Use of Impact Testing to Predict Softness, Cow Preference, and Hardening Over Time of Stall Bases

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ABSTRACT

The objective of this study was to assess the softness and durability of commercially available free-stall bases, and to determine the relationship of stall base softness to cow preference. Clegg impact values were recorded at the University of Wisconsin–Madison Arlington Agricultural Research Station on June 19, 2002, and again on July 24, 2003. The Clegg Impact Soil Tester (model 95051, Lafayette Instruments, Lafayette, IN) with a 20-kg hammer was used in this study. The impact of the hammer on the free-stall base results in a digital display based on peak deceleration of the hammer's impact with the free-stall base in tens of gravities (CIV/H). The CIV/H value, as measured by the Clegg Impact hammer, is based on peak deceleration of the 20-kg hammer's impact with the surface, from a height of 30 cm. Clegg impact measures were highly correlated with cow preference measurements. This relationship suggests that Clegg impact measures of compressibility were good indicators for predicting stall-base acceptance. A cork mattress, 4 foam mattresses, 4 rubber mattresses, 4 rubber mats, and a waterbed were evaluated in this study. Foam-based mattresses lost cushioning ability faster than rubber mattresses or rubber mats. Clegg impact values increased over the 13-mo time period for most stall base types, which indicated a tendency of stall bases to harden.

(**Key words:** freestall base, compressibility, hardness, cow preference)

Abbreviation key: CCC = cork-filled mattresses, CCM1 = polyethylene foam-filled mattress with Cow Flex cover, CCM2 = polyethylene foam-filled mattress with Super Mat cover, CIV/H = Clegg impact value (H denotes the heavy 20-kg Clegg hammer), FBS = 7.6-cm waterproof soft foam mats, with a waterproof, premium rubber top cover, HVC = 3.1-cm-thick vulcanized rubber mats with a pebble top and large corrugated under-

surface. M100 = composite foam interior in a polyvinyl chloride sealed envelope with a polyvinyl chloride cover, PMFL = Pasture Mat with felt layer, PMFO = Pasture Mat with foam layer, PVC = polyvinyl chloride, SBII = solid rubber antislip cover over a 2.2-cm foam pad, SCP = 4.4-cm-thick pads composed of a foam cushion completely encased in rubber, SDP = 3.6-cm vulcanized rubber pads with a textured surface and deeply grooved bottom, UMR = 7.6-cm-thick mats made of recycled tire rubber that was mixed with pliable polyurethane adhesive and mold-formed under pressure, WATR = cow waterbed.

INTRODUCTION

Cow comfort is vital for cow health and dairy profitability. Lying is an important behavior for cows as it allows cows to rest. The type of stall base affects dairy cow comfort and stall use, which indirectly affect the cow's health and welfare, and therefore, its profitability. The dairy industry is currently inundated with a variety of stall base options. Producers need a means to determine which of these bases provides superior performance, as free-stall bases represent a significant investment. Cushioning is one of the key elements that determines a free-stall base's value.

Comfortable stalls encourage cows to maximize lying times (Brouillette and Spanski, 1998). Maximizing comfort reduces stress, thereby increasing milk production, productive life, and profit potential, while reducing injuries (House et al., 2003). Blood flow across the mammary gland is increased 20 to 25% when the cow is lying down, thereby increasing nutritional efficiency and milk production (Rulquin and Caudal, 1992). Because cows spend 40 to 50% of their day lying in free-stalls, attention to stall design and especially the softness of flooring is necessary to maximize productive life (Rushen et al., 2001).

Increasing herd size has increased demand for a lying surface with minimal bedding and labor requirements (McFarland, 2003). Producers now have many options: sand, waterbeds, foam mattresses, rubber-filled mattresses, mattresses containing combinations of foam and rubber, and rubber mats. There are few scientific

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studies evaluating the wide range of recommendations for free-stall design and surfaces (Tucker and Weary, 2001; Gaworski et al., 2003).

