten, C., 2005). Dairy cow locomotion was studied on flooring with four different coefficients of static friction (Phillips, C.J.C. and Morris, I.D., 2001). The optimum coefficient of static friction was found to be between 0.4 and 0.5. Cows walk at a slower pace and display a different walking pattern in the presence of slurry when compared to dry or wetted concrete (Phillips, C.J.C. and Morris, I.D., 2000). Vokey et al. (2003) noted that cows housed in barns with rubber alleys and sand stalls maintained balance between the lateral and medial claw, and had the lowest net growth of dorsal wall as compared to cows in other stall and alley configurations.

Data are limited on the long-term effects of intensive production systems; however, concern has been expressed about the comfort, well-being, behavior, reproduction, and udder, foot, and leg health of cows kept continuously on concrete. As a safeguard, many cows are moved from concrete to dirt lots or pasture, at least during the dry period. Also, rate of detection and duration of estrus are higher for cows on dirt lots or pastures than for cows on concrete (Britt et al., 1986). The second author visited 113 dairies during 2005-2006 and observed cows exhibiting increased activity on *dry* rubber flooring in breezeways, as well as cows avoiding concrete areas when rubber flooring was an option. Dairies in the northeastern U.S. reported successful use of pedometers for heat detection. The link between walking activity and fertility show the potential of pedometers as a tool for increasing fertilization rates (Roelofs, J.B., et al, (2005); López-Gatius, F., et al, (2005); Eerdenburg, F.J.C.M. van, (2006).

Fig. 2.1: Fair Oaks cows. Given the opportunity, cows will seek their level of comfort in well-designed stalls that have plenty of space for a cow to stretch out and relax, as on this well-managed dairy.

Cows seek their level of comfort (Fig. 2.1). Physical accommodations for dairy cattle should provide a relatively clean dry area for the animals to lie down and be comfortable (Jarrett, 1995). It should be conducive to cows lying for as many hours of the day as cows' desire. Cows need a certain amount of resting time each day just as they need their nutrient requirements. For every hour of resting above seven hours daily, a cow should produce an extra kilogram of milk (Grant, 2004, 2005). Blood flow to the udder, which is related to the level of milk production, is substantially higher (28%) when a cow is lying than when a cow is standing (Metcalf et al., 1992; Jarrett, 1995). Table 2.2 illustrates the daily time budget for a typical cow (Grant, 2004, 2005)

Table 2.2: Daily time budget for typical cow in milk (courtesy R. Grant, Miner Agricultural Research Institute, Chazy, NY).

| Activity | Time spent / day (h) |
|---|---|
| Eating | 5.5 (9 – 14 meals / day) |
| Resting | 12 – 14 (including 6 of rumination) |
| Standing or walking in alleys | 2 – 3 |
| Drinking | 0.5 |
| Total Time Needed | 21 – 22 |

Criteria for a satisfactory environment for dairy cattle include thermal comfort (effective environmental temperature), physical comfort (injury-free space and contact surfaces), disease control (good ventilation and clean surroundings), and freedom from fear. Cattle can thrive in almost any region of the world, if they are given ample shelter from excessive wind, solar radiation, and precipitation.

Heat stress affects the comfort of cattle more than does cold stress. Milk production can be increased during hot weather by the use of sunshades, sprinklers, and other methods of cooling (Roman-Ponce et al., 1977; Armstrong et al., 1984, 1985; Schultz et al., 1985; Buchlin et al., 1991; Armstrong, 1994; Armstrong and Welchert, 1994) as well as by dietary alterations. Tomaszewski et al., (2005) report that cooling ponds may improve animal welfare and provide heat stress relief without adverse effect.

In 2000, near Fair Oaks, Indiana, third generation Dutch-descent dairy families from Michigan and Western states rejuvenated dairying in Indiana by developing multiple 3000 cow units. Cow comfort, cleanliness, milk quality, nutrition, and high milk production are emphasized. Milking cows are housed in free stall barns bedded with sand. When temperatures are above 70°F in the barn, cows are cooled with sprinklers and fans. Cooled cows are found to produce 80 pounds of milk as compared to 71.5 pounds of milk in uncooled cows (Gordie L. Jones, 2005, personal communication).

In assessing cow cooling in hot climates, the jury is still out on tunnel-ventilated free-stall barns, but there is widespread acceptance of holding pen cooling (Quaife, T., and Roenfeldt, S., 2006). Temperatures that are consistently higher than body temperature can cause heat prostration of lactating cows (Van Baale, M., et al., 2006) but additional energy intake (+1% $°C^{-1}$) and higher heat production by the cow can compensate for lower temperatures, even extremely low ones. Consideration also needs to be given to humidity levels and wind chill factors in determining effective environmental temperatures. Adaptation to cold results in a thicker hair coat and more subcutaneous fat, which also reduces cold stress (Curtis, 1983; Holmes and Graves, 1994).

Brown Swiss cows proved they were better adapted to heat stress than Holsteins, as they did not benefit from different cooling systems as did Holsteins (Correa-Calderon, A., et al., 2005). Hillman et al., (2005) indicate that when core body temperature reaches 38.9°C, cows seek to cool themselves by standing. Core body temperature rose while cows were lying; remained unchanged standing under fans; and dropped while cows stood under fans with feed line spray.

## Bedding

Comfortable stalls are of the utmost importance to high producing dairy cattle. Of all the factors that encourage cows use free stalls, the condition of the bed is likely to be the most important (Bickert and Smith, 1998; Weary and Tucker, 2006). When choosing a stall bed, producers must consider climate, how management of the bed will impact manure handling, and how these decisions will affect cows. A Wisconsin study found that cows favor the softest available stall beds (Fulwider, W.K. and Palmer, R.W., 2004a; 2004b). Cows in this study also favored different beds at different times of the year due to climatic change. Deep-bedded sand and rubber crumb-filled mattresses with a foam layer were found to be equally attractive to cows during all but the coldest periods of the year. Cows preferred waterbeds over all other available bases during the cold of winter, probably due to their ability to retain warmth. Waterbeds must be well-bedded until cows are acclimated to the "wobbly" nature of this bed type. It may be advisable to acclimatize heifers to waterbeds before they are turned in with a milking group maintained on waterbeds.

Stalls should have bedding to allow for cow comfort. Bedding over rubber mats and mattresses helps keep the base dry, minimizing the potential for bacterial infection, as well as being a "lubricant" between the cow's skin and the mattress and to insulate the udder against cold temperatures. Some producers recess rubber crumb-filled mattresses and bed with sand (Mowbray et al., 2003), effectively enjoying the benefits of each bed type. The attributes of sand regarding conforming to the cow and providing unparalleled traction cannot be denied. Finding a reliable, inexpensive source of high quality sand (no rocks or pebbles which may cause hoof damage or lameness) and dealing with the high labor component and manure handling complications that go with sand deter many producers from utilizing this stall base type.

On the other hand, what is in front of the cow has as much to do with cow comfort as what is under her (S.D. Young, Ontario, Canada, 1999, personal communication). If neck rails are placed too low, the cow may feel cramped and be reluctant to enter or use the stall(s). Tucker et al., (2005) suggest that producers may wish to use the neck rail to keep cows from standing in and soiling stalls and provide a comfortable flooring surface in the alley to stand on. Fulwider and Palmer (2005) reported that cows spent less time standing in stalls when rubber alley mats were installed. This may also increase useful life of beds. (Avoid beds that are too hard (concrete, concrete with solid rubber mats and compacted earth).

Swollen hocks and knees result from a bed that does not provide sufficient cushion. Wechsler et al., (2000) reported that cows on mats and mattresses had a higher incidence of hairless patches, scabs, and wounds on the carpal and tarsal joints than cows on straw beds. Findings by Sogstad et al., (2006) indicate that cows with wounds and swellings at the tarsus have more clinical mastitis and teat injuries cows. They further related that free stall cows suffer from a higher prevalence of metabolic claw and infectious lesions than do tie-stall cows. Fulwider et al., (2007), found that cows maintained on waterbeds or in sand stalls suffered fewer hock lesions than cows kept on mattresses.

Mattresses are soft when they are new, but filling becomes compacted and the surface becomes extremely hard within a few months. Recessing mattresses several centimeters below the curb allows for deep sand or other bedding, reducing tarsal joint lesions. This may however result in lesions at the tuber calcis when contacting the cement curb at the rear of the stall (Mowbray et al., 2003). The second author saw this successfully implemented on one dairy. PVC pipe was mounted at the rear of stalls to hold sand. The PVC pipe is non-abrasive and cows had no lesions. Weary and Taszkun (2000) found that the number and severity of lesions increased with age and; and that length of stall for cows on deep-bedded sawdust was associated with severity of lesions.

Lameness issues were further investigated by Sogstad et al., (2005). Heifer lameness prevalence was low, but 29% had at least one lesion. Heifers in tie-stalls had fewer heel-horn erosions, sole haemorrhages, and white line fissures than those in free stalls.

Risk factors for:

- Lameness: Parity 3+; narrow cubicles
- Heel horn erosions: Post-calving 5-7 months; solid concrete alleys
- White line haemorrhage: Post-calving 3-5 months; solid concrete alleys
- Sole hemorrhage: Parity 1; Post-calving 5-7 months; short cubicles
- White line fissures: Slatted concrete alleys
- Asymmetrical claws: Parity 2+
- Corkscrew claws: Solid concrete alleys

Beds with mounds, lumps or holes reduce cow comfort and cause difficulties when cows get up. Lack of comfort and difficulty in rising, both discourage free stall usage (Bickert and Smith, 1998). More research is required with regard to cow comfort and its long-term effects on cows in early lactation, the socially subordinate, and lame with regard to free stall maintenance and stocking density (Tucker et al., 2004).

When handled properly, many fibrous and granular bedding materials may be used (Midwest Plan Service, 2000), including straw, sand, wood chips, sawdust, shavings, bark, shredded newspaper, composted manure, corn stalks, peanut, sunflower, or rice hulls. Inorganic bedding materials (sand or ground limestone) provide an environment that is less conductive to the growth of mastitis pathogens. Sand bedding may also keep cows cooler than straw or sawdust. Regional climatic differences and diversity of bedding options should be considered when bedding materials are being selected. Bedding should be non-abrasive, absorbent, free of toxic chemicals or residues that could injure animals or humans, and of a type not readily eaten by the animals.

Bedding rate should be sufficient to keep the animals dry between additions or changes. Any permanent stall surface, including rubber mats, should be cushioned with dry bedding (Albright, 1983; Albright et al., 1999). Bedding material added on top of the base absorbs moisture and collects manure tracked into the stall, adds resiliency, makes the stall more comfortable, and reduces the potential for injuries (Midwest Plan Service, 2000).

Bedding mattresses over hard stall bases such as concrete or well-compacted earth can provide a satisfactory cushion. This innovation cuts bedding use in stall (tie stall and stanchion) and free stall barns while providing cushion, traction, with less bedding required and reduces stall maintenance (House, 1999). A bedding mattress consists of bedding material compacted to 8 to 10 cm (3 to 4 in) and enclosed in a fabric (heavyweight polypropylene or other similar material). Shredded rubber may be used and is recommended as mattress filler (Underwood et al., 1995). Rubber should be packed firmly to prevent shifting and settling. Small amounts of bedding (chopped straw) on top of the mattresses keep the surface dry and the cows clean (Midwest Plan Service, 2000). A Canadian study showed that cows presented with mattresses with three different amounts of sawdust bedding, cows spent significantly more time lying in stalls with the maximum bedding (Tucker, C.B., and Weary, D.M., 2004). The general public and consumers of dairy products, who know very little about dairy housing, have heard that cows are sleeping on mattresses, waterbeds, or in "beach barns". This enhances their opinion that farmers are concerned about the welfare of their animals. Also, there is the fact that rubber tyres are being recycled rather than going into landfills (House, 1999). Two bedding methods have emerged as top candidates (Bickert and Smith, 1998): 1) mattresses with bedding on top and 2) a deep layer of sand. According to Bickert and Smith (1998), sand can be considered to be the gold standard for a free stall base and bedding. If other materials are to be considered as alternatives or evaluated on the basis of cow comfort, sand is the basis for comparison. The only logical choice for not using sand has little to do with cow comfort and udder health, but with the difficulty it adds to the manure system or the availability of high quality sand (no rocks or pebbles as they can cause hoof damage or lameness). Furthermore, loose sand conforms to the shape of body components - knees, hocks, etc. This reduces pressure on projecting bones and body part contacts by distributing force or weight over a larger lying surface area (Bickert and Smith, 1998). When sand beds are not maintained properly (sand level with the curb), lying times are reduced relative to the level of sand; or 2.33 hours per day when the sand level is 13.7 cm below the curb (Drissler et al., 2005).

Recently, Weary and Tucker (2006) focused on the latest on free-stall comfort as follows: neck rail: cows prefer these higher and closer to the front of the stall; brisket board: lying times are longer when these are removed; Stall partitions: cows prefer these wide apart-more than 48 inches improves lying time and reduces standing; stall surface: plentiful bedding prevents injuries and improves lying time; and standing surface: cows prefer soft, dry surfaces (also at the feed bunk and alley ways) which can prevent injuries and diseases. Tucker et al., (2006) suggest new approaches to dairy cow housing are needed.

Milking Center Design

Until the advent of centralized milking centers, most cows were milked in their stalls. A disadvantage of this method is that it is labor intensive and hard on the knees of those milking the cows. The idea of milking cows on an elevated herringbone platform originated in Australia (O'Callaghan, 1916; Albright and Fryman, 1964). Early USA designs enabled a single person to milk two cows while seated on a swivel chair or to use elevated side opening parlors (Albright and Fryman, 1964).

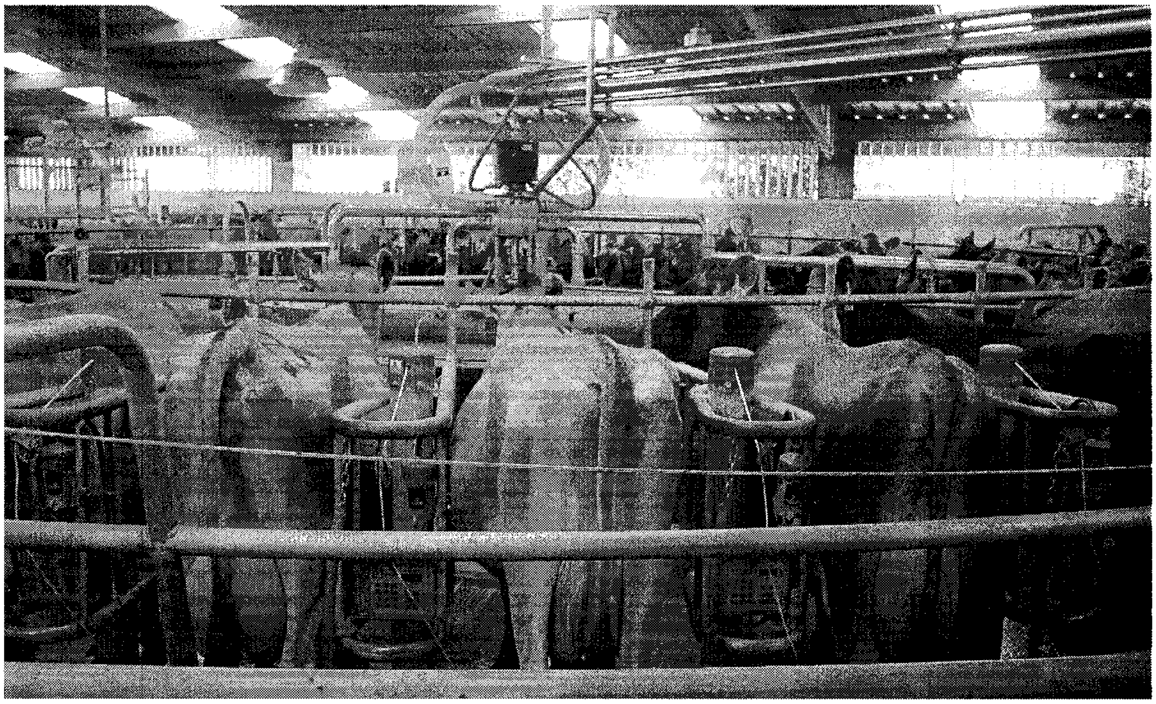

Fig. 2.2: Rotary milking center, Turlock, CA. These California Jerseys take a turn on the rotary. Cattle are easy to train to enter and exit the rotating platform: training often takes only 3 days.