Preference testing is valuable because it allows the cows to show what they prefer in a given environment (Wagner-Storch et al., 2003). A suitable stall bed should conform to the shape of a resting cow, and should provide cushioning as the cow rises and reclines (McFarland, 2003). The most important factor determining the suitability of cow mattresses is softness (Sonck et al., 2000). Given a choice, cows will lie on the softest available mattresses (Nilsson, 1992; Sonck et al., 1999). Cows also spend more time lying on softer mattresses, reducing injuries to both knees and hocks (Tucker and Weary, 2001). Impact injury potential and lifetime cushioning performance of free-stall beds must be taken into account, as they represent a significant investment for producers (Tierney and Thomson, 2003).

Laboratory testing of rubber crumb mattresses and rubber mats found mattresses to be superior in models of short-term injury protection, but with significantly reduced long-term performance. Rubber mats changed little over time, suggesting they are a good long-term investment (Tierney et al., 2001). New rubber-crumb beds tested were 70 mm thick. After 3 yr of continuous use, they measured between 40 to 50 mm (Tierney and Thomson, 2000). Short-term wear and elasticity tests have been developed in Belgium (Sonck et al., 2000). The short-term wear test was performed in the laboratory with an apparatus that simulates the movement of a cow's foot over the mattress, measuring abrasion and deformation resistance. Three of the 9 mattresses included in the study failed this test. The elasticity test measures the recovery time of cattle mattress materials, which is important because they are under considerable and almost permanent compression.

Testing cow preference for different free-stall bases is difficult in commercial situations. It would be useful to have an objective testing technique that would predict cow preference for a product. The objective of this study was to assess the softness and durability of 13 commercially available free-stall bases using a Clegg Hammer technique, and to determine the relationship of stall base softness to cow preference.

MATERIALS AND METHODS

Clegg impact values were recorded for 13 different free-stall bases at the University of Wisconsin–Madison Arlington Agricultural Research Station on June 19, 2002, and again on July 24, 2003. One stall base type was replaced before the second test so a total of 14 different stall base types were tested. The Clegg impact value is a measurement of compressibility. Large Clegg

values indicate less compressibility. The Clegg Impact Soil Tester (model 95051, Lafayette Instruments, Lafayette, IN) with a 20-kg hammer was used in this study. The Clegg hammer consists of 2 simple parts: a flat-ended, hardened steel hammer (13 cm in diameter) and a guide tube. The hammer was dropped from a predetermined height of 30 cm. The impact of the hammer on the free-stall base results in a digital display based on peak deceleration of the hammer's impact with the free-stall base in tens of gravities. A typical range for Clegg impact value (H denotes the heavy 20-kg Clegg hammer; CIV/H) is 0 to 100, but values over 100 are possible. Three successive blows on the same spot at the front and back of the free-stall base were recorded. Four of the bases tested (**CCM1** = Comfy Cow mattress, **PMFO** = Pasture Mat with foam layer between the rubber interior and top cover, **PMFL** = Pasture Mat with felt layer, and **WATR** = cow waterbed) were from a previous study (Wagner-Storch et al., 2003), and 9 were new. Those free-stall bases with high cow preference values were retained for comparison reasons. Sections of 1 to 8 bases of each base type were randomly arranged in each row of 1 of 2 pens, in this naturally ventilated, 4-row, tail-to-tail barn. These pens had different stocking densities. The north side had 54 stalls with a 66% stocking density, and the south side had 50 stalls and was stocked at 101%.

Clegg values were recorded on 4 stall bases of each type (with the exception of PMFO and PMFL, which had 5 and 3, respectively). The CCC stall bases were included in the June 19, 2002, measurements, but were replaced with new PMFO, which were included in the July 24, 2003, measurements. The measurements were taken approximately 35 cm from the front and back of each base. Waterbeds reacted differently than the other stall surfaces because the fluid contained within could move as the Clegg hammer struck. To simulate the pressure exerted on the stall surface by a cow and its effects on Clegg values, the Clegg hammer test was repeated with 1 or 2 people standing in the center of the stall. Because it was impossible to know the true effect of cows on waterbed stability, they were excluded from this analysis.

Clegg impact values were recorded for 1 cork-filled mattress, 4 foam-filled mattresses, 4 rubber-filled mattresses, 1 water-filled mattress, and 4 rubber mats. The descriptive code, product name, supplier name and address, and product classification of each stall base tested is listed in Table 1. The Cow Comfort Corkmat (**CCC**) was a cork filled mattress with a waterproof cover. The CCM1-based stalls were composed of cross-linked, closed-cell, nonabsorbent polyethylene foam and vinyl from the automobile industry, and the Cow-Flex Tafcoat waterproof cover. The **FBS**-based stalls

Table 1. Descriptive code, product name, supplier name and address, and product classification of all stall base types tested.¹

Descriptive code	Product name	Product supplier	Supplier address	Product class
CCC	Cow Comfort corkmat	Amorim Industrial Solutions	Trevor, WI	Cork-filled mattress
CCM1	Comfy Cow mattress, CF cover	Sikkema's Equipment	Byron Center, WI	Foam-filled mattress
FBS	Foamat Bedding System	Foxworthy Supply	Kent City, MI	Foam-filled mattress
M100	DeLaval cow mattress M100	DeLaval, Inc.	Kansas City, MO	Foam-filled mattress
CCM2	Comfy Cow mattress, SM cover	Sikkema's Equipment	Byron Center, WI	Foam-filled mattress
PMFO-New	Pasture Mat with foam insert, 2003	Dodgeland Ag Systems	Platteville, WI	Rubber-filled mattress
PMFO	Pasture Mat with foam insert, 2000	Dodgeland Ag Systems	Platteville, WI	Rubber-filled mattress
PMFL	Pasture Mat with felt insert, 2000	Dodgeland Ag Systems	Platteville, WI	Rubber-filled mattress
UMAR	Ulti-Mat all rubber cow mattress	Zartman Farms Cow Comfort Systems	Ephrate, PA	Rubber-filled mattress
SCP	Supreme Comfort pad	Humane Mfg. LLC	Baraboo, WI	Rubber mat
SBII	Kraiburg Softbed II	Agromatic	Fond du Lac, WI	Rubber mat
HVYC	Heavy Cush	J & D Mfg.	Eau Claire, WI	Rubber mat
SDP	Berg-Simplex Dairy Pad	Berg Equipment Corp.	Marshfield, WI	Rubber mat
WATR	Cow Waterbeds	Relative Products	Reedsburg, WI	Waterbed

¹Products listed were donated and installed by the supplier listed. CF = Cow Flex, SM = Super Mat. Listing of products by product name is not an endorsement for the product.

contained a 7.6-cm waterproof soft foam mat, with a waterproof, premium rubber top cover. The **M100**-based stalls consisted of composite foam in PVC sealed envelope with a PVC cover. The **CCM2**-based stalls were made of cross-linked, closed-cell, nonabsorbent polyethylene foam and the Super Mat geo-textile cover with urethane topcoat. The PMFO-based stalls were composed of a multicelled, rubber crumb-filled mattress with a 2.5-cm foam pad and needle-punched polypropylene top cover coated with wax to increase water shedding. These were installed in 2000. In 2003 identical mattresses were installed (PMFO-New) to test the effect of aging. The PMFL-based stalls consisted of a multicelled, rubber crumb-filled mattress with a 1.9-cm felt pad and needle-punched polypropylene top cover coated with wax to increase water shedding. The **UMAR**-based stalls were 7.6 cm thick and made of recycled tire rubber that was mixed with pliable polyurethane adhesive and mold-formed under pressure. The top cover was nonwoven and water resistant. The **SCP**-based stalls were 4.4 cm thick and were composed of a foam cushion completely encased in rubber. The **SBII**-based stalls were composed of a solid rubber anti-slip cover over a 2.2-cm foam pad. The rear one-third of the mat was sloped to enhance drainage. The **HVYC**-based stalls were 3.1-cm-thick vulcanized rubber mats with a pebble top and large corrugated undersurface. The **SDP**-based stalls consisted of 3.6 cm vulcanized rubber with a textured surface and deeply grooved bottom.