Due to labor shortages and high wages, New Zealand dairy farmers were motivated to develop rotary centers (Gooding, 1971). At the time, these systems were a great innovation, but had high maintenance costs. Simple layouts with automated gates and milking machine detachers became popular. Possibly due to less walking distances (Smith et al., 1998) and greater efficiency and automation at the entry and exit points, currently there is a new wave of rotary parlors for larger herds in the USA. Quaife

(1999) claims that today's rotary milking centers (Fig. 2.2) will remain a viable option for some larger producers and not fade away like they did in the 1970's. Since 2000, Fair Oaks and other 3000-cow multiple unit dairies are milking their cows on 72-cow rotary parlor platforms.

Extensive time and motion studies have been conducted on different milking center designs (Armstrong and Quick, 1986; Armstrong, 1992). The addition of automation, such as powered gates, enabled simple designs, such as herringbones, trigons and polygons, to achieve greater labor efficiency than the early smaller rotaries. Good reviews illustrating different milking center layouts can be found in Bickert (1977), Armstrong (1992), and Midwest Plan Service (2000).

The most commonly used design used to be the herringbone where two rows of cows are milked from a central pit. Currently, the parallel milking center is the most commonly installed in the U.S. The milking machines are attached from the rear between the cow's legs instead of from the traditional side position. During milking, the cows stand at 90° relative to the pit. All the cows are released at once after milking by lifting either an entire row of stanchions or a long bar which runs in front of the animals. This design is more efficient than older style herringbones that did not have the rapid-exit feature. Herringbone milking centers with the rapid exit design combine some of the best features of both herringbones and parallel milking centers. New heifers are easier to train to a herringbone and the cows can be easily milked from the side (Armstrong et al., 1989, 1990), especially with rapid exit stalls (Fig.2.3).

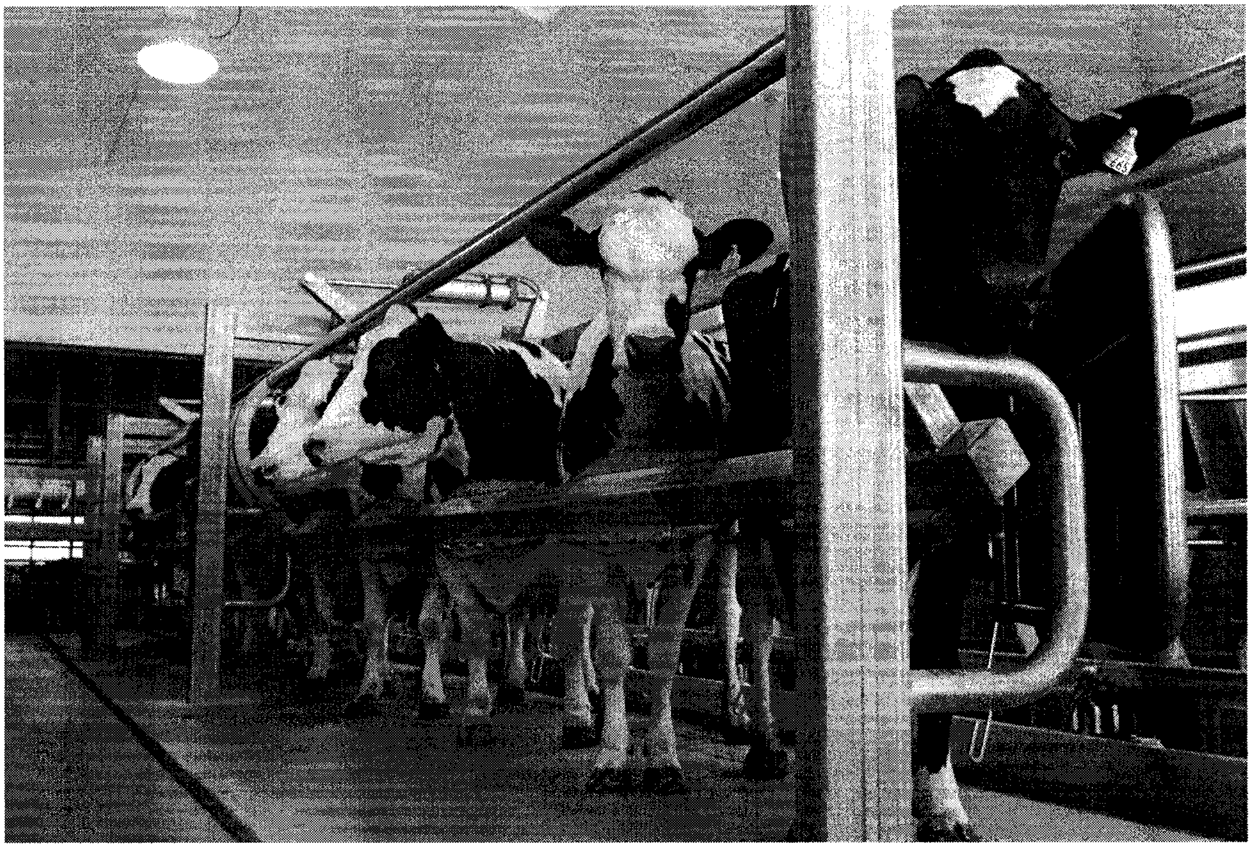

Fig. 2.3: Herringbone rapid-exit brisket bar. The straight, rapid-exit brisket bar in a herringbone allows cows and heifers of various sizes to be milked together with ease and maximum comfort. Longer cows slide along the bar. Heifers may adapt more easily to being milked in a herringbone. Cows of varying age, size and infirmity may have difficulty making the sharp turn into a parallel milking center (photograph courtesy of DeLaval, Inc.).

The use of a powered crowd gate to make the holding pen smaller induces cows to enter the milking center voluntarily. Crowd gates should not be used to forcibly push cows or apply electric shocks. The second author would like to note that producers have indicated that automatic alley scrapers and crowd gates do cause injuries resulting in death or the need to dispose of cows prematurely. According to Fahey et al. (2002), the length of time in the holding pen indicates exposure of cows for short time (40 min) to increased time (120 min) stays does not significantly affect production or stress indicators in the short term (4 wk). Proper training of cows and of milking center operators will also improve the efficiency of cow movement through the facility. Cows should be encouraged to enter voluntarily without prodding. The milker should avoid leaving the pit to chase cows as this conditions the cows to wait for the milker to come after and chase them. Cows also have individual preferences for music, weather, certain people and the side of the milking center they will enter (Albright et al., 1992). Since cows are creatures of habit, it is imperative to be consistent from one milking to the next. Recommendations for milking machine and udder sanitation can be found in the 'Ag Guide' (Albright et al., 1999).

Automation and robotic milking

Housing and herd management developments have important effects on the well-being of dairy cattle and the cattle enterprise is well-suited for the application of electronics and automation (Albright, 1987; Smith et al., 1998). Robotic milking systems have the greatest potential economic benefit for the 50-120 cow dairy (Rotz et al., 2003). The second author had the opportunity to visit six dairies utilizing robotic milking centers in Canada (see Fig. 2.5). Producers appreciated that the robot gave them the opportunity to attend their children's school events without having to plan around milking times. They also reported having more time to tend cows without the drudgery of milking.

Rodenburg (2004) has noted that most conventional free stall barns can be successfully adapted for robotic milking systems. Producers who may be concerned about cows' adapting to the robotic milking system, Weiss et al., (2004) has indicated that this varies widely within cows, but all adapt within days. Cows may be attracted to the milking unit by desire to feed or to be milked, although motivation to feed is given first priority (Melin, et al., 2006). Graziers may also utilize this technology. Spörndly and Wredle (2005) recommend providing water in the pasture area for animal welfare reasons, but have found no negative effect in water provided only at the barn with walking distance up to ~300m. Behavioral and physiological responses of robotic and conventionally milked cows have been studied (Hopster et al., 2002; Hagen et al., 2004). They report that conventional milking and robotic were equally acceptable regarding cow welfare. The simulation process may be useful in optimizing dairy facility efficiency and layout before construction begins (Halachmi, 2004).

Pastell et al., (2006) have assembled a system in a robotic milking system that can weigh the cow, while analyzing her step and kick behavior while in the robot, and how it may change over time. Preliminary data analysis indicates that this system is very promising for early detection of limb and hoof disorders.

Over time, capital investments for cow comfort and sanitary requirements have increased markedly. Labor-saving practices have been developed to reduce the drudgery of dairy farming. Many top-producing cows continue to be housed and milked in labor-intensive tie-stall barns. For these tie-stall barns with improved design (Zurbrigg et al., 2005) there are now silo unloaders, gutter cleaners, battery-operated silage carts, portable straw choppers, automatic detaching milking machines with low milk lines, and mechanized manure handling.

Behavior and Management

Few scientific data are available on cows and grooming. Cows with access to motorized brushes have a glossier hair coat than others. The second author has observed that animals will actively seek out the motorized brush and apply it to many parts of the head and body (see Fig. 2.4). Producers reported that cows without access to an automatic brush during the dry period would spend a few days at the brush upon return to the milking barn. Cows were also reported to spend time at the brush immediately after calving. The second author noted that some dairies did not wish to invest in multiple brushes often placed a single one in a common walkway.

Fig. 2.4: Motorized brush. Cows seek out this brush to groom themselves. It is well-worn, and less than 1 year old. This motorized brush is located in the walkway and accessible to 400 cows as they enter and exit the milking center. Producers who have provided motorized brushes for their cows report that cows spend the bulk of their free time for days at the brush if they have been previously kept in a pen without one (e.g. during the dry period) (photo courtesy of DeLaval, Inc.).

The dairy cow has been called 'the foster mother of the human race' (Rankin, 1925). A relationship develops between the milker and the cow which is a vital part of the milk extraction process and as machine milking took over from hand milking this relationship was considered by many to have diminished. After her calf is removed, the cow is milked with a minimum of manual stimulation in highly automated surroundings.

Caretakers in high-producing herds are aware of the importance of such changes. For as long as cows have been milked, there has been the art of cow care that results in more milk from healthier, contented cows. It has been recognized that the dairy cow's productivity can be adversely affected by discomfort or maltreatment. Alert handlers have the perception and ability to read 'body language' in animals. For example, healthy calves and cows will exhibit a good stretch after they get up, then relax to a normal posture. Increased standing of cattle is now often taken as a sign of discomfort or discontent in studies of cow and calf confinement (Albright, 1987).

Cattle under duress show signs by bellowing, butting or kicking. Behavioral indications of adjustments to the environment are always useful signs of whether the environment needs to be improved. In some cases, the way animals behave is the only clue that stress is present (Stephens, 1980; Albright, 1983). Looking-up behavior in the holding pen has been linked to low motivation to be milked due to fear of humans (Ishiwata et al., 2005). This behavior was most common in cows during lactation 3 and under, positively correlated with flight starting distance and entrance order, and negatively correlated with productivity.

Clues to a cow's mood and condition can be obtained by observing the animal's tail. When the tail is hanging straight down, the cow is relaxed, grazing or walking, but when the tail is tucked between the cow's legs, it means the animal is cold, sick, or frightened. During mating, threat or investigation, the tail hangs away from the body. When galloping, the tail is held straight out, and a kink can be observed in the tail when the animal is in a bucking, playful mood (Kiley-Worthington, 1976; Albright, 1986a; Albright and Grandin, 1993; Albright and Arave, 1997).

According to Kiley-Worthington (1976), when studying the cause and function of tail movement it is necessary to consider the whole posture of the animal as well as the contexts that give rise to it. In cattle (and horses) the immediate association one makes with lateral tail movements is with cutaneous irritation. In these species there are morphological changes of the tail which point to its use as a fly switch.

Much has been made about getting cows to move more quickly into the milking center. The second author noticed that cows self-loaded with ease in large milking centers staffed by one milker. While one side was prepped and milkers attached, the other side loaded with no trouble. When milking centers are over-staffed, people get in the way. One producer was in the process of adapting his cows to come in without grain and it was not going well. Ceballos and Weary (2002) found that small quantities of feed reduced the need to push cows or use other interventions that may negatively affect cows. Producers with robotic milking systems effectively utilize feeding motivation to get cows into the robot. Halachmi et al., (2006) suggests there is an opportunity to increase milk yields by feeding pellets rich in digestible neutral detergent fiber to selected high producers.

## Tail-Docking

According to the 'Ag Guide' with references on this subject (Albright et al.,1999), docking of tails is a controversial yet common practice performed on cows that are milked from the rear or that have filthy switches. Tail-docking has been prohibited in the United Kingdom and some other European countries and the Canadian and American Veterinary Medical Associations officially oppose routine tail-docking in dairy cattle.

Under conditions of high fly numbers, tail-docked heifers tail flick more often and are forced to use alternative behaviors such as rear leg stomps and head turning to try to rid themselves of flies. More flies settle on tail-docked cows than on intact cows; the proportion of flies settling on the rear of the cow increases as tail length decreases. Grazing and rumination are disturbed when fly attacks are intense, and substantial losses to the USA cattle industry have been attributed to flies causing interference with grazing. Excellent fly control is therefore especially important for tail-docked cattle. A study of tail-docking in New Zealand (Matthews et al.,1995) found no difference in cortisol concentrations between docked and intact cows, but there were also no differences in milk yields, body weights, somatic cell counts, frequency of mastitis, or milker comfort among the treatments studied (intact tails, trimmed tails, docked tails). Tucker et al., (2001) found little merit for tail-docking with regard to cow cleanliness, udder cleanliness and health, though they reported significant differences in cleanliness between cows. They suggest that behavior or use of stalls is responsible. Research on tail-docking by the USDA-ARS Livestock Behavior Research Center and Purdue University scientists from 1997 to present demonstrated that well-being of calves (at docking) and heifers and cows (after docking) can be compromised by acute pain, increased fly numbers and irritation, and signs of increased sensitivity or chronic pain in the stump (Eicher and Dailey, 2002; Eicher et al., 2001, 2002). Trimming switches with clippers is preferred as an alternative to tail-docking in dairy herds (Stull, et al., 2002).

<u>Stray Voltage</u>

Stray electrical voltages from malfunctioning electrical equipment can cause discomfort to dairy cows and lower milk production. Numerous research studies have quantified the physiological and behavioral responses of dairy cattle to electrical currents (Lefcourt, 1991; Aneshansley et al., 1992; Hannah, 2002). The electrical currents required for perception, behavioral change, or physiological effects to occur are widely variable. Dairy cows can feel very low voltages of only 1.0 volt when they occur between a water bowl and the rear hooves (Gorewit et al., 1989). Reinemann (2005) stated that the current level required to produce a behavioral response was less than that required to cause a short-term reduction in feed and water intake, and milk production. Some cows in the study responded by submerging the entire muzzle in the water bowl, effectively providing a larger contact surface area while reducing the maximum local current density in the muzzle. Reinemann (2004) also notes that if cows have adequate time to consume water between current pulses, water was consumed at the same rate as in the absence of current stimulus. Furthermore, symptoms associated with problems of stray voltage or electrical current are not unique, and many factors other than stray voltage and electrical current can cause similar problems in behavior, health, or milk production (Gorewit et al., 1992).

The sources of relatively small amounts of electrical currents passing through animals are often very difficult to locate. Stray voltage or electrical currents may arise because of poor electrical connections, corrosion of switches, frayed insulation, faulty equipment, or heavily loaded power lines.

Information on how to detect and correct stray voltage problems has been known for some time (Appleman, 1991). Periodic evaluation of facilities for stray voltage is suggested. Solutions include voltage reduction, control of sources of voltage leakage, gradient control by use of equipotential planes and transition zones, and isolation of a portion of the grounding or grounded neutral system from the animals. Proper installation of electrical equipment and complete grounding of stalls and milking center equipment should help prevent stray voltage problems. Although stray voltages and electrical currents cannot be totally eliminated, they can be reduced (Albright et al., 1991, 1999; Lefcourt, 1991; Gorewit et al., 1992). Even after appropriate surveillance procedures detect no significant levels of voltage or current at cow contact points, some farmers will insist that their problems are stray voltage. Blaming stray voltage provides the opportunity to blame low milk production, high somatic cell counts, reproduction, and a variety of other maladies on a cause that they claim is out of their control (Graves, 2006).

Social Environment

Dairy cattle are social animals that function within a herd structure and follow a leader to and from pasture or milking center. Cows exhibit wide differences in temperament, and their behavior is determined by inheritance, instinct, physiology, hormones, prior experience and training. Cows are normally quiet (non-vocal) and thrive on gentle treatment by handlers. Handling procedures are more stressful for isolated animals; therefore, attempts should be made to keep several cows together during medical treatment, artificial insemination, or moving cows from one group to another (Whittlestone et al., 1970; Arave et al., 1974). Cattle should have visual contact with each other and with their caretakers (Albright et al., 1999).