The stall base preference study was conducted at the University of Wisconsin–Madison Arlington Agricultural Research Station free-stall barn from June 19 to December 17, 2002. The barn is a naturally ventilated, 4-row, 104-stall, tail-to-tail barn that is not insulated. It is 30.5 m wide and 36.6 m long and has a roof pitch

of 10.2/30.5. The barn is oriented east to west. The eave sidewall height is 3.7 m. The barn has a wood post frame structure with 15.2-cm × 15.2-cm wood posts situated at the feed bunk line and at the front of the internal row of stalls. Ventilation is controlled by a 16.5-cm eave opening and 2.7-m adjustable curtains. The barn has a 61-cm ridge opening. Fans and sprinklers were not used. Stalls were 1.2 m wide and 2.4 m long. Brisket boards were 3.8-cm × 19.1-cm boards attached onto and below stall dividers, approximately 1.7 m from the rear curb and down to the top of the stall surface. Neck rails were mounted 1.14 m above the top of the rear curb, or approximately 1.07 m above the stall surface. All stall bases had a concrete base, with a 7.6-cm upward slope toward the brisket board. Stalls were bedded with sawdust twice weekly and soiled bedding was removed following the scheduled milking (parlor system) or human intervention time (automatic milking system). Stall bedding dates were not recorded, so stall usage by days since bedding was not analyzed.

A closed-circuit monitor camera system, with one camera on each side (ADT Security Systems, Inc., Menlo Park, CA), was used to observe cow activity 24 h/d. A Pelco VCR and Simplex Monochrome Multiplexer (Clovis, CA) were used to record digital images. Stalls were panned in a specific order by video cameras. Stall numbers were assigned accordingly for identification purposes. There were 2 pens in the barn: the north pen, which housed cows milked with a robotic milker, and the south pen, which housed cows milked 2 times per day in a conventional parlor. The stocking density decreased steadily in the north pen, beginning with a high stocking density of 76%, and ending in December with a low stocking density of 44%, for an average 66% stocking density. The south pen averaged a 101% stocking density. The stocking density was relatively steady,

Figure 1. Free-stall barn layout and observation recording form (not to scale; 13 stall base types).

reaching a high stocking density of 105% in July and a low stocking density of 92% in October. Cows on the 66% stocking density side had to pass through the robot to access the feed alley and through a one-way gate on the west end to return to the free-stall area.

The free-stall barn layout and observation recording sheet (not to scale) is shown in Figure 1. Stalls were identified by stall number and stall base type. Observations were taken 2 d/wk, 4 times/d at 1400 h, 2000 h, 0400 h, and 0900 h, from June 19 until December 17, 2002. The 1400 h observation time allows for possible delays in the regularly scheduled 1200 h tape change. Regularly scheduled dark times were from 2130 h to 0330 h. The 0400 observation time allowed for stall use observation after the lights were turned on. The 2000 h and 0900 h observation times allowed for observations 2 h after scheduled parlor milking times, while still allowing for variation in milking times and allowing cows time to eat after returning from the parlor.

When viewing videotape images and recording observations, the following steps were used. First, stalls were observed in sequential order on the south side of the

barn and assigned a status of empty, cow lying in stall, cow standing half-in-and-out, cow standing in stall, or unsure. Unsure was the designation for stalls that could not be accurately recorded as any of the aforementioned. Stalls in the north pen were then similarly observed.

Second, the percentages of each status (empty, lying, standing, half-in-and-out, unsure) were calculated as the number of stall-day-status observations divided by the total number of stall-day observations for the different categories or factors tested across the 6-mo study. Stall occupied (lying, standing, half-in-and-out) percentages were calculated using stall-day lying, standing, standing half in/half out, and unsure observations, divided by the total number of stall-day observations. The unsure percentages were very small and had little impact on other stall statuses.

Percentages for different factors analyzed using logistic regression with the GENMOD procedure in Statistical Analysis Software (SAS Inst., Inc., Cary, NC) and contrast statements were used to determine significant differences between percentages (Stokes et al., 1995).

Table 2. Clegg impact test results in the 101% stocking density pen¹ (% lying order).

Base type	CIV/H value ² (rear)	SE ³	CIV/H value ⁴ (front)	SE ⁵	Percentage lying ⁶	Percentage standing ⁷	Percentage half in/half out ⁸	Percentage occupied ⁹
FBS	1.5	0.0	1.6	0.1	62.42 ^a	22.52 ^{ab}	5.51 ^a	90.45 ^a
PMFO	4.5	0.2	4.6	0.1	59.65 ^a	22.15 ^{ab}	6.11 ^a	87.91 ^{ab}
UMAR	2.5	0.1	2.6	0.1	58.93 ^a	19.18 ^{bc}	6.21 ^a	84.32 ^{bc}
PMFL	6.2	0.2	5.9	0.2	52.90 ^b	21.56 ^{ab}	6.16 ^a	80.62 ^c
CCM1	5.3	0.4	6.9	0.6	52.10 ^b	24.61 ^a	4.58 ^a	81.29 ^c
SCP	5.7	0.1	6.4	0.3	50.54 ^b	17.05 ^{cd}	5.57 ^a	73.17 ^d
SBII	7.6	1.1	6.6	1.2	43.09 ^c	14.91 ^d	6.06 ^a	64.05 ^e
HVYC	7.0	0.1	7.7	0.3	41.93 ^c	16.46 ^{cd}	6.68 ^a	65.06 ^e
Pooled SE ¹⁰					0.02	0.01	0.01	0.01

^{a,b,c,d,e}Percentages within columns with different letters are significantly different ($P < 0.05$).

¹Stall status percentages are from the stall base preference study conducted from June 19 through December 17, 2002. The base types are: CCM1 = Comfy Cow mattress with Cow-Flex Top Cover, Sikkema's Equipment, Byron Center, MI; FBS = Foammat Bedding System, Foxworthy Supply, Kent City, MI; PMFO = Pasture Mat with foam layer, Promat Ltd., Seaforth, Ontario, Canada; PMFL = Pasture Mat with felt layer, Promat Ltd., Seaforth, Ontario, Canada; UMAR = Ulti-Mat all rubber cow mattress, Zartmann Farms, Ephrata, PA; SCP = Supreme Comfort pad, Humane Manufacturing, Baraboo, WI; SBII = Kraiburg Softbed II, Agromatic, Fond du Lac, WI; and HVYC = heavy cush, J & D Manufacturing, Eau Claire, WI.

²CIV/H value is the average of the first impact, approximately 30 cm from the rear of a stall base, with a 20-kg Clegg hammer on 3 to 5 stall bases of each base type from the June 19, 2002, test day.

³Standard error for the Clegg impact value for the rear of each stall base type.

⁴CIV/H value is the average of the first impact approximately 30 cm from the front of a stall base with a 20-kg Clegg hammer on 3 to 5 stall bases of each base type from the June 19, 2002, test day.

⁵Standard error for the Clegg impact value for the front of each stall base type.

⁶Percentage lying is percentage of stalls observed with a cow lying, for the period June 19 to December 17, 2002.

⁷Percentage standing is the percentage of stalls observed with a cow standing in the stalls, for the period June 19 to December 17, 2002.

⁸Percentage half in/half out is percent of stalls observed with a cow standing half in/half out, for the period June 19 to December 17, 2002.

⁹Percentage occupied is percent of stalls with a cow observed half in/half out + lying + standing in the stalls, for the period June 19 to December 17, 2002.

¹⁰Pooled SE for each stall status.

Each side was analyzed separately due to different stocking densities in the south and north pens. Stocking densities were a function of herd management and were not intentionally set as part of the study's design. The CATMOD procedure of SAS was used to model lying and occupied as binary outcomes. The PROC GLM was used to run a 1-way ANOVA using least significant differences for pairwise comparisons of the change from the first to second Clegg test between stall base groups.