Many dairymen allow their cows to develop their own individual personalities as long as no special care or treatment is required. Mass handling of cows dictates that individual cows fit into the system rather than the system conforming to the habits of the cow. The slow milker, the kicker, the boss cow, the timid cow, the explorer, and the finicky eater are usually removed from larger herds, regardless of pedigree.

Although concern is expressed from time to time about temperament and behavioral problems, most attempts at reinforcing correct behavior and disciplining improper behavior have been successful. One dairy study showed that behavior as a reason for disposal was less than 1% of cases. Other categories included: reproductive disorders and diseases; 36%, udder problems and mastitis; 23%, anatomical problems (feet, legs, and skeleton); 11%, digestive problems; 11%, metabolic problems; 7%, and low yield; 4%. The cows culled for behavior mainly represent the truly wild ones which would not conform to training and management (Albright and Beecher, 1981; Albright, 1986b).

Although creatures of habit, gentle dairy animals may be excited into rebellion by the use of unnecessarily severe methods of handling (e.g. shouting and shock prods) and restraint. Attempts to force an animal to do something it does not want to do, often end in failure and can cause the animal to become confused, disoriented, frightened or upset. Handling livestock requires that they be 'outsmarted' rather than outfought and that they be 'outwaited' rather than hurried (Battaglia, 1998b). Most tests of will between the handler and the cow are won by the cow.

Considerable self-stimulation and 'inwardness' occur in cattle due to the rumination process. During rumination, cows appear relaxed with their heads down and their eyelids lowered. Resting cows prefer to lie on their chest, facing slightly uphill.

Also, through cud-chewing as well as mutual and self-grooming, aggression is reduced and there is little or no boredom (Albright, 1986b).

Management developments which have improved the comfort and well-being of dairy cattle include raising calves in individual pens or hutches (Baker, 1981), providing exercise prior to calving (Lamb et al., 1979), grooving or roughening polished, slick concrete flooring (Albright, 1983, 1994, 1995), making use of pasture or earthen exercise lots and removing slatted floors (Albright, 1983), and eliminating stray voltage (Appleman, 1991). Individual stalls (cubicles/free stalls) have resulted in cleaner cows and fewer teat injuries than loose housing. Dairy cattle thrive best when they are kept cool, free from flies and pests and provided with a dry, comfortable bed to lie down (Albright, 1986b).

Dairy cattle have traditionally been kept in groups of 40 to 100 cows. In commercial dairy herds, in Arizona, New Mexico, and Texas, variation in group size - small (50 to 99), medium (100 to 199), and large (200 or more) - did not cause a problem *per se*. Large herd size, however, can affect management decisions because overcrowding with insufficient number of headlocks or inadequate water and feed manger space per cow, irregular or infrequent feeding, and excessive walking distance to and from the milking parlor have a greater impact on behavior and well-being than does group size (Albright et al., 1999).

Self-locking mangers have become standard equipment for large dairy herd operations. In order to evaluate the effects of restraint using self-locking stanchions, 64 Holstein cows from peak to late lactation were restrained at feeding time for 4 h per day for four weekly periods. Milk production, somatic cell counts, mastitis or other health concerns, plasma cortisol concentrations, and total daily feed intake were unaffected by restraint. For the cows locked in stanchions, their eating frequency over 24 h was significantly reduced, but dry matter intake was not affected. Total rumination frequency over 24 h was not significantly different for cows that were restrained; however restrained cows ruminated less during the day following release. Behaviorally, cows that were locked in the stanchions spent significantly more time lying in free stalls after release from restraint. Grooming was also one of the first behaviors performed following release. Grooming was considered to be a behavioral need and was significantly increased during all times when cows were not locked up. Acts of aggression were elevated during all periods following restraint. The use of self-locking stanchions did not appear to affect substantially the overall well-being of the cow (Bolinger et al., 1997). In a similar lock-up trial, milk production was reduced and cortisol increased during the summer months in Utah (Arave et al., 1996a, 1996b).

Other Purdue work with detailed observations, using intact and cannulated cows, suggests a behavioral need for the cow to rest and to ruminate on her left side (Grant et al., 1990; Albright, 1993).

## Cow and Calf Handling

Milk production is a by-product of the reproductive process. Therefore, an essential part of the onset of lactation is the birth of a calf. Unfortunately, newborn calves are sometimes cast aside especially during economic downturns. Calves require special handling and care from the time they are born. The most important point to remember is to feed the newborn calf colostrum soon after birth and within the first 6 h.

A calf should be given 8-10% of its body weight in fresh colostrum by bottle, bucket or tube feeder; twice within 24 h following birth. Colostrum is nutrient rich and provides the calf with vital immunoglobulins. Good nutrition along with proper handling starts a calf on its way toward a healthy life. If young calves are to be marketed, the following three procedures should be used:

1. Provide individual care and colostrum for two to three days after birth.
2. Calves should always have a dry haircoat, have a dry navel cord, and walk easily before being transported. A day-old calf can stand, but it is unsteady and wobbly and is not ready for market (Albright and Grandin, 1993). In England and Canada, the sale of calves under one week old is forbidden. Calves should not be brought to a livestock market until they are strong enough to walk without assistance. To reach adequate strength and vigour, calves need to be a minimum of five days old (Grandin, 1990).
3. Handle calves in transit carefully, protecting them from the sun and heat stress in the summer, and from the cold and wind chill in winter.

By observing behavior and carefully following these recommendations healthier and contented dairy cattle are assured:

1. Always keep hooves trimmed to prevent lameness. A cow with properly trimmed hooves and healthy feet and legs will stand quietly and occasionally shift her weight. Cows with feet and leg problems are more restless, crampy, and uncomfortable; they appear to walk in place. Foot and leg lameness is the single greatest insult to the welfare

of the modern high-producing dairy cow (Albright et al., 1999).

2. Breed first-calf heifers to bulls with a reputation for easy calving.

3. Use caution with calf pullers to prevent internal injuries.

4. If internal injury happens during calving, lift the cow into a standing position for rehabilitation. Nonambulatory or downed animals must not be dragged. Provisions should exist for lifting downer cows. Devices to aid and promote standing include hip lifters (hip clamps), slings (wide belt and hoist), inflatable bags, and warm water flotation systems (Albright et al., 1999).

5. To prevent downed cattle from milk fever and other metabolic disorders, obtain the services of a competent veterinarian or dairy specialist.

6. To prevent mastitis, keep the udder dry and dip teats before and after milking.

7. When loading dairy animals for shipping, allow plenty of handling space. Cattle need ample room to turn, the leaders will then move into the chute, with other animals following. This is an example of leadership - followership as in cattle or sheep, goats and ducks.

8. Stair steps are recommended for loading ramps. Each step should be 10 cm high with a 30 cm tread width.

9. Loading ramps for young stock and animals that are not completely tame should have solid sides.

10. Never attempt to transport cows which become emaciated or too weak to stand. If rehabilitation does not occur within a reasonable time, the animal should be humanely killed on the farm (Livestock Conservation Institute, 1992; National Institute for Animal Agriculture, 2004).

11. When transporting young dairy animals or producing cows, always handle them gently. Since cows are curious, allow them to quietly investigate their new environment and ease into it without outside distractions.

12. Try to ship dairy animals under favorable weather conditions. Avoid extremely hot or extremely cold temperatures that create undue stress and may cause sickness.

Dairy producers have much to gain when cows and young stock are properly handled and cared for (Albright and Grandin, 1993; Albright et al., 1999). Recently, Palmer (2005) has compiled valuable information on animal handling needs including methods, locations, and possible systems.

The Canadian guide (Agriculture Canada, 1990) contains a complete transportation section including definitions, general information, vehicles, containers, space requirements, protecting cattle, food, water and rest for cattle in transit, unfit cattle, pregnant cattle, precautions in cold or hot, humid weather and transportation stress. There is also a section on assembly yards, sales yards, and processing facilities that includes unfit cattle, holding and handling, education of personnel, slaughter and emergency procedures.

Bull Handling

The safety of humans and animals is the chief concern underlying management practices. By virtue of their size and disposition, dairy bulls may be considered as one of the most dangerous domestic animals. Management procedures should be designed to protect human safety and to provide for bull welfare (Albright et al., 1999)

Threat Postures

There are certain major behavioral activities related to bulls. These are threat displays, challenges, territorial activities, female seeking and directing (nudging), and female tending. These behavioral activities tend to flow from one to another (Fraser, 1980). Threat displays in bulls and ungulates (e.g. antelope, bison) are a broadside view (Fig.2.6) when a person or a conspecific invades its flight zone. The threat display of the bull puts him in a physiological state of fight -or- flight. The threat display often begins with a broadside view with back arched to show the greatest profile, followed by the head down, sometimes shaking the head rapidly from side to side, protrusion of the eyeballs and pilo-erection of the hair along the topline. The direct threat is head-on with head lowered and shoulders hunched and neck curved to the side toward the potential object of the aggression. Pawing the ground with the forefeet, sending the earth flying behind or over the back as well as rubbing or horning the earth are often components of the threat display. If in response to the threat display the recipient animal advances with head down in a fight mode, a short fight with butting of horns or heads ensues. If the recipient of the threat has been previously subdued by that animal, he will likely withdraw with no further interaction (Albright and Arave, 1997).

While a bull is showing a threat display, if an opponent such as another bull (or person) withdraws to about 6 m, the encounter should subside and the bull will turn away. If not, the bull will circle, drop into the cinch (flank) body position, or start with a head-to-head or head-to-body pushing. At the first sign of any of the above behaviors, humans should avoid the bull and exit rapidly and hopefully via a predetermined route.

Many people lack the background, attitude, and precaution of dealing with dangerous bulls and parturient cows; therefore additional training and bull/cow behavior information are needed. It is wise to respect and be wary of all bulls especially dairy bulls as they are not to be trusted. Any bull is potentially dangerous. He may seem to be a tame animal, but on any given day he may turn and severely injure or perhaps kill a person, young or old, inexperienced or experienced. This is especially true when a cow is in estrus and needs to be removed from 'his' group or move the group to the holding pen for milking. Never handle the bull alone and never turn your back on a bull. To move cattle or to appear larger and to protect oneself, carry a cane, stick, handle, metal pipe or plastic pole with flap. For further information about bull behavior and handler safety refer to Albright and Arave (1997).

Other Dairy Animals

In addition to bulls, humans must be careful around certain steers, heifers, and recently calved cows protecting their calves. Some animals are different and do not follow the threat display behavior previously mentioned. Be careful of following behavior, walking the fence, bellowing, a cow in estrus and the bull which protects the cow, thereby attacking the handler. An animal's first attack should be its last and it should be sent to the abattoir (Wilson, 1998).

The system of management under which dairy cattle are raised and kept has a profound effect on their temperament, and this is not always taken into consideration. For example, bull calves should never be teased, played with as a calf, treated roughly or rubbed vigorously on the forehead, and the area of the horns. The Fulani herdsmen stroke under the chin (rather than on top of the head) as an appeasement, taming, grooming-like behavior. This is essentially the way cows groom each other (Hart, 1985; Albright and Grandin, 1993; Albright and Arave, 1997).

Transport Developments

Transportation was reviewed by Albright and Arave (1997). Knowledge and utilization of the flight zone are important during the movement of dairy cattle. Cows should be moved at a slow walk, particularly if the weather is hot and humid or if the flooring is slippery.

Heartrate transmitters were implanted in lactating Holstein cows prior to travel (Ahn et al., 1992). Cows were transported 402 km in about 6 h over various road surface conditions in an 8.2 m-long livestock trailer. The two-way journeys started in the morning and ended late afternoon. Cows stayed overnight and were brought back late afternoon. This two-day journey was repeated one week later. Feed and water were provided during the interim between travels, with cows receiving their normal ration for that period. Cows were milked by portable machine according to their regular schedule and confined to a fenced corral of approximately 0.4 hectare. Heart rates taken as travel commenced averaged 89.7 bpm and differed significantly ($P < 0.01$) from all hourly readings. Average heartrate for hours 2, 3, 4, 5, 6 averaged 77.0, 74.8, 71.3, 74.4, and 72.9 bpm respectively (which are all similar to a resting heart rate of 76.5 bpm). Heart rates differed significantly ($P < 0.01$) by road surface averaging 83.3 bpm on a dirt road, 81.2 bpm on a paved rural three and four lane road, 76.1 bpm on paved two lane desert road, and 73.6 bpm on the paved motorway. Heart rates observed gave evidence of habituation on the day of travel and also from week one to week two.

Transport is particularly stressful for young calves that experience mortality rates greater than 20% and bruised stifles to an incidence of 50% or more (Hemsworth et al., 1995). Research on transport of dairy calves has shown that immunological systems are affected by the age at which transport occurs within the first week of life and cognitive changes can be detected at least 6 weeks post-transport. Additionally, adverse effects of transport of young calves can be modulated by several known modulators (yeast cell-wall products) and ascorbic acid, decreasing morbidity and mortality (Eicher, 2006, personal communication and Eicher et al., 2004). Eicher (2006) further indicates that attention must be paid to length of studies regarding young calves, as they may succumb to disease one month following transport.

Calves behavioral and physiological (cortisol, heart rate) reactions to being loaded onto a truck, transported for 30 minutes and unloaded were observed. It took more time and effort to load pair-raised calves than individually housed calves ($P < 0.01$) and less effort to load those that had received additional contact ($P < 0.01$) as compared to those who had received minimal contact. During loading, additional contact calves had lower heart rate ($P < 0.05$) than those that had received minimal contact. During transport pair-housed calves had lower heart rates ($P < 0.05$) as compared to the individually housed calves (Lensink et al. 2001)

Human-Animal Interactions

Recently, this subject has been reviewed by Albright and Arave (1997), Hemsworth and Coleman (1998), and Hemsworth et al. (2002).

The Behavior of the Cow person

Studies on homogeneous dairy herds as defined by similar feeding policy, feeding levels, breed and genetic potential, grazing management and climate, demonstrate the effect of the cow person's behavior and personality (Seabrook, 1972, 1977, 1991, 1994). The highest performance cow people, in terms of milk yield for a given level of input, have the following traits: self-reliant; considerate; patient; independent; persevering; difficult to get on with; forceful; confident; suspicious of change; not easygoing; inadaptable; not neat; not modest; not a worrier; not talkative (quiet); uncooperative; nonsocial ('grumpy'). In summary, they are confident introverts. Some of these traits may seem to be socially undesirable, but it is the cows and not another human's reaction which is critical. People with these traits were more stable and had an air of confidence, enabling them to develop a relationship with their cows which positively influenced the animal's performance. Cows under the care of such a person easily out produced a person lacking confidence or a confident extrovert ('cheerful Charlie') tending to have only average production achievement from their cows.

Building on this work, Reid's (1977) study on high-producing herds both in North America (Canada and USA) and England yielded some important results. Reid concluded that the high production cow person was able to minimize output of adrenaline by the cow and obtain a higher percentage of the milk yield which her genetic capacity permits than others would obtain from the same cow under similar conditions. The high-production cow person achieves this by constant attention to the behavior patterns or performance of each individual cow in the herd. Other interests of Reid's 'confident introverts' included vegetable growing, but the most startling fact was that they also grew either roses, gladioli or chrysanthemums, species that have different varieties requiring specific treatment and which respond to feeding at specific times of the year. The best cowmen were also attuned to instant recognition of each animal in the herd and the individuality of their cows, plus a close identification with the herd. In many cases it was difficult to define whether the herd was regarded as an extension of the family or the reverse.

The Behavior of the Cow

Albright (1978) and Seabrook (1980) have shown that animal behavior differs among dairy herds. One factor which varies both within and between groups of cows is flight distance or, how close one can approach an individual animal without it moving away. In some dairy herds, this distance may be almost zero, whereas in others it may be as high as 6m (20 ft). For individual animals in these herds there will be ranges of values, but they may be lower for one herd than the lowest for another herd. Why do these differences exist, and how do they arise? Some variation could be attributed to conditional learning, e.g. the 'memory' of being struck by a handler, but there is little evidence to account for all of the differences. Seabrook (1994) has shown that animals are effective discriminators and perceive by experience and learning. Cows made the greatest number of approaches under test conditions to the familiar person and fewest to the stranger. Cow person behavior in the milking parlor showed 2.1 times per cow $min^{-1}$ for higher yielding dairy units as compared to 0.5 times per cow $min^{-1}$ for lower yielding units. Likewise, cow person behavior in the milking center talking 'with' and 'to' cows were 2.1 times per $min^{-1}$ and 9.1 words per cow $min^{-1}$ in higher yielding dairy units.