RESULTS AND DISCUSSION

Three measurements of CIV/H were taken on grass-covered pastureland and approximately 35 cm from the front and the rear of each stall tested. The pasture was less-than-10-cm-high grass on silt loam prairie soil. There was generally a slight increase in CIV/H value, with subsequent strikes on a given spot due to compression. In this study, the first strikes at the rear of the stall were used because it was felt that measurements at the rear of the stall best characterized the stall surface as experienced by a cow. Unless stated otherwise, CIV/H values referenced relate to the first strike at the rear of the stall.

Cow preference for percentage lying, standing, half in/half out, occupied, and CIV/H are shown in Tables 2 and 3. Percentage lying was defined as stalls with a cow observed lying in the stall. Percentage occupied was defined as stalls observed with a cow standing half in/half out, lying, or standing in the stall. These tables reflect values in the south and north pens of the barn, with stall stocking densities of 101 and 66%, respectively.

Table 2 shows CIV/H for the front and rear of stall base types, and cow preference for lying, standing, half in/half out, and occupied for each base type in the 101% stocking density pen. The three softest mattresses (FBS, PMFO, UMAR) had an average Clegg value of 2.2 CIV/H, and were clearly preferred for percentage lying and occupied. The softest rubber mat (SCP) had Clegg values similar to those of the harder mattresses (PMFL, CCM1) available in this pen. The harder mattresses (PMFL, CCM1) had an average Clegg value of 5.7 CIV/H, more than twice as hard as the most preferred bases in this pen. Rubber mats (SBII, HVYC) were the hardest stall bases available in this pen, averaging 7.3 CIV/H, and were the least preferred.

Table 3. Clegg impact test results in the 66% stocking density pen¹ (% lying order).

Base type	CIV/H value ² (rear)	SE ³	CIV/H value ⁴ (front)	SE ⁵	Percentage lying ⁶	Percentage standing ⁷	Percentage half in/half out ⁸	Percentage occupied ⁹
M100	3.6	0.1	3.9	0.2	48.84 ^a	8.87 ^b	4.03 ^{ab}	61.74 ^a
PMFO	4.5	0.2	4.6	0.1	46.83 ^a	10.32 ^{ab}	2.91 ^{bcd}	60.05 ^a
CCM2	2.6	0.3	2.5	0.3	35.33 ^b	11.20 ^a	3.38 ^{abc}	49.91 ^b
WATR	7.4	3.1	6.4	2.4	31.75 ^b	3.97 ^d	4.50 ^a	40.21 ^c
PMFL	6.2	0.2	5.9	0.2	20.32 ^c	6.35 ^c	2.01 ^d	28.68 ^d
CCC	7.3	0.4	6.8	0.4	18.32 ^{cd}	3.77 ^d	2.45 ^{cd}	24.54 ^{de}
SDP	6.3	0.2	7.0	0.4	15.65 ^d	5.14 ^d	2.49 ^{cd}	23.28 ^e
Pooled SE ¹⁰					0.01	0.01	0.01	0.02

a,b,c,d,e Percentages within columns with different letters are significantly different ($P < 0.05$).

¹Stall status percentages are from the stall base preference study conducted from June 19 through December 17, 2002. The bases are: CCC = Cow Comfort Corkmat, Amorim Industrial Solutions, Trevor, WI; M100 = DeLaval cow mattress M100, DeLaval, Inc., Kansas City, MO; CCM2 = Comfy Cow mattress with Super-Mat top cover, Sikkema's Equipment, Byron Center, MI; PMFO = Pasture Mat with foam layer, Promat Ltd., Seaforth, Ontario, Canada; PMFL = Pasture Mat with felt layer, Promat Ltd., Seaforth, Ontario, Canada; SDP = Simplex Dairy Pads, Berg Equipment Corp., Marshfield, WI; and WATR = Cow waterbeds, Relative Products, LLC, Reedsburg, WI.