While in the lower yielding dairy units, they were 0.3 times per $min^{-1}$ and 2.1 words per cow $min^{-1}$, respectively. Table 2.3 summarizes responses with dairy cows using pleasant or aversive handling.

Table 2.3: General response of animals under different handling treatments (Seabrook, 1991).

| Action of Cow | Pleasant Handling | Aversive Handling |
|---|---|---|
| Mean entry time to milking center (seconds per cow) | 9.9 | 16.1 |
| Flight distance (nervousness) (m) | 0.5 | 2.5 |
| Dunging in milking center (times per h) | 3.0 | 18.2 |
| Free approaches to humans (times / min) | 10.2 | 3.0 |

Observations of identical one-person units show behavior differences in terms of how long it takes cows to enter the milking center. In some herds the cows are keen to enter; in others they are reluctant to do so. Studies showed the milking centers and their identically sized and shaped collecting yards to be in excellent condition. It is the relationship between the cow person and the cows which seems to explain differences in entry time. It is fallacious to talk about the behavior of dairy cows in isolation; the actual pattern is a reflection of the relationship between human and cow. This connection was realized in the 1940s by Rex Patterson, the pioneer of large-scale dairy farming in England, when he publicly stated that the biggest effect on herd yield and cow behavior on his one-person dairy units was exerted by the cow person (Seabrook, 1972, 1977, 1980). More recently, Seabrook and Wilson (2000) have noted that the attitudes and behavior of stockpersons have been little studied, in spite of being fundamental to animal well-being and performance. Verbal encouragement tends to be lacking with some managers / employers, who may be quick with criticism. They further indicate that the veterinary profession could play an important role by giving due praise to encourage diligent fulfillment of the most disliked work, e.g. cleaning and hoof trimming.

Research (Munksgaard et al.,1995; Passille de et al.,1996; Rushen et al.,1999; Rousing and Waiblinger, 2004)) with cows and calves show clearly that cattle learned to discriminate between humans based on their previous experience and cues based on the colour of clothing worn; approaching them positively; and avoiding those who handled them aversively. Aversive handling can result in a generalized fear of people making handling more difficult and increases the chances of injury to both animal and handler. This fear can be overcome by positive handling. Discrimination was generalized to other locations and cattle appear to be more fearful of humans in an unfamiliar location (Passille de, et al., 1996).

In order to determine if an aversion corridor could be used to evaluate various handling practices, 60 cows were randomly assigned to 5 different treatments; electric prod, shouting, hitting, tail twisting and control. Cows walked down a corridor and treatments were applied at the end of the corridor. Preliminary results suggest that cows found the electric prod most aversive, followed by shouting, hitting, tail twisting and control (Pajor et al., 1998). In a follow-up experiment, 54 cows were randomly assigned to 4 treatments (hit/shout, brushing, control and food). The time and force required for cows to walk down the corridor were measured. Cows on the hit / shout treatment took more time and required more force to walk through the corridor than cows on other treatments ($P < 0.001$). In addition, brushed cows took longer to move through than cows given food ($P < 0.05$) (Pajor et al., 1999). Aversion learning methods show promise as an effective method to determine which handling procedures cows find more aversive or friendly.

Establishing the Relationship

In higher performance herds, where cow person and cow enjoy a good relationship, the animals have a short flight distance, tend to move quickly into the milking center and are comfortable in the cow person's presence. Cow people establish and maintain the relationship by frequently touching and communicating with the animals, treating them with special care at critical points such as calving and first milking after calving, and assuming the roles of both boss animal and caring mother substitute. This close relationship enables the cow person to spot changes in the cows' behavior quickly and thus to prevent situations from developing which could adversely affect performance. In addition, the atmosphere created by this kind of psychological environment seems to be more conducive to rest, which means that the cows may be able to reserve more energy for milk production.

The Implications for Animal Welfare

The animals in the herd where there is a good relationship between people and cows', production is higher, as cows release less adrenaline to block milk letdown. The cows are less nervous, more settled and steady in an environment created by a confident cow person. The pertinent point, from an animal welfare point of view, is that these are not necessarily the best equipped herds technically, e.g. in milking center design. Cow behavior that indicated fear of humans was moderately ($P < 0.05$) to highly ($P < 0.01$) correlated with production and composition. By regression analysis, fear of humans accounted for 19% of variation in milk yield between farms (Breuer et al., (2000). In other words, cows can be under stress in a well-designed system if they cannot develop a good relationship with people. Similarly, they may be in a poor system technically, but may be content and under little stress if they have confidence in and a good relationship with the person who tends to them.

Efficient dairy management and animal welfare would both be served by selecting cow persons who have the correct traits and then further training them to develop a relationship with their animals and so ensure that the animals are able to live in an environment where stress is reduced to a minimum. Design of a system from a welfare perspective is only part of the solution. The most important factor in determining stress is the behavior and attitude of the cow person (Seabrook, 1980).

There are now national programs that provide animal welfare assessments or audits of dairies. An assessor will use many tools such as guidelines, tape measure, stop watch, a body condition score card, locomotion score card, and a hygiene score card (Roenfeldt, 2005).

Husbandry Procedures

Certain dairy cattle behavior (e.g. aggression and kicking) put at risk the health and well-being of herdmates as well as the humans handling the cattle. Several devices and procedures can reduce or modify these behaviors. Certain identification procedures, clipping milk cows, training them with a halter, and milking procedures must be done properly to minimize negative effects on cattle health (Agriculture Canada, 1990; Battaglia, 1998a; Albright et al., 1999). Step-by-step, learn-by-doing techniques for identification, milking, mastitis treatment, downer cows, weaning and training to eat and drink, and body condition scoring of dairy cows have been summarized (Battaglia, 1998a). Castration may be performed on bull calves except those being raised as veal calves. The same is true early in life for dehorning (Battaglia, 1998a). Many dairy calves are born with more than the usual four teats. These supernumerary teats can grow and develop much like a normal teat. They detract from the general appearance of the animal; have the potential to disrupt the milking process later on and to become infected. For these reasons, it is a good practice to remove these extra teats as early as possible in the calf's life. If it is done immediately following birth at the same time the navel is treated, the calf is easy to handle and one qualified person can accomplish the task (Battaglia, 1998a). Because the calf is very young, the cut bleeds only slightly. Removal can be performed in the first 3 mo of life with sharp scissors or scalpel. Older calves and heifers close to calving should have extra teats removed under local anaesthetic by a qualified person (Albright et al., 1999).

## Conclusions

Observation of dairy cattle has been going on for centuries and helps to increase knowledge and improves husbandry techniques. A more logical approach to the study of cow behavior and training is now advocated linking it with commercial operations. Time saved through automation should be invested in observing animals. Knowledge of normal behavior patterns provides an understanding about cattle and results in improved management and handling that will achieve and maintain higher milk yields, animal comfort and well-being. Dairy cattle must fit in well with their herdmates as well as their handlers. For those who like to work with dairy cattle, proper mental attitude of handlers must blend in with skilful management and humane care in today's highly competitive, technological, urban-based society.

## References


Agriculture Canada (1990) Recommended code of practice for the care and handling of dairy cattle. Publication 1853 1E, Ottawa, Ontario, 41 pp.

Ahn, H.M., Arave, C.W., Bunch, T.D. and Walters, J.L. (1992) Heart rate changes during transportation of lactating dairy cows. Journal of Dairy Science 75 (suppl. 1), 166 (abstract).

Albright, J.L. (1978) The behavior and management of high yielding dairy cows. Proceedings British Oil and Cake Mills-Silcock Conference, London, UK, 31 pp.

Albright, J.L. (1983) Putting together the facility, the worker and the cow. Proceedings of the 2nd National Dairy Housing Congress, American Society of Agricultural Engineers. St Joseph, Michigan, USA, pp. 15-22.

Albright, J.L. (1986a) Bovine body language. In: Broom, D.M., Sambraus, H.H. and Albright, J.L. (eds.) Farmed Animals. Torstar Books, New York, pp. 36-37.

Albright, J.L. (1986b) Milk from contented cows - operation of a dairy farm. In: Broom, D.M., Sambraus, H.H. and Albright, J.L. (eds.) The Encyclopedia of Farmed Animals. Equinox (Oxford) Ltd, UK, pp. 56-57.

Albright, J.L. (1987) Dairy animal welfare: current and needed research. Journal of Dairy Science 70, 2711-2731.

Albright, J.L. (1993) Feeding behavior of dairy cattle. Journal of Dairy Science 76, 485-498.

Albright, J.L. (1994) Behavioral considerations - animal density, concrete/flooring. In: Proceedings National Reproduction Workshop. American Association Bovine Practitioners. Rome, Georgia, USA, pp.171-176.

Albright, J.L. (1995) Flooring in dairy cattle facilities. Animal Behavior and the Design of Livestock and Poultry Systems. NRAES-84. Northeast Regional Agricultural Engineers Service, Cornell University, Ithaca, New York, USA, pp. 168-182.

Albright, J.L. and Arave, C.W. (1997) The Behavior of Cattle. CAB International, Wallingford, Oxon, UK, 306 pp.

Albright, J.L. and Beecher, S.L. (1981) Computerized dairy herd disposal study-behavior and other traits. Journal of Dairy Science 64 (suppl. 1), 91 (abstract).

Albright, J.L. and Fryman, L.R. (1964) Evolution of dairying in Illinois with special emphasis on milking systems. Journal of Dairy Science 47, 330-335.

Albright, J.L. and Grandin, T. (1993) Understanding dairy cattle behavior to improve handling and production. Videotape. Journal of Dairy Science 76 (suppl. 1), 235 (abstract).

Albright,J.L., Dillon, W.M., Sigler, M.R., and Wisker, J.E. (1991) Dairy farm analysis and solution of stray voltage problems. Agri-Practice 12; 23-27.

Albright,J.L.,Cennamo, A.R. and Wisniewski, E.W. (1992) Animal behavior considerations. Proceedings National Conference on Milking Center Design. Northeast Regional Agricultural Engineers Service, Cornell University, Ithaca, New York, USA.

Albright, J.L., Bickert, W.G., Blauwiekel, R., Morrill, J.L., Olson, K.E. and Stull, C.L. (1999) Guidelines for dairy cattle husbandry. In: Mench, J.A. (ed.) Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, 1st Revised edn. Federation of Animal Science Societies, Savoy, Illinois, USA, 120 pp.

Aneshansley, D.J., Gorewit, R.G., and Price, L.R. (1992) Cow sensitivity to electricity during milking. Journal of Dairy Science. 75, 2733-2744.

Anon. (1971) Five types of rotary milkers. New Zealand Journal of Agriculture 123(3), 34-35.

Appleman, R.D. (1991) Effects of electrical voltage/current on farm animals: how to detect and remedy problems. United States Department of Agriculture, Agriculture Research Service. Agriculture Handbook 696, Superintendent of Documents, Government Printing Office, Washington, DC, USA.

Arave, C.W., Albright J.L. and Sinclair, C.L. (1974) Behavior, milk yield and leucocytes of dairy cows in reduced space and isolation. Journal of Dairy Science 59, 1497-1501.

Armstrong, D.V. (1992) Milking systems for large dairies. Proceedings Milking Center Design National Conference. Northeast Regional Agricultural Engineering Service, Cooperative Extension, Cornell University, Ithaca, New York, USA.

Armstrong, D.V. (1994) Heat stress interaction with shade and cooling. Journal of Dairy Science 77, 2044-2050.

Armstrong, D.V. and Quick, A.J. (1986) Time and motion to measure milking parlor performance. Journal of Dairy Science 69, 1169-1177.

Armstrong, D.V. and Welchert, W.T. (1994) Dairy cattle housing to reduce stress in a hot climate, In: Buchlin, R.(ed.) Dairy Systems for the 21st Century. Proceedings 3rd International Dairy Housing Conference. American Society of Agricultural Engineers, St. Joseph, Michigan, USA, pp. 598-604.

Armstrong, D.V., Wiersma, F., Gingg, R.G. and Ammon, D.S. (1984) Effect of manger shade on feed intake and milk production in a hot arid climate. Journal of Dairy Science 67 (suppl.1), 211 (abstract).

Armstrong, D.V., Wiersma, F., Fuhrmann, T.J. and Tappan, J.M. (1985) Effect of evaporative cooling under a corral shade on reproduction and milk production in a hot, arid climate. Journal of Dairy Science 68 (suppl.1), 167(abstract).

Armstrong, D.V., Gamroth, M.J., Welchert, W.T. and Wiersma, F. (1989) Parallel milking parlor performance and design. Technical Paper PR-89-101. American Society of Agricultural Engineers, St. Joseph, Michigan, USA.

Armstrong, D.V., Gamroth, M.J., Smith, J.F., Welchert, W.T. and Wiersma, F. (1990) Parallel milking parlor performance and design considerations. Technical Paper 904042, American Society of Agricultural Engineers, St. Joseph, Michigan, USA.

Baker, F.H. (ed.) (1981) Scientific Aspects of the Welfare of Food Animals. Council for Agriculture Science and Technology, Ames, Iowa, USA, Report 91.

Battaglia, R.A. (1998a) Dairy cattle management techniques. Handbook of Livestock Management, 2nd edn. Prentice Hall, Upper Saddle River, New Jersey, USA, pp. 179-207.

Battaglia, R.A. (1998b) Handbook of Livestock Management, 2nd edn. Prentice Hall, Upper Saddle River, New Jersey, USA, 589pp.

Bickert, W.G. (1977) Milking parlor types and mechanization. Technical Paper 77-4552. American Society of Agricultural Engineers, St. Joseph, Michigan, USA.

Bickert, W.G. and Smith, J.F. (1998) Free stall barn design and management for cow comfort. Proceedings of the Midwest Dairy Management Conference. Minneapolis, Minnesota, USA, pp. 103-118.

Bolinger, D.J., Albright, J.L., Morrow-Tesch, J., Kenyon, S.J. and Cunningham, M.D. (1997) The effects of restraint using self-locking stanchions on dairy cows in relation to behavior, feed intake, physiological parameters, health and milk yield. Journal of Dairy Science 80, 2411-2417.

Britt, J.H., Armstrong, J.D. and Scott, R.G. (1986) Estrus behavior in ovarectimized Holstein cows treated repeatedly to induce estrus during lactation. Journal of Dairy Science 69 (suppl. 1), 91(abstract).

Buchlin, R.A., Turner, L.W., Beede, D.K., Bray, D.R., and Hemken, R.W. (1991) Methods to relieve heat stress for dairy cows in hot, humid climates. Applications of Engineering in Agriculture 7, 241-247.

Curtis, S.E. (1983) Environmental Management in Animal Agriculture. Iowa State University Press, Ames, Iowa, USA, 409 pp.

Eicher, S.D. and Dailey, J.W. (2002) Indicators of acute pain and fly avoidance behaviors in Holstein calves following tail docking. Journal of Dairy Science 85, 2850-2858.

Eicher, S.D., Johnson, T.A., Cary, D.C., Patterson, J.A. (2004) Yeast cell wall products plus ascorbic acid: Potential immune modulators for neonatal calves. Proceedings of the Conference of Research Workers in Animal Diseases: 144.

Eicher, S.D., Morrow-Tesch, J.L., Albright, J.L., Dailey, J.W., Young, C.W., and Stanker, L.H. (2000) Tail-docking influences on behavioral, immunological, and endocrine responses in dairy heifers. Journal of Dairy Science 83, 1456-1462.

Eicher, S.D. Morrow-Tesch, J.L., Albright, J.L. and Williams, R.E. (2001) Tail-docking alters fly number, fly-avoidance behaviors and cleanliness, but not physiological measures. Journal of Dairy Science 84, 1822-1828.

Fahey, A.G., Schutz, M.M., Pajor, E.A., Eicher, S.D., Larkin, S.J., and Scott, K.A. (2002) The effect of holding pen time on milk production and blood components in dairy cows. Journal of Dairy Science 85 (Suppl. 1), 82-83 (abstract).

Fraser, A.F. (1980) Farm Animal Behavior, 2nd edn. Bailliere Tindall, London, 291 pp.

Gooding, B. (1971) Farmers combine. New Zealand Journal of Agriculture 123(3), 36-38.

Gorewit, R.C., Aneshansley, J.D., Ludington, R.A., Pellerin, R.A and Shao, Xin (1989) AC voltage effects in water bowls: effects on lactating Holsteins. Journal of Dairy Science 72, 2184-2192.

Gorewit, R.C., Aneshansley, J.D., and Price, L.R. (1992) Effects of voltages on cows over a complete lactation. Journal of Dairy Science 75, 2719-2725.

Grandin, T. (1990) Calves you sell should be old enough to walk. Hoard's Dairyman 135, 776.

Grant, R. (2005) All cows need "Vitamin R." Hoard's Dairyman 150, 658.

Graves, R.E. (2006) Is stray voltage to blame? Hoard's Dairyman 151, 36.

Grant, R.J., Colenbrander, V.F. and Albright, J.L. (1990) Effect of particle size in forage and rumen cannulation upon chewing activity and laterality in dairy cows. Journal of Dairy Science 73, 3158-3164.

Gustafson, G.M. (1993) Effects of daily exercise on the health of tied dairy cows. Preventative Veterinary Medicine 17, 209-223.

Hart, B.L. (1985) The Behavior of Domestic Animals. W.H. Freeman, New York, USA, 390 pp.

Hemsworth, P.H., Coleman, C.J., Barnett, J.L., Borg, S., and Dowling, S. (2002) The effects of cognitive behavioral intervention of commercial dairy cows. Journal of Animal Science 80, 68-78.

Hemsworth, P.H. and Coleman, G.J. (1998) Human-Livestock Interactions: The Stockperson and the Productivity and Welfare of Intensively Farmed Animals. CAB International, Wallingford, Oxon, UK, 152 pp.

Hemsworth, P.H., Barnett, J.L., Beveridge, L. and Mathews, L.R. (1995) The welfare of extensively managed dairy cattle: a review. Applied Animal Behavior Science 42, 161-182.

Holmes, B.J. and Graves, R.E. (1994) Natural ventilation for cow comfort and increased profitability. In: Dairy Systems for the 21st Century. Proceedings 3rd International Dairy Housing Conference. American Society of Agricultural Engineers, St. Joseph, Michigan, USA, pp. 558-568.

House, H.K. (1999) Mattresses: the case of cow comfort. Hoard's Dairyman 144, 11.

Jarrett, J.A. (1995). Rough concrete was making cows lame. Hoard's Dairyman 140, 697.

Kiley-Worthington, M. (1976) The tail movements of ungulates, canids and felids with particular reference to their causation and function as displays. Behavior 56, 69-115.

Kilgour, R. (1985) The definition, current knowledge and implementation of welfare for farm animals - a personal view. In: Mickley, L. and Fox, M. (eds.) Advances in Animal Welfare Science. The Humane Society of the United States, Washington, DC, USA, pp. 31-46.

Lamb, R.C., Baker, R.O., Anderson, J.J. and Walters, J.L. (1979) Effects of forced exercise on two-year-old Holstein heifers. Journal of Dairy Science 62, 1791-1797.

Lefcourt, A.M. (ed.) (1991) Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems. Agriculture Handbook Number 696. United States Department of Agriculture, Washington, DC, USA.

Lensink, B.J., Raussi, S., Boivin, X., Pyykkonen, M., and Vessier, I. (2001) Reactions to handling depend on housing condition and previous experience with humans. Applied Animal Behavior Science 70, 187-199.

Livestock Conservation Institute / National Institute for Animal Agriculture (1992) Proper Handling Techniques for Non-ambulatory Animals. Downer Task Force, Madison, Wisconsin, USA, 19pp.

Matthews, L.R., Phipps, A., Verkerk, G.A., Hart, D., Crockford, J.N., Carragher, J.F., and Harcourt, R.G. (1995) The effects of tail docking and trimming on milker comfort and dairy cattle health, welfare and production. Contract Research Report to Ministry of Agriculture and Food. Wellington. Animal Behavior and Welfare Research Center, AgResearch Ruakura, Hamilton, NZ.

McFarland, D.F. (2003). Free-stall design: cow recommended refinements. Proc. Of the 5th Int'l. Dairy Housing Conf., Fort Worth, TX. Am. Soc. Agric. Eng., St. Joseph, MI, pp. 131-138.

Metcalf, J.A., Roberts, S.J., and Sutton, J.D. (1992) Variations in blood flow to and from the bovine mammary gland measured using transit time ultrasound and dye dilution. Research in Veterinary Science 53, 59-63.

Midwest Plan Service (1985) Dairy Housing and Equipment Handbook, 4th edn. Iowa State University, Ames, Iowa, USA.

Midwest Plan Service (2000) Dairy Freestall Housing and Equipment Handbook. 7th edn. Iowa State University, Ames, Iowa, USA, 136pp.

Munksgaard, L., Passille, de A.M., Rushen, J., Thoxberg, K. and Jensen, M.B. (1995) The ability of dairy cows to distinguish between people. In: Rutter, S.M., Rushen, J., Randle, H.D. and Eddison, J.C. (eds.) Proceedings 29th International Congress. International Society for Applied Ethology. Exeter, UK, and Universities Federation of Animal Welfare, Potters Bar, UK, p. 14.
O'Callaghan, M.A. (1916) Farm Implement and Machinery Review, October (Australia).

Pajor, E., Rushen, J. and Passille de, A.M. (1998) Development of aversion learning techniques to evaluate dairy cow handling practices. Journées de Recherche et Colloque en Productions Animales. Presented at Hôtel des Gouverneurs, Sainte-Foy, Quebec, Canada, May 21-22 (abstract).

Pajor, E., Rushen, J. and Passille de, A.M. (1999) Aversion learning techniques to evaluate dairy cow handling practices. 91st Annual Meeting American Society of Animal Science, Indianapolis, Indiana, USA, July 21-24. Journal of Animal Science 77, (abstract).

Palmer, R.W. (2005) Animal Handling Needs, Chapter 4. Dairy Modernization. Thomson Delmar Learning, Clifton Park, New York pp. 51-60.

Passille de, A.M., Rushen, J., Ladewig, J. and Petherick, C. (1996) Dairy calves discrimination of people based on previous handling. Journal of Animal Science 74, 969-974.

Plumb, C.S. (1893) Does it pay to shelter milk cows in winter? Purdue University Agricultural Experiment Station. Bulletin 47, West Lafayette, Indiana, USA.

Quaife, T. (1999) Rotary parlors are here to stay. Dairy Herd Management 36(3), 44-48.

Quaife, T. and Roenfeldt, S. (2006) Keep cows cool. Dairy Herd Management 43(2), 20-28.

Rankin, G.W. (1925) The Life of William Dempster Hoard. W.D. Hoard & Sons Press, Fort Atkinson, Wisconsin, USA.

Reid, N.S.C. (1977) To endeavour to correlate any common factors which exist in herdsmen in high yielding dairy herds. Nuffield Farming Scholarship Report, London, UK, 21pp.

Roenfeldt, S. (2005) What do your cows say about their welfare? Dairy Herd Management 42(8) 24-28.

Roman-Ponce, H.W., Thatcher, W., Buffington, D.E., Wilcox, C.J. and Van Horn, H.H. (1977) Physiological and production responses of dairy cattle to a shade structure in a subtropical environment. Journal of Dairy Science 60, 424-430.

Rousing, T. and Waiblinger, S. (2004) Evaluation of on-farm methods for testing the human-animal relationship in dairy herds with cubicle loose system-test-retest and inter-observer reliabilityand consistency of familiarity to test person. Applied Animal Behavior Science 85, 215-231.

Rushen, J., Passille de, A.M., and Munksgaard, L. (1999) Fear of people by cows and effects on milk yield, behavior, and heart rate at milking. Journal of Dairy Science 82, 720-727.

Schultz, T.A., Collar, L.S. and Morrison, S.R. (1985) Corral misting effects on heat stressed lactating cows. Journal of Dairy Science 68, (suppl.1), 239 (abstract).

Seabrook, M.F. (1972) A study to determine the influence of the herdman's personality on milk yield. Journal of Agricultural Labor Science 1, 45-59.

Seabrook, M.F. (1977) Cowmanship. Farmers Weekly, London, 24 pp.

Seabrook, M.F. (1980) The psychological relationship between dairy cows and dairy cowmen and its implications for animal welfare. International Journal for the Study of Animal Problems 1, 295-298.

Seabrook, M.F. (1991) The human factor - the benefits of humane and skilled stockmanship. In: Carruthers, S.P. (ed.) Farm Animals: It Pays To Be Humane. Center for Agricultural Strategy, University of Reading, Reading, UK, pp. 62-70.

Seabrook, M.F. (1994) Psychological interaction between the milker and the cow. In: Bucklin, R. (ed.) Dairy Systems for the 21st Century. American Society of Agricultural Engineers, St Joseph, Michigan, USA. pp. 49-58.

Smith, J.F., Armstrong, D.V., Gamroth, M.J. and Harner, J. III. (1998) Factors affecting milking parlor efficiency and operator walking distance. Applied Engineering in Agriculture 14, 643-647.

Stephens, D.B. (1980) Stress and its measurement in domestic animals: a review of behavior and physiological studies under field and laboratory situations. Advances in Veterinary Science and Comparative Medicine 24, 179.

Stull, C.L., Payne, M.A., Berry, S.L., and Hullinger, P.J. (2002) Evaluation of the scientific justification for tail-docking in dairy cattle. Journal of the American Veterinary Medical Association 220, 1298-1303.

Tucker, C.B., Zdanowicz, G., and Weary, D.M. (2006) Brisket boards reduce freestall use. Journal of Dairy Science 89, 2003-2007.

Underwood, W., McClary, D., and Kube, J. (1995) The bovine perfect sleeper or use of shredded rubber filled polyester mattresses to prevent injury to dairy cattle housed in tie stalls. Bovine Practitioner 29, 143-148.

Van Baale, M., Smith, J., Jamison, C., Rodriguez, R., and Baumgard, L. (2006) Evaluate the efficacy "heat stress audits" of your cooling system through core body temperature.

Weary, D. and Tucker, C. (2006) What's the latest in freestall comfort? Hoard's Dairyman 151, 357.

Whittlestone, W.G., Kilgour, R., de Langen, H. and Duirs, G. (1970) Behavioral stress and the cell count of milk. Journal of Milk and Food Technology 33, 217-220.

Wilson, P. (1998) An animal's first attack should be its last. Hoard's Dairyman 143, 787.

Wood, M.T. (1977) Social grooming in two herds of monozygotic twin dairy cows. Animal Behavior 25, 635-642.

# CHAPTER 3

## INFLUENCE OF FREE-STALL BASE ON TARSAL JOINT LESIONS AND HYGIENE IN DAIRY COWS

### Introduction

Plumb (1893) demonstrated economic and welfare advantages from housing dairy cows during cold winter months rather than leaving them outside. The design and dimension of stalls affect usage by cows (Tucker et al., 2004). Cows should be able to perform the natural movements associated with getting up and lying down without injury; cows provided with a softer bed are known to stand up and lie down twice as often as cows on concrete (Haley et al.,2001). Cows should be provided comfortable well-maintained beds (Tucker et al., 2006), and enough beds, so as not to have to wait to lie down (Wierenga, 1990). Cushioning ability of stall beds is an important feature in stall design (Fulwider and Palmer, 2004a; Manninen et al., 2002).

Severe leg injuries may result in pain and suffering (Wechsler et al., 2000). Sogstad et al. (2006) reported that more clinical mastitis and teat injuries were associated with cows exhibiting tarsal wounds and swellings. According to Haley et al. (1999) mattresses were responsible for fewer leg injuries than concrete stalls. Fewer leg injuries were reported for cows maintained on deep-bedded stalls versus rubber-filled mattresses (Weary and Taszkun, 2000). Wechsler et al. (2000) noted that cows bedded with straw had fewer scabs, wounds, and hairless tarsal joints than those in free-stalls with soft lying mats. Tucker et al. (2003) noted that lying surface affects udder health, and although the relationship between organic bedding and mastitis are well known, the costs associated with maintaining deep-bed systems resulted in increased rubber filled mattress use. Cow preferences for softer lying surfaces corresponded with reduced incidence and severity of leg injuries in dairy cows (Tucker et al., 2003). Westerath et al. (2006) found that tarsal joint lesion scores increased steadily over time whether finishing bulls were kept on slatted concrete, slatted concrete with rubber, or free-stalls with a foamed ethylene vinyl acetate mat, a rubber mat, or a rubber filled mattress. Sand stalls were protective with regard to tarsal joint lesions, while rubber filled mattresses provided no advantage when compared to concrete stalls (Vokey et al., 2001). Sand is considered by many as the ideal stall surface for injury reduction, although stall maintenance is an issue.

Bewley et al. (2001) reported that WI dairy producers felt that sand provided some cow comfort advantages, but indicated higher satisfaction with bedding costs and manure handling in mattress-based systems. They found no difference in rolling herd average milk production or somatic cell scores between herds with these bed types. Cow preference tests (Fulwider and Palmer, 2004b; Wagner-Storch et al., 2003) showed that waterbeds were low to intermediate in preference as cows require time to adjust to the wobbly nature of this bed type.

Sand and rubber filled mattresses are among the most commonly used stall bases in the Midwest. Producers have strong opinions regarding these base types. Waterbeds have been the focus of few research projects, are relatively new, and gaining in popularity due to purported minimal bedding needs, low incidence of tarsal joint abrasion, and greater useful life as compared with other mattress types. Due to the novelty of compost pack barns, 6 dairies were included in this study. The purpose of this study was to compare rubber filled mattress, sand, and waterbed lying area surfaces for dairy cows with respect to tarsal joint lesions, hygiene and somatic cell count based on field data collected on many dairies.

## Materials and methods

A total of 113 dairies in 5 states (WI, MN, NY, IA, IN) and comprising 90,162 cows were visited during a 4-mo period beginning October 14, 2005. Due to mixtures of bed types within a pen, or ineligible bed (foam mattress or rubber mat) or bedding types (recycled manure solids); only 94 dairies were included in the free-stall hygiene analysis. Cows were maintained on 1 base type for a minimum of 1 yr to be eligible for the tarsal joint and tuber calcis study, which limited data to 85 free-stall dairies. The free-stall dairy farm units ranged from 80 to 4,286 cows, with a mean of 803 cows. An attempt was made to visit equal numbers of dairies of each bed type in each state. Compost pack dairies were smaller in size ranging from 66 to 195 cows with a mean of 99 cows.

The North American manufacturer of cow waterbeds, Advanced Comfort Technology, Inc., Reedsburg, WI provided a list of dairies utilizing waterbeds (55) plus neighboring dairies with sand (16), or rubber filled mattresses (26) for the selected states. Initial contact with producers was made and an appointment requested within the week. Fifty-three additional dairies were included which was comprised of 113 as a result of stopping at a dairy, or requesting names of local producers who may be willing to participate at the local veterinary office, feed mill, university extension office, equipment dealer, or participating producers.

Ninety-four dairies were included in the hygiene analysis (Table 3.1) as bed or bedding type of the remaining dairies did not fit study traits. Only 85 dairies had cows on the given bed type long enough to be included in the tarsal joint and tuber calcis analysis

(Table 3.1). Production information, stocking density, stall dimensions, bedding amount, bedding frequency and type, and the number of cows in fourth lactation or greater were recorded. All sand-stall dairies included in the analysis had a concrete manure curb at the rear of the stall. Bedding materials most commonly used on dairies that provided waterbeds or rubber filled mattresses included sawdust, rice hulls, chopped straw, or lime. Five free-stall dairies re-used (recycled) sand, whereas all others bedded with new sand. None of the dairies included in the analysis used recycled manure or digester solids as bedding materials. Six compost pack dairies in MN were included as supplemental information, since they are a relatively new innovation, and may be of interest to producers for special needs cows.

Table 3.1: Farms visited and cows recorded for tarsal joint lesions[1] and hygiene by free-stall bed type included in the analysis.

| Stall bed type | Tarsal -scored Farms | Tarsal -scored cows | Hygiene-scored Farms | Hygiene-scored cows |
|---|---|---|---|---|
| Compost[2] | 6 | 399 | 6 | 399 |
| RFM[3] | 31 | 3,615 | 38 | 4,131 |
| Sand | 26 | 3,651 | 27 | 3,855 |
| Waterbed | 28 | 2,561 | 29 | 2,725 |
| Totals | 91 | 10,226 | 100 | 11,110 |

[1]Fewer farms were included in the tarsal study as cows were required to be on the specified bed type for a minimum of 1 yr.
[2]Compost pack included as supplemental information.
[3]Rubber-filled mattress

One pen of cows that contained the highest numbers of early lactation multiparous cows was individually scored in the on each dairy at milking time. All scores were assigned by 1 individual. If the dairy had more than 1 pen of cows that fit the above criteria, the pen with the oldest cows was measured.