²CIV/H value is the average of the first impact approximately 30 cm from the rear of a stall base with a 20-kg Clegg hammer on 3 to 5 stall bases of each base type from the June 19, 2002, test day.

³Standard error for the Clegg impact value at the rear of each stall base type.

⁴CIV/H value is the average of the first impact approximately 30 cm from the front of a stall base with a 20-kg Clegg hammer on 3 to 5 stall bases of each base type from the June 19, 2002 test day.

⁵Standard error for the Clegg impact value at the front of each stall base type.

⁶Percentage of stalls observed with a cow lying, for the period June 19 to December 17, 2002.

⁷Percentage of stalls observed with a cow standing in the stalls, for the period June 19 to December 17, 2002.

⁸Percentage of stalls observed with a cow standing half in/half out, for the period June 19 to December 17, 2002.

⁹Percentage of stalls with a cow observed half in/half out + lying + standing in the stalls, for the period June 19 to December 17, 2002.

¹⁰Pooled SE for each stall status.

Table 3 shows CIV/H for the front and rear of stall base types, and cow preferences for lying, standing, half in/half out, and occupied in the 66% stocking density pen. The 2 most preferred mattresses (M100, PMFO) for lying and occupied in this pen had an average Clegg value of 4.0 CIV/H. The second most preferred group (CCM2, WATR) in this pen had an average Clegg value of 5.0 CIV/H, differing little in CIV/H from the most preferred bases in this pen. This result obviously was caused by the abnormally low CIV/H value for CCM2. The CCM2 was a foam-filled mattress, and the softest base available in this pen at 2.6 CIV/H. It could be that this base did not rank higher by cows because it had a stiffer top cover. The M100, which was a harder base than the CCM2, may be preferred because of its slick, non-abrasive vinyl top cover. The PMFO was also harder than the CCM2, was more preferred than a softer base in each pen. The least preferred bases in this pen (PMFL, CCC, SDP) had an average Clegg value of 6.6 CIV/H, or 32% harder than the other bases in this pen.

Table 4 shows CIV/H for pastureland and the 14 bases tested June 19, 2002, and/or July 24, 2003 (13 mo apart). Clegg Impact testing results showed that foam-filled mattresses lose cushioning ability faster than rubber-filled mattresses or rubber mats. On average, foam-filled mattresses (Figure 2) increased by 1.1 CIV/H, rubber-filled mattresses increased 0.1 CIV/H,

and rubber mats increased 0.7 CIV/H in cushioning ability. The change in compressibility between foam- and rubber-filled mattresses, over the 13-mo period was significantly different.

Figure 3 shows the average Clegg CIV/H values for the front and back of the stall base. Over the 13-mo period, foam-filled mattresses increased by 1.8 CIV/H, rubber-filled mattresses by 0.3 CIV/H, and rubber mats increased by 0.6 CIV/H. The change in compressibility for foam-filled mattresses was significantly greater than that for rubber-filled mattresses or rubber mats.

The cork-filled mattress, CCC (Table 4) was the hardest mattress in the study at 7.3 CIV/H. Only the rubber mat, SBII had a higher CIV/H value. The CCC stall base was replaced with PMFO-New before the second measurement was taken. During the June 2002 Clegg Impact tests, CCM1, which had been installed for over 3 yr, was comparable in CIV/H to SCP, the softest rubber mat. On average, the foam mattresses lost the most compressibility. The CCM1, a 3-yr-old base, was the hardest foam mattress and lost the least in compressibility. At 5.3 CIV/H, the CCM1 had twice the CIV/H value as the average 2.6 CIV/H of the other 3 foam mattresses. Pastureland tested at 3.6 CIV/H, and was equivalent or softer than all but 4 mattresses (FBS, M100, CCM2, UMAR) at the first test, and softer than all but 2 (FBS, UMAR) 13 mo later.

Table 4. Difference in Clegg impact values over a 13-mo period.