Leg lesion measurements

Five areas on both rear legs were scored for skin lesions. These were lateral and medial surfaces of the tarsal joint and the lateral, medial, and dorsal surfaces of the tuber calcis. This was similar to the 2-point scoring system utilized by Weary and Taszkun (2000), but extended to a 4-point scale. The following scores were assigned: 0 (no hair loss or swelling), 1 (hair loss, no swelling), 2 (swelling), or 3 (severe swelling). Hair loss patches (score 1) were 1.8 cm in diameter or larger. Score 2 swellings were smaller than 7.4 cm in diameter and may or may not have had a dry scab; but no bleeding or drainage. Swellings larger than 7.4 cm in diameter were assigned score 3, and may have been purulent, extensive, or bleeding. If a cow suffered hair loss or swelling, both legs were generally affected. If a cow suffered a number of lesions on both legs it was noted, but only the most severe lesion per location was utilized in the analysis. Whenever knees could be scored without interrupting cow flow in the, scores of 0, 1, 2, or 3 were assigned using the same scoring system. All injuries observed were noted.

Cow hygiene measurements

Hygiene scores were assigned to every cow in the selected pen. Each cow was assigned a score with 1 being clean and 5 being soiled. The hygiene score card used by Reneau et al. (2005) was used as a guide. Hygiene score 1 was assigned to cows with no visible manure stains or dried manure. A score of 2 was given to cows with manure stains, but no visible dried manure on the legs or udder. Cows with dried or wet manure on the legs or udder received a score of 3. Heavily soiled cows were assigned a score of

4; while a score of 5 was reserved for cows that had both manure stains and dried manure on the legs, udder, and ventral abdomen (i.e., alley-layers).

Production information

Rolling herd averages for milk, fat, protein, somatic cell count, cow age, the number of mature cows defined as fourth lactation or greater, culling rate, and annual death rate were provided from herd records. Data were collected regarding frequency of barn cleaning and stall bedding, bedding type, and number of cows lame on the day of visit.

Statistical analysis

Lesion scores were analyzed as the percentage of cows per farm with lesions and by the percentage of cows with a specific lesion location. Differences in tarsal joint and tuber calcis lesions, lesion severity, hygiene percentages, and hygiene level between bed types were analyzed with a completely randomized 1-way ANOVA with farm as the experimental unit (SAS 9.1). Pair-wise comparisons were compiled using t-tests when there were significant differences between bed types. Fisher's protected LSD (t-test) was performed to control the error rate for pair-wise comparisons; i.e., pair wise comparisons were only done if the analysis of variance F-test was significant. Pearson correlations were used for comparing lesion scores, hygiene scores, and production measures.

## Results and discussion

Tarsal lesions

Cows on rubber filled mattress dairies had more score 1 ($P \leq 0.0001$), 2 ($P < 0.0001$), and 3 ($P < 0.0001$) lesions than cows on sand or waterbeds (Table 3.2). Compost pack cows exhibited no lesions of any kind, with the exception of a few cows on 1 dairy that were recently purchased from a free-stall facility. There was no difference between cows on sand or waterbeds with regard to lesion score, although there was a difference in lesion location.

Table 3.2: Influence of free-stall bed type on percent of cows with various lesion scores.

| Stall bed type | Lesion score 0[1] | 1[2] (SEM) | 2[3] (SEM) | 3[4] (SEM) |
|---|---|---|---|---|
| Compost[5] | 100.0 | 0.0 | 0.0 | 0.0 |
| RFM[6] | 28.4 | $54.6^{ax}$ (4.4) | $14.0^{a}$ (1.4) | $3.0^{a}$ (0.4) |
| Sand | 75.0 | $22.5^{b}$ (4.7) | $2.3^{b}$ (1.5) | $0.2^{b}$ (0.4) |
| Waterbed | 64.8 | $29.8^{y}$ (4.3) | $5.0^{b}$ (1.4) | $0.4^{b}$ (0.4) |

$^{ab}$Percentages within columns with different letters are different ($P < 0.0001$).
$^{xy}$ Percentages within columns with different letters are different ($P = 0.0001$).
[1]Lesion score 0 was no hair loss or swelling.
[2]Lesion score 1 represented hair loss on the tarsal joint or tuber calcis, 1.8 cm in diameter or larger and no swelling.
[3] Lesion score 2 was swelling no larger than 7.4 cm in diameter with no bleeding or drainage.
[4] Lesion score 3 was swellings larger than 7.4 cm in diameter and may have been bleeding or purulent.
[5] Compost pack included as supplemental information, not analyzed.
[6]Rubber-filled mattress

When broken down by lesion location, rubber filled mattress cows had more lateral tarsal joint lesions ($P < 0.01$) than those on sand; and more ($P < 0.03$) than cows on waterbeds (Table 3.3). There was no difference between the 3 bed types regarding medial surface tarsal joint lesions. The only comparison that resulted in a difference for lesions on the lateral tuber calcis was between cows on sand or waterbeds ($P = 0.03$) with cows on sand having fewer. Only 1% of affected cows on sand or waterbeds suffered lesions that involved swelling, while 2% of mattress cows had swelling at the lateral tuber calcis location. A greater percentage of cows on sand had dorsal lesions ($P <$

0.0001) than cows on rubber filled mattress or waterbed, likely due to abrasion with the concrete curb in deep bed stalls. Pearson correlations with 85 farms (rubber filled mattress, sand, and waterbed) indicated a negative correlation between frequencies of lesion score 2 and stall length (r = -0.23; $P = 0.05$).

Table 3.3: *Influence of free-stall bed type on percent of affected cows and lesion location.*

| | Tarsal joint | | Tuber calcis | | |
|---|---|---|---|---|---|
| Stall bed type | Lateral (SEM) | Medial (SEM) | Lateral (SEM) | Dorsal | Medial (SEM) |
| Compost[1] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RFM[2] | $81.9^{ar}$ (0.3) | 3.0 (0.5) | 49.7 (0.2) | $2.7^{y}$ | 13.4 (0.3) |
| Sand | $17.8^{s}$ (0.3) | 4.8 (0.5) | $29.2^{s}$ (0.3) | $29.4^{x}$ | 20.0 (0.3) |
| Waterbed | $40.9^{b}$ | 2.7 | $67.4^{r}$ | $1.9^{y}$ | 17.5 |

$^{ab}$ Percent within columns with different superscripts are different ($P = 0.03$).
$^{rs}$ Percent within columns with different superscripts are different ($P = 0.01$).
$^{xy}$ Percent within columns with different superscripts are different ($P = 0.0001$).
[1] Compost pack included as supplemental information.
[2] Rubber-filled mattress

The present study is in agreement with Weary and Taszkun (2000), with lesions being most prevalent on cows with rubber filled mattress beds. The lateral tarsal joint and lateral tuber calcis were the most affected locations on rubber filled mattress bed cows in both studies, although they reported a higher percentage of cows affected (91%). Their study included 6 rubber filled mattress dairies, took place in the Pacific Northwest, and different or more abrasive bedding materials may have been a factor. Cows on sand beds were similarly affected (24%) in their study with the dorsal tuber calcis being the most often injured location, perhaps as a result of contact with the concrete curb when sand becomes low. These injuries may be prevented by bedding more frequently, which could be advantageous in controlling *Streptococcus* spp., as suggested by Kristula et al. (2005) who further noted that sand stalls are generally filled only once weekly. Low percentages of cows suffered lesions at the medial surface of the tarsal joint (3.3, 4.2, and

2.7) on rubber filled mattresses, sand, or waterbeds, respectively. Percentages of cows with lesions at the medial tuber calcis were more common (13.7, 17.6, and 17.5) on rubber filled mattresses, sand, or waterbeds, respectively. Sand-bedded cows had the highest proportion of medial tuber calcis lesions at 20% (Table 3.3), which differs from Weary and Taszkun (2000). This may be the result of short sand lying area, stalls not maintained "full" and subsequent abrasion on the concrete curb.

Knee lesions

Hairless knees were frequently observed (28 to 61% of cows on 7 dairies) on dairies when cows were bedded with coarse or recycled sand containing larger particles. Knees were swollen on 7 to 11% of cows on 3 dairies that utilized coarse sand. When sand and recycled sand dairies were compared for average knee score, recycled-sand dairies had more ($P = 0.04$) hairless knees than dairies using new sand. Fifty percent of dairies with cows on waterbeds had some cows with hairless knees, while the average percent for all waterbed dairies was $0.05 \pm 0.02$. The dairy with the most affected cows (hair loss, 15%; swelling 13%) was the only dairy with a 10.2- × 10.2-cm cast iron brisket locator. Cows may have bumped their knees against the iron when rising. The next 2 most affected waterbed dairies had knee hair loss of 8% and 7% and swelling of 3% and 1%, respectively.

Cow hygiene

Cows maintained on mattresses or waterbeds had greater proportions of lower hygiene scores than cows on sand ($P < 0.0001$; Table 3.4). Hygiene scores for compost cows were most similar to those held by cows on waterbeds. Cows that were assigned scores of 1 or 5 were very few and not different.

Table 3.4: Influence of stall bed type on percent of cows and hygiene score.

| Stall bed type | $1^{1}$(SEM) | $2^{2}$(SEM) | $3^{3}$(SEM) | $4^{4}$(SEM) |
|---|---|---|---|---|
| Compost[5] | 0.0 | 79.0 | 20.3 | 0.8 |
| RFM[6] | 0.4(0.00) | $84.0^{a}$(0.01) | $15.2^{b}$(0.01) | $0.4^{b}$(0.00) |
| Sand | 0.4(0.00) | $73.2^{b}$(0.01) | $23.8^{a}$(0.01) | $2.5^{a}$(0.00) |
| Waterbed | 0.4(0.00) | $80.4^{a}$(0.01) | $18.6^{b}$(0.01) | $0.6^{b}$(0.00) |

[ab] Percentages within columns with different letters are different ($P < 0.0001$).
[1] Score 1 represents cows with no visible manure stains or dried manure attached to them.
[2] Score 2 was given to cows with manure stains, but no visible dried manure on the legs or udder.
[3] Score 3 reflected cows with dried or wet manure on the legs or udder.
[4] Score 4 was assigned to heavily soiled cows.
[5] Compost pack barns may be of interest to larger producers as special needs facilities. It is included here as supplemental information.
[6] Rubber-filled mattress

Dairies with rubber filled mattresses or waterbeds bedded more frequently ($P = 0.02$), at 3.9 times weekly, versus sand dairies which bedded 1.9 times weekly (Table 3.5). Somatic cell counts by bed type were not different (Table 3.5). Barns with rubber filled mattresses were cleaned more frequently (3.4/d) than either sand (2.5 / d, $P = 0.05$) or waterbed dairies (2.4 / d, $P = 0.04$).

Table 3.5: Associations of bed type with percent mature cows, somatic cell count, percent culled and weekly winter bedding frequency.

| Stall bed type | Mature cows[1] (SEM) | SCC[2] (SEM) (1000's/ml) | Cull cows[3] (SEM) | Bedding frequency[4] (SEM) |
|---|---|---|---|---|
| Compost[5] | 19.4 | 176.7 | 20.4 | 0.3 |
| RFM[6] | $13.3^{s}$ (1.6) | 241.5 (14.5) | $29.4^{x}$ (1.4) | $3.9^{a}$ (0.5) |
| Sand | $13.5^{b}$ (1.8) | 235.2 (16.1) | 25.6 (1.5) | $1.9^{b}$ (0.6) |
| Waterbed | $19.8^{ar}$ (1.8) | 232.5 (15.2) | $22.8^{y}$ (1.5) | $3.9^{a}$ (0.6) |

[ab] Percentages with different superscripts within column differ ($P = 0.02$).
[rs] Percentages with different superscripts within column differ ($P = 0.01$).
[xy] Percentages with different superscripts within column differ ($P = 0.001$).
[1] Mature cows are defined as those in fourth lactation or greater.
[2] Somatic cell count
[3] Percentage of cows culled annually.
[4] Bedding frequencies are on a per week basis for winter months.
[5] Compost pack is included here as supplemental information.
[6] Rubber-filled mattress

Pearson correlations were obtained for rubber filled mattress, sand, and waterbed farms combined. Somatic cell counts were correlated with score 3 lesions (r = 0.32; $P$ = 0.003), annual death rate (r = 0.34; $P$ = 0.002), and percentages of cows reported lame on the day of visit (r = 0.45; $P$ < 0.0001). There was a significant correlation (r = 0.60, $P$ = 0.0006) for score 3 lesions and somatic cell count for rubber filled mattresses. Somatic cell count had an r = -0.46 ($P$ = 0.01) with stall length for rubber filled mattress dairies. This trait was positive and not significant for sand and waterbed bases. Stall width was correlated with somatic cell count (r = -0.49) for rubber filled mattress ($P$ = 0.005), while negative and not significant for sand and waterbed bases.

Death rate (r = 0.52; $P$ < 0.004) and cows reported lame on the day of the visit (r = 0.52; $P$ < 0.001) were related to somatic cell count in rubber filled mattress herds. The somatic cell count relationship was true for all 3 base types: 29 rubber filled mattress dairies, r = 0.39 ($P$ = 0.001); 27 sand dairies, r = 0.45 ($P$ = 0.02); and 29 waterbed dairies, r = 0.39 ($P$ = 0.04). Lame cow percentages were correlated (r = -0.22) with neck rail height ($P$ = 0.05). When dairies were split by thirds for the percentage of cows with score 2 and 3 lesions, the best and worst for somatic cell count were rubber filled mattress (219.7 ± 24.3), (242.7 ± 25.4); sand (228.9 ± 28.1), (201.7 ± 28.1); waterbed (232.0 ± 26.7), (251.0 ± 26.7). Somatic cell counts listed represent thousands of cells/ml.

Poor hygiene of the hind legs and udder was associated with increased somatic cell score (Reneau et al., 2005; Schreiner and Ruegg, 2003). Veissier et al. (2004) reported a tendency for soiling to increase as the number of stall beds per cow decreased. The farm with the cleanest cows had the least mastitis (Ward et al., 2002). Our study found no difference in somatic cell count by bed type. A possible explanation for there being no difference between bed types for somatic cell count is that none of the dairies used recycled manure or digested solids as bedding. The average somatic cell count for each bed type (Table 3.5) including compost pack was lower than the 2005 national average of 296,000 (Miller and Norman, 2006).

Best and worst practices

Since dairies in this study voluntarily participated there may have been a bias towards well-managed dairies being included. Dairies with rubber filled mattresses which had the fewest cows affected by lesions and the least severe lesions bedded daily or every other day with 1 to 1.4 kg of straw or a non-irritating kiln dried shavings. The main difference between dairies with the least and most severely affected cows was in frequency of adding bedding. The rubber filled mattress dairy with the lowest percentage of cows with lesions (12% lesion score 1; 2% lesion score 2, 0% lesion score 3) bedded daily with sawdust. When the top and bottom third of rubber filled mattress dairies were sorted by percentages of cows with combined score 2 and 3 lesions, differences were found for rolling herd average milk production (7,530 ± 698 kg vs. 10,206 ± 698) kg ($P$ = 0.005). There was no relationship between milk production and lesions on sand or waterbed dairies. The third of cows on sand dairies with the lowest lesion percentages (0.0 ± 1.3) had an average annual milk production of 8,818 ± 772 kg and the third with the highest lesion percentages (4.8 ± 1.3) had an average annual milk production of 9,070 ± 772 kg . The difference in average annual milk production between these 2 groups of dairies was ($P$ = 0.71). The third of cows on waterbed dairies with the lowest lesion percentages averaged 0.7 ± 1.2, while the third with the highest lesion percentage was 9.3

± 1.2. There was no difference for average annual milk production (8,063 ± 735 kg) between these dairies. The third of rubber filled mattress dairies with the fewest score 2 and 3 lesions (4.19 ± 1.14) had an average annual milk production of 7,530 ± 698 kg, while the third with the most lesions (27.0 ± 1.1) averaged 10,206 ± 698 kg ($P = 0.005$), which was the highest production for any third regardless of bed type.

On rubber filled mattress dairies, somatic cell count, death loss, and the number of cows reported lame on the day of visit were all positively correlated percentage of lesions. A possible explanation for positive correlation between milk production and lesions on rubber filled mattress dairies is that stalls on these dairies may have been too short or narrow for the cows. Narrow stalls were correlated with lesion score 3 ($r = -0.52$, $P = 0.01$) on rubber filled mattress dairies. There was a correlation between somatic cell count and stall width (-0.50, $P = 0.005$), and stall length (-0.46, $P = 0.01$). Dairy producers on rubber filled mattress dairies whose priority is maximum production may have constructed stalls with less space for their cows.

Lateral tarsal joint hair loss on 5 dairies with recycled sand was 18%, 19%, 19%, 39%, and 59%. The recycled sand dairy with 59% hairless lateral tarsal joints had beds that consisted of 95% recycled sand. Four percent of their cows had score 2 lesions and 0% had score 3 lesions. These cows were among the most likely candidates in the sand category to have swollen tarsal joints. Recycled sand contains more large particles than new sand (Kristula et al., 2005) and this may have been a contributing factor to the increased lesion rates. When sand base dairies were sorted into thirds by percentages of cows with combined score 2 and 3 lesions, differences were found between the best and worst by lesion percentages for percent annual death rate (7.3 ± 1.1 vs. 4.1 ± 1.1) $P$ = 0.04), and percent reported lame on the day of visit (3.2 ± 0.7 vs. 1.1 ± 0.7) $P$ = 0.05).

Only one-third of the dairies visited had sand management that kept hair loss below 10% of cows, and swellings below 2%. A dairy with rubber filled mattresses had the most cows (11%) afflicted with severe (score 3) lesions, while the most affected cows on sand or waterbed dairies was 2%. Actual sand lying area for cows ranged in length from 140 to 239 cm; the concrete curb holding sand from 8 to 28 cm; sand area plus curb ranged from 165 to 284 cm. The most important factor to keep cows comfortable and prevent injury in sand stalls may be keeping stalls filled (Drissler et al., 2005). Sand stalls were filled anywhere from 0.3 to 7 times weekly. Some curbs were beveled which may make stalls more comfortable when sand levels become low, and easier to rake clean. Sand bedding of high quality may be superior in preventing lesions, but sand that is coarse or contains sharp stone or rocks may result in more cows with tarsal joint hair loss and swellings than their counterparts on well-managed rubber filled mattress or waterbed dairies.

The primary difference between the best and worst waterbed dairies for tarsal joint lesions was frequency of bedding to keep the surface dry and non-abrasive. The best waterbed dairies bedding frequency was twice daily to every other day and used 0.45 to 1.40 kg per stall per day of straw, kiln dried shavings, and some used lime in combination with chopped straw or shavings. Dairies with more lesion-affected cows generally bedded once or twice weekly. One waterbed dairy had lesion-free cows and filled the front of the stall with sawdust twice weekly, allowing the cows free access to pull it back.

## Base type details

### Rubber filled mattresses

Producers with rubber filled mattress were making every effort to make cows comfortable. Dairies with rubber filled mattress had the lowest stocking density at 99%, had the highest neck rails (118.5 ± 1.2 cm), widest stalls (117.8 ± 0.8 cm), were the least satisfied with cow comfort, and had the highest culling rate.

### Sand

There is much variation in sand within a given geographic area, and more between different regions of the country. Finer-grained sand was less abrasive and resulted in fewer hairless knees, tarsal joints and tuber calci.

Sand-stall dairies had the highest stocking density at 107%. They had the narrowest stalls (115.8 ± 0.9 cm). Sand stalls would have the shortest lying area if the concrete curb was subtracted from bed length.

Three sand dairies had herd averages in excess of 13,608 kg, the average being 8171.9 ± 107.0 kg. One of these had only 1 cow with a score 1 lesion, bedded with screened, fine-grained, dry silica sand, and had a 106% stocking density (cows per stall). The second dairy had only score 1 lesions. These cows were bedded with fine-grained sugar sand and stocked at 107%. The third dairy utilized recycled sand, had many cows with lesions, some with swelling, as well as hairless and some swollen knees. This dairy was stocked at 125% and was similar to average rubber filled mattress dairies for percent of cows with score 2 and 3 lesions, but 2/3 fewer cows had score 1 lesions. Actual sand length of bed was 127 cm.

Waterbeds

These dairies were stocked at 103%, and had a lower culling rate (Table 3.5) than rubber filled mattress. Stall dimensions on waterbed dairies were intermediate between rubber filled mattress and sand stalls. Waterbed dairies had more mature cows ($4^{th}$ lactation or greater) than dairies with rubber filled mattresses or sand.

Compost pack

Cows on these dairies had more freedom and no injuries as there were no stalls to contend with and few injury-causing obstacles in barns. There is a greater requirement for bedding and it must be cultivated twice daily for proper maintenance. Barns are cleaned out entirely once yearly and then deep-bedded. Bedding is added every 2 to 4 wk as need is indicated by cleanliness of cows. If a bedding type other than sawdust is used, it must be carefully considered as not all types of bedding lend themselves to this management system. Many free-stall producers visited expressed interest in this type of barn for special needs cows.

## Conclusions

Cows on rubber filled mattresses suffered more lesions and more severe lesions than cows on sand or waterbeds. There was a difference by bed type for location of lesions. Cows kept on rubber filled mattresses or waterbeds had better hygiene than their counterparts on sand, as sand-laden manure was more likely to cling to legs. Bedding frequency was greater for rubber filled mattress and waterbed dairies than sand. Culling rates were lower on waterbed than rubber filled mattresses dairies, and lower on waterbed than sand dairies, which may have resulted in there being more fourth lactation and greater cows residing on waterbed dairies. All 3 bedding types can be successfully used, but attention to detail (stocking density, stall length, stall width) and frequent filling or addition of non-abrasive bedding materials is essential for low lesion counts and clean cows. Severe leg lesions were correlated with somatic cell count. Dairies with higher percentages of lesions have higher somatic cell count, death loss, lameness, and culling rates.

## References

Bewley, J., R.W. Palmer, and D.B. Jackson-Smith. 2001. An overview of experiences of Wisconsin Dairy Farmers who modernized their operations. J. Dairy Sci. 84:717-729.

Drissler, M., M. Gaworski, C.B. Tucker, and D.M. Weary. 2005. Freestall maintenance: effects on lying behavior of dairy cattle. J. Dairy Sci. 88:2381-2387.

Fulwider, W.K. and R.W. Palmer. 2004a. Use of impact testing to predict softness, cow preference, and hardening over time of stall bases. J. Dairy Sci. 87:3080-3088.

Fulwider, W.K. and R.W. Palmer. 2004b. Stall usage differences of thirteen different free-stall base types. Prof. Anim. Sci. 20:470-482.

Haley, D.B., J. Rushen, and A.M. de Passillé. 1999. Effects of softer flooring on behavior, health and productivity of dairy cows in tie-stall housing. Page 127 in Proc. 33rd International Society for Applied Ethology. Bøe, K.M., M. Bakken, and B.O. Braastad, eds. Agricultural University of Norway. Lillehammer, Norway.

Haley, D.B., A.M. de Passillé, and J. Rushen. 2001. Assessing cow comfort: effects of two floor types and two tie stall designs on the behavior of lactating dairy cows. Appl. Anim. Behav. Sci. 71:105-117.

Kristula, M.A., W. Rogers, J.S. Hogan, and M. Sabo. 2005. Comparison of bacteria populations in clean and recycled sand used for bedding in dairy facilities. J. Dairy Sci. 88:4317-4325.

Manninen, E., A.M. de Passille, J. Rushen, M. Norring, and H. Saloniemi. 2002. Preferences of dairy cows kept in unheated buildings for different kind of cubicle flooring. Appl. Anim. Behav. Sci. 75:281-292.

Miller, R.H. and H.D. Norman. 2006. Somatic cell counts of milk from 2005 DHI herds. Animal Improvement Programs Laboratory, ARS-USDA, Beltsville, MD. Online. Available: http://www.aipl.arsusda.gov/publish/dhi/current/sccrpt.htm.

Plumb, C.S. 1893. Does it pay to shelter milk cows in winter? Purdue University Agric. Exp. Station. Bulletin 47, West Lafayette, Indiana, USA.

Reneau, J.K., A.J. Seykora, B.J. Heins, M.I. Endres, Farnsworth, and R.F. Bey. 2005. Association between hygiene scores and somatic cell scores in dairy cattle. J. Am. Vet. Med. Assoc. 227:1297-1301.

SAS 9.1, 2002-2003. Sas Institute, Inc., Cary, NC.

Schreiner, D.A. and P.L Ruegg. 2003. Relationship between udder and leg hygiene scores and subclinical mastitis. J. Dairy Sci. 86:3460-3465.

Sogstad, Å.M., O. Østerås, and T. Fjeldaas. 2006. Bovine claw and limb disorders related to reproductive performance and production diseases. J. Dairy Sci. 89:2519-2528.

Tucker, C.B., D.M. Weary, and D. Fraser. 2003. Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. J. Dairy Sci. 86:521-529.

Tucker, C.B., D.M. Weary, and D. Fraser. 2004. Free-stall dimensions: Effects on preference and stall usage. J. Dairy Sci. 87:1208-1216.

Tucker, C.B., G. Zdanowicz, and D.M. Weary. 2006. Brisket boards reduce free-stall use. J. Dairy Sci. 89:2003-2007.

Veissier, I. J. Capdeville, and E. Delval. 2004. Cubicle housing systems for cattle: Comfort of dairy cows depends on cubicle adjustment. J. Anim. Sci. 82:3321-3337.

Vokey, F.J., C.L. Guard, H.N. Erb, and D.M. Galton. 2001. Effects of alley and stall surfaces on indices of claw and leg health in dairy cattle housed in a free-stall barn. J. Dairy Sci. 84:2686-2699.

Wagner-Storch, A.M., R.W. Palmer, and D.W. Kammel. 2003. Factors affecting stall use for different free-stall bases. J. Dairy Sci. 86:2253-2266.

Ward, W.R., J.W. Hughes, W.B. Faull, P.J. Cripps, J.P. Sutherland, and J.E. Sutherst. 2002. Observational study of temperature, moisture, pH and bacteria in straw bedding, and faecal consistency, cleanliness and mastitis in cows in four dairy herds. Vet. Rec. 151:199-206.

Weary, D.M., and I. Taszkun. 2000. Hock lesions and free-stall design. J. Dairy Sci. 83:697-702.

Wechsler, B., J. Schaub, K. Friedli, and R. Hauser. 2000. Behavior and leg injuries in dairy cows kept in cubicle systems with straw bedding or soft lying mats. Appl. Anim. Behav. Sci. 69:189-197.

Westerath, H.S., L. Gygax, C. Mayer, and B. Wechsler. 2006. Leg lesions and cleanliness of finishing bulls kept in housing systems with different lying area surfaces. Vet. J. In press.

Wierenga, H.K. 1990. Social dominance in dairy cattle and the influences of housing and management. Appl. Anim. Behav. Sci. 27:201-229.

# CHAPTER 4

## EFFECT OF STALL BASE ON HERD HEALTH, COSTS, AND PRODUCER SATISFACTION

### Introduction

Several different stall bases are currently available to producers (Fulwider and Palmer 2004b). It is important to remember that most bases can be successfully utilized with proper bedding management. The real difference between base types is the effect on cows and base costs over time. There is a difference between stall bases with regard to cushioning ability and how quickly it is lost (Fulwider and Palmer, 2004a; Sonck et al., 2000).

Lesion location differs, and prevalence is higher with some base types than others (Fulwider, et al., 2006; Weary and Taszkun, 2000), indicating a need for more bedding, and more frequent bedding.

Preference studies allow cows to choose which bases they prefer lying and standing. Given a choice between rubber filled mattresses with different bedding amounts, cows preferred and spent more time lying on mattresses with the most bedding material (Tucker and Weary, 2004). Overall, cows preferred foam mattresses and rubber filled mattresses for lying, while waterbeds were the most preferred base during cold weather (Fulwider and Palmer, 2004b).

Many studies have been conducted regarding bed and bedding type, hygiene and somatic cell count (Manninen et al., 2002; Tucker et al., 2003; Ward, et al., 2002). Reneau et al. (2005) found a stronger relationship between somatic cell counts and hind limb hygiene than between somatic cell count and udder hygiene, the strongest relationship was between somatic cell count and udder-hind limb composite score. They also found that hygiene score increased with parity. Bewley et al. (2001) reported no difference in milk production or somatic cell count between producers with sand or mattress stalls.

Lesion location differs, and prevalence is higher with some base types than others (Fulwider et al., unpublished; Weary and Taszkun, 2000), which may indicate a need for more bedding and more frequent bedding. Sogstad et al. (2006) reported cows with tarsal wounds and swellings had more clinical mastitis and teat injuries. Cows with hock and knee swellings move more slowly (Haskell et al., 2006), which provides an additional incentive for producers to prevent these conditions.

Cost over the number of years the base is expected to provide comfort, as well as base maintenance costs must be compared. Stall bases have different bedding requirements, therefore bedding availability and cost must be carefully considered before construction begins. Bewley et al. (2001) reported no difference in milk production or somatic cell count between producers with sand or rubber filled mattress stalls.

## Materials and Methods

Over a 4-mo period beginning October 14, 2005, the first author visited 113 dairies in five states (WI, MN, NY, IA, IN). These herds represented 90,162 cows. One pen of early lactation cows was scored for hygiene, tarsal joint and tuber calcis lesions on each dairy. Cows were required to have spent the prior year on a specific base type in order to be eligible for the tarsal lesion analysis. Free-stall dairy farm units had a mean of 803 cows, and ranged from 80 to 4,286. An attempt was made to visit an equal number of dairies with each base type in each state.

Advanced Comfort Technology, Inc., the North American manufacturer of waterbeds provided a list of dairies utilizing waterbeds, and their neighbors who were using other stall base types. Initial contact was made by the first author and an appointment requested within the week. An additional 53 dairies were included in the study as a result of requesting the names of potential participants at equipment dealers, feed mills, university extension offices, veterinary offices and participating producers.

Having a bed or bedding type that did not fit study parameters resulted in only 94 dairies being included in the hygiene analysis. The tarsal joint and tuber calcis analysis required cows to be on the given base type for a minimum of one yr, which resulted in utilization of only 85 dairies. Producers were interviewed with regard to production information, stall dimensions, stocking density, number of cows in fourth lactation or greater, bedding amount, type, and frequency. All but five sand-stall dairies utilized new sand, the others re-used (recycled). Hygiene, lesion incidence, and lesion severity results were presented at the 2006 ADSA annual meeting (Fulwider et al., 2006) and were summarized in the results and discussion.

Stall dimensions

After all cows from a pen were scored, stall dimensions in their pen were measured. Measurements were taken from two random stalls in both an exterior and interior row. Stall width was measured between stall dividers, behind the neck rail. Stall length was measured from the front of the bed to the rear. If no brisket locator was present, the measurement was taken from the exterior wall, curb, or in the event of head to head stalls, the measurement taken was curb to curb. In the case of sand stalls, the stall length was measured the same way, but curb dimension was also recorded. Neck rail height was measured from the stall base to the under side of the neck rail. Sand stall neck rail measurement was taken from the bottom of the brisket locator to the underside of the neck rail.

Leg lesion measurements

Five areas including the lateral and medial tarsal joint and the lateral, medial, and dorsal, tuber calcis were scored for skin lesions on a 4-point scale. Cows with no hair loss were assigned a score of 0, hair loss = 1, swelling = 2, severe swelling = 3. Hair loss patches were 1.8-cm in diameter or greater. Swellings assigned score 2 were 7.4-cm or less in diameter, while score 3 swellings were larger and may have been purulent, extensive, or bleeding. Knees were scored whenever possible without interrupting cow flow in the parlor. All injuries were recorded.

Cow hygiene measurements

Every cow in the selected pen was assigned a hygiene score between 1 and 5, with 1 being a very clean cow and 5 very soiled. Score 1 was assigned to cows with no dried manure or manure stains. Cows with manure stains and no dried manure were assigned score 2. Cows with wet or dried manure on the legs and udder were assigned score 3. Extremely soiled cows were assigned score 4, while score 5 was reserved for cows with both manure and manure stains on legs, udders, and ventral abdomen.

Production information

Data were collected during interview regarding milk, fat, and protein production, somatic cell count, number of cows in fourth lactation or greater, cull rate, death rate, and number of cows reported clinically lame on the day of visit.

Producer satisfaction

Satisfaction values were collected on milking systems, restraining systems, and production and animal well-being as affected by stall base. These were scored 1 to 5, with 5 being very satisfied.

Stall base purchase and maintenance costs

Producers reported the amount of time required to bed, fill, and groom stalls per week. Cost and amount of materials used to bed or fill stalls per week was collected, as well as the frequency and amount of bedding or fill. Information regarding frequency of barn cleaning and stall bedding, and bedding type were also collected.