Stall base ¹	Number of stalls	CIV/H ² June 19, 2002	SE	CIV/H ² 7-24-03	SE	Difference (CIV/H) July 24, 2003– June 19, 2002
CCC	4	7.3	0.4	NA	NA	...
CCM1	4	5.3	0.4	5.6	0.2	0.3
FBS	4	1.5	0.1	2.3	0.1	0.8
M100	4	3.6	0.1	4.6	0.4	1.0
CCM2	4	2.6	0.3	4.6	0.8	2.0
PMFO-NEW	4	NA	NA	5.5	0.8	...
PMFO	5	4.5	0.2	4.9	0.3	0.4
PMFL	3	6.2	0.2	5.9	0.7	-0.3
UMAR	4	2.5	0.1	2.8	0.1	0.3
SCP	4	5.7	0.1	7.5	0.4	1.8
SBII	4	7.6	1.1	8.2	1.2	0.6
HVYC	4	7.0	0.1	7.1	0.2	0.1
SDP	4	6.3	0.2	6.7	0.2	0.4
WATR	4	7.4	3.1	NA	NA	...
Average	4	5.0		5.5		0.7
Pooled SE ³						0.4
Pasture	4	3.6		NA		...

¹Stall bases listed were utilized in a cow preference study (Fulwider, 2004), conducted June 19 to December 17, 2002. The bases are: CCC = Cow Comfort Corkmat, Amorim Industrial Solutions, Trevor, WI; CCM1 = Comfy Cow mattress with Cow-Flex top cover, Sikkema's Equipment, Byron Center, MI; FBS = Foammat Bedding System, Foxworthy Supply, Kent City, MI; M100 = DeLaval cow mattress M100, DeLaval, Inc., Kansas City, MO; CCM2 = Comfy Cow mattress with Super-Mat top cover, Sikkema's Equipment; PMFO = Pasture Mat with foam layer, Promat Ltd., Seaforth, Ontario, Canada; PMFL = Pasture Mat with felt layer, Promat Ltd., Seaforth, Ontario, Canada; UMAR = Ulti-Mat all rubber cow mattress, Zartmann Farms, Ephrata, PA; SCP = Supreme Comfort Pad, Humane Manufacturing, Baraboo, WI; SBII = Kraiburg Softbed II, Agromatic, Fond du Lac, WI; HVYC = Heavy Cush, J & D Manufacturing, Eau Claire, WI; SDP = Simplex Dairy Pads, Berg Equipment Corp., Marshfield, WI; and WATR = Cow Waterbeds, Relative Products, LLC, Reedsburg, WI.

²Clegg CIV/H value is the average of the first impact, approximately 30 cm from the rear of a stall base with a 20-kg Clegg hammer on 3 to 5 stall bases of each base type from the June 19, 2002, and July 24, 2003, test days.

³Pooled standard error for the difference in CIV/H values.

Figure 2. Difference in Clegg impact values at the rear of the stall base for different base types. **Figure 3.** Difference in Clegg impact values for the combined average of the front and rear of the stall base for different base types.

Table 5. Clegg correlation coefficient (r)¹ between CIV/H value² for the rear of the stall base and lying or occupied³ percentages⁴ at high and low stocking densities (SD).

Item	101% SD ⁵	66% SD ⁶
CIV/H vs. lying	-0.90	-0.78
CIV/H vs. occupied	-0.84	-0.84

¹Correlations are calculated with CIV/H value that is the average of first impact at the rear of the stall with a 20-kg Clegg hammer on 3 to 5 stall bases of each base type.

²Clegg value (CIV/H) utilized taken from data collected June 19, 2002.

³Occupied is defined as lying + standing + half in/half out.

⁴Percentage = number of stall-day-status observations/total number of stall-day observations by stall base by side.

⁵The 101% SD pen is the north pen with 101% stocking density.

⁶The 66% SD pen is the north pen with 66% stocking density.

The rubber-filled mattresses in the study increased by an average of 0.1 CIV/H in compressibility. The PMFO increased 0.4 CIV/H. The PMFL decreased by 0.3 CIV/H. The