Statistical analysis

Lesion scores were analyzed as percentage of cows per farm with lesions and by specific lesion location. Differences in hygiene levels and percentages, and lesion severity and percentages and producer satisfaction were analyzed with a completely randomized one-way analysis of variance with farm as the experimental unit (SAS 9.1). When there were significant differences between bed types, pair-wise comparisons were compiled using t-tests. Fisher's protected LSD (t-test) was performed to control the error rate for pair-wise comparisons. Pearson correlations were used for comparing hygiene scores, lesion scores, and production measures.

## Results and Discussion

Tarsal lesions

Cows maintained on rubber filled mattresses had more score 1 ($P < 0.0001$), 2 ($P < 0.0001$), and 3 ($P < 0.0001$) lesions than cows on sand or waterbed. There was a difference in lesion location between cows on sand or waterbeds, but not for lesion score. Cows on sand were most affected by medial surface tarsal joint lesions (4.8%) while waterbed cows were least affected (2.7%). Cows on sand had fewer lateral tuber calcis lesions than cows on waterbeds ($P = 0.03$), while cows on rubber filled mattresses fell in between. Sand-bedded cows had more dorsal lesions ($P < 0.0001$) than cows on rubber filled mattresses or waterbeds. This was likely due to abrasion with the concrete manure curb in deep bedded stalls. Sand-bedded cows more often had medial tuber calcis lesions (20%) than cows on rubber filled mattresses (13%) or waterbeds (18%).

Knee and thigh lesions

Hairless knees were observed on cows for all three stall base types. The two dairies with the highest percentage of injury: hairless: 42% and 32%; swollen: 2% and 5%, kept cows on rubber filled mattresses. Dairies that recycled sand had more ($P = 0.04$) hairless knees (61% of cows on the most affected dairy) than those using new sand. Dairies that provided waterbeds that had the most cows with knee lesions: hairless: 8% and 3%; swollen: 7% and 1%)

Cows on rubber filled mattresses had bloody abrasions on thighs on 37% of dairies surveyed. Dairies that had the most thigh abrasions had 29%, 22%, 13%, as compared to the worst sand bed dairy (1%) and waterbed dairy (4%).

Herd characteristics

Ninety-one herds were included in this analysis. Dairies with sand beds tended to have larger herds and the highest stocking density, although there was no significant difference between base types for herd size, stocking density, or stall rows in the barn (Table 4.1). Stocking density ranged from 99 cows per 100 stalls for rubber filled mattresses to 107 cows per 100 stalls in sand barns. Sand barns were more likely to be 4-row barns than either rubber filled mattress or waterbed barns.

Table 4.1: Total herd cow numbers, number of cows scored, average stocking density, and number of stall rows per barn by bed type.

| Stall bed type | Number of herds | Average herd size | Standard deviation | Cows scored | Stocking density | SEM | Stall rows per barn |
|---|---|---|---|---|---|---|---|
| [1]RFM | 33 | 905.7 | 1936.6 | 3,971 | 99.4 | 0.03 | 4.7 |
| Sand | 27 | 1098.5 | 1149.6 | 3,854 | 107.0 | 0.04 | 4.3 |
| [2]WB | 31 | 467.1 | 563.2 | 2,725 | 102.8 | 0.03 | 4.6 |

[1]Rubber-filled mattress
[2]Waterbed

Stall dimensions: lameness, lesions, and somatic cell count.

The greatest difference for stall length and width (Table 4.2) was between rubber filled mattress and sand stalls ($P = 0.11$). Sand stall length may be misleading as the concrete manure curb added 7.6-cm to 27.9-cm to the length of these beds. Sand and rubber filled mattress stalls also had the greatest difference for neck rail height (Table 4.2), with sand at 116.3-cm and rubber filled mattress at 118.6-cm. Somatic cell count was correlated with stall width (-0.50) in barns with rubber filled mattresses ($P = 0.01$), and with stall length (-0.46, $P = 0.01$).

Table 4.2: Stall width, length, and neck rail height by bed type.

| Stall bed type | Stall width | SEM | Stall length | SEM | Neck rail height | SEM |
|---|---|---|---|---|---|---|
| [1]RFM | 46.4 | 0.3 | 67.8 | 1.2 | 46.7 | 0.5 |
| Sand | 45.6 | 0.4 | 70.8 | 1.5 | 45.8 | 0.5 |
| [2]WB | 46.0 | 0.3 | 70.0 | 1.3 | 46.0 | 0.5 |

[1]Rubber-filled mattress
[2]Waterbed

In sand barns, stall length was correlated with the percentage of mature cows (0.56, $P = 0.01$). This may be due to there being enough room to prevent abrasion as her leg is entirely on the bed. Stall length was correlated with the percentage of cows with score 2 lesions or swellings (-0.23, $P = 0.04$), across all stalls. When stalls were too short, cows may have been more likely to abrade legs on the curb. For dairies with rubber filled mattresses, the percentages of lesion 1-affected cows were correlated with stall length (-0. 37, $P = 0.07$), which was very similar to the sand correlation with stall length (-0. 38, $P = 0.08$). Percentage of cows with lesion score 3 was correlated with stall width (-0.52, $P = 0.01$). Narrow stalls may not give cows the opportunity to change position.

The percentage of cows reported lame on farms on the day of visit (Table 4.3) was correlated with somatic cell count (0.45, $P < 0.0001$) and neck rail height (-0.22, $P = 0.05$) across all base types. Lame cows and somatic cell count appear to increase together; this may provide an additional incentive to prevent lameness. Increasing neck rail height may be an effective way to reduce lameness, especially if cows are observed standing half-in-and-out of stalls. The percentage of cows reported lame was correlated (-0.38) with stall length on dairies with rubber filled mattresses ($P = 0.04$), and with somatic cell count (0.52, $P = 0.002$). The percentage of lame cows was correlated with somatic cell count for cows on sand at 0.45 ($P = 0.02$). In sand barns, the percentage of lame cows was correlated with the number of times per day manure was removed (-0.45, $P = 0.03$), perhaps indicating a need to increase manure removal frequency. Manure was removed more frequently from barns with rubber filled mattresses than either dairies with sand or waterbeds ($P = 0.05$). Annual culling rate was higher for dairies with rubber filled mattresses than dairies with waterbeds ($P = 0.001$), while dairies with sand stalls fell in between. There was no difference between base types for the percentage of cows reported lame or annual death rate.

Table 4.3: Times manure is removed per day; percent culled annually, died annually, and reported lame on the day of visit by bed type.

| Stall bed type | Times manure removed per day | Percent culled | Percent died | Percent lame |
|---|---|---|---|---|
| [1]RFM | $3.4^{x}$ | $29.4^{a}$ | 6.1 | 2.1 |
| Sand | $2.5^{y}$ | 25.5 | 5.9 | 2.2 |
| [2]WB | $2.4^{y}$ | $22.8^{b}$ | 6.6 | 2.4 |

Means with different superscripts within column differ.
$^{ab}P = 0.001$
$^{xy}P = 0.05$.
[1]Rubber-filled mattress
[2]Waterbed

Cow Hygiene

Cows maintained on rubber filled mattresses or waterbeds had better hygiene than those maintained on sand ($P < 0.0001$). In this study, this was primarily due to sand-manure spatter clinging to cows lower legs. Producers with rubber filled mattresses or waterbeds bedded cows more frequently ($P = 0.02$) at 3.9 times per week, while sand dairies filled stalls 1.9 times per week (Table 4.3). Frequent bedding keeps stalls dry as well as providing a constant level of "lubrication" between the cow and the bed. When sand stalls are not filled regularly, the cow may not experience the level of comfort required for maximum comfort and production. Dairies with rubber filled mattresses cleaned barns more frequently (3.4 times per day) than dairies with either sand ($P = 0.05$) or waterbeds ($P = 0.04$). Somatic cell count did not differ by bed type. Hygiene score was correlated with neck rail height for dairies with rubber filled mattresses (-0.52, $P = 0.003$) and waterbeds (-0.40, $P = 0.03$), but not sand. Therefore, producers must be mindful of finding the right neck rail height for the cows in their herd, to maximize hygiene and minimize lameness.

There were more mature cows, defined as being in fourth lactation or greater, on dairies with waterbeds than those with rubber filled mattresses ($P = 0.01$), or sand ($P = 0.02$) (Table 4.4). This could be highly beneficial to producers looking to increase cow numbers, or for those wishing to increase income by selling dairy replacements.

Table 4.4: Percent mature cows, somatic cell count, bedding frequency per week, and bedding cost per week by bed type.

| Stall base type | [1]Percent mature cows | SEM | [2]SCC | SEM | Bedding frequency | SEM | Bedding cost | SEM |
|---|---|---|---|---|---|---|---|---|
| [3]RFM | 13.3[b] | 1.5 | 241.4 | 14.5 | 3.9[a] | 0.5 | 0.89 | 0.1 |
| Sand | 13.5[d] | 1.6 | 235.2 | 16.1 | 1.9[b] | 0.6 | 0.97 | 0.1 |
| [4]WB | 19.8[ac] | 1.8 | 232.0 | 15.2 | 3.9[a] | 0.6 | 0.73 | 0.1 |

Means with different superscripts within column differ.
[ab] $P = 0.01$
[cd] $P = 0.02$
[1]Fourth lactation or greater
[2]Somatic cell count
[3]Rubber-filled mattress
[4]Waterbed

The percentage of cows with lesion score 3 was correlated with somatic cell count on dairies with rubber filled mattresses (0.60, $P = 0.001$). Lesions were more prevalent and more serious on dairies with rubber filled mattresses. Since somatic cell count appears to increase with swelling-type lesions, this may provide incentive to for those producers with high lesion counts to adjust management. There was no difference for somatic cell count among base types. Dairies with waterbeds or rubber filled mattresses bedded more frequently than dairies with sand stalls ($P = 0.01$), although sand dairies had higher bedding costs.

Producer satisfaction

Producers who provided waterbeds for their cows were more satisfied with cow longevity than those with rubber filled mattresses ($P < 0.0001$) or sand ($P = 0.001$) (Table 4.5).

Table 4 .5: Producer satisfaction with cow longevity, lameness, hock injury, teat injury, mastitis, somatic cell count, udder health, and hygiene.

| Stall base type | Cow longevity | Lame | Hock | Teat | Mastitis | SCC[1] | Udder health | Hygiene |
|---|---|---|---|---|---|---|---|---|
| [2]RFM | $3.5^{by}$ | $3.8^{l}$ | $3.8^{b}$ | 4.1 | 3.8 | 3.9 | 4.3 | 4.4 |
| Sand | $4.1^{x}$ | $4.0^{s}$ | $4.8^{a}$ | 4.5 | 3.9 | 3.8 | 4.5 | 4.5 |
| [3]WB | $4.5^{a}$ | $4.5^{kr}$ | $4.7^{a}$ | 4.3 | 3.9 | 4.1 | 4.5 | 4.3 |

Means with different superscripts within column differ.
$^{ab}P < 0.0001$
$^{kl}P = 0.001$
$^{rs}P = 0.05$
$^{xy}P = 0.01$
[1]Somatic cell count
[2]Rubber-filled mattress
[3]Waterbed

Dairymen with waterbeds were also more satisfied with lameness prevalence than those with rubber filled mattresses ($P = 0.001$) or sand ($P = 0.05$) (Table 4.5). Producers who provided sand or waterbeds were more satisfied with lameness prevalence than those with rubber filled mattresses ($P < 0.0001$).

Regarding cow comfort (Table 4.6), producers with sand stalls were more satisfied than those with rubber filled mattresses ($P = 0.05$), as were those who provided waterbeds ($P = 0.01$) for cows. Those who provided waterbeds were more satisfied with bedding use and cost than those who had rubber filled mattresses ($P = 0.05$), or sand ($P = 0.003$). This may be due to the fact that producers with waterbeds tend to bed frequently and use less bedding, usually sawdust or lime.

Table 4.6: Producer satisfaction with cow comfort, bedding cost and use, manure management, maintenance labor, and stall base life.

| Stall bed type | Cow comfort | Bedding cost and use | Manure management | Labor | Base life |
|---|---|---|---|---|---|
| [1]RFM | $3.9^{hy}$ | $4.0^{l}$ | $4.1^{a}$ | $3.8^{s}$ | $3.6^{b}$ |
| Sand | $4.9^{g}$ | $3.7^{d}$ | $3.1^{b}$ | $3.7^{y}$ | $4.0^{y}$ |
| [2]WB | $4.7^{x}$ | $4.7^{ck}$ | $4.5^{a}$ | $4.3^{rx}$ | $4.7^{ax}$ |

Means with different superscripts within column differ.
$^{ab}P < 0.0001$
$^{cd}P = 0.003$
$^{gh}P = 0.001$
$^{kl}P = 0.05$
$^{rs}P = 0.03$
$^{xy}P = 0.01$
[1]Rubber-filled mattress
[2]Waterbed

Producer satisfaction with manure management was highest for dairies with rubber filled mattresses or waterbeds when compared to sand ($P < 0.0001$) (Table 4.6). Producers with waterbeds were most satisfied with stall maintenance labor than those with rubber filled mattresses ($P = 0.03$), and more than those with sand ($P = 0.01$).

When base life was considered, producers with waterbeds were the most satisfied, more than producers with rubber filled mattresses ($P < 0.0001$), and more than those with sand ($P = 0.01$).

## Conclusions

All base types can be successfully managed. Producers must be aware of the differences in management required, especially when considering a change in base type. It is imperative that producers visit other dairies that are successfully using other types of equipment and technology whether building new, or remodeling old facilities. Stall dimensions must match not only cow size, but be designed with the base type in mind. Perhaps sand stalls should have as much bed length as rubber filled mattresses or waterbeds in addition to the curb, if cow comfort and less tarsal joint abrasion are priorities. Reducing lameness and lesions are important not only to increase production and longevity, but to maintain low somatic cell count and maximize profit. This study indicates a relationship between cow longevity and length of sand stall. Dairies with waterbeds have more mature cows than those with other base types. This may be due in part to the waterbed moving with the cow much in the same way that sand does. Producer satisfaction values support the findings of this study. More research needs to be done to determine the reasons for these differences.

## References


Bewley, J., R.W. Palmer, and D.B. Jackson-Smith. 2001. An overview of experiences of Wisconsin Dairy Farmers who modernized their operations. J. Dairy Sci. 84:717-729.

Fulwider, W.K. and R.W. Palmer. 2004a. Use of impact testing to predict softness, cow preference, and hardening over time of stall bases. J. Dairy Sci., 87: 3080-3088.

Fulwider, W.K. and R.W. Palmer. 2004b. Stall usage differences o.f thirteen different free-stall base types. Prof. Anim. Sci., 20(6), 470-482.

Fulwider, W. T. Grandin, D. Lamm, N. Dalsted, D. Garrick, and B. Rollin. 2006. J. Anim. Sci. Vol. 84, 1/J. Dairy Sci. Vol. 89, Suppl. 1, p. 411, Abstract.

Manninen, E., A.M. de Passille, J. Rushen, M. Norring, and H. Saloniemi. 2002. Preferences of dairy cows kept in unheated buildings for different kind of cubicle flooring. Appl. Anim. Behav. Sci., 75(4): 281-292.

Reneau, J.K., A.J. Seykora, B.J. Heins, M.I. Endres, Farnsworth, and R.F. Bey. (2005) Association between hygiene scores and somatic cell scores in dairy cattle. J. Am. Vet. Med. Assoc. 227, 1297-1301.

Sogstad, Å.M., O. Østerås, and T. Fjeldaas. 2006. Bovine claw and limb disorders related to reproductive performance and production diseases. J. Dairy Sci. 89, 2519-2528.

Sonck, B., J. Daelemans, J. Langenakens. 1999. Preference test for free-stall surface material for dairy cows. Pages 1-9 in Emerging Technologies for the 21st Century. Am. Soc. Ag. Eng. St. Joseph, MI.

Tucker, C.B., D.M. Weary, and D. Fraser. 2003. Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. J. Dairy Sci. 86: 521-529.

Ward, W.R., J.W. Hughes, W.B. Faull, P.J. Cripps, J.P. Sutherland, and J.E. Sutherst. 2002. Observational study of temperature, moisture, pH and bacteria in straw bedding, and faecal consistency, cleanliness and mastitis in cows in four dairy herds. Vet. Rec., 151(7): 199-206.

Weary, D.M., and I. Taszkun. 2000. Hock lesions and free-stall design. J. Dairy Sci. 83: 697-702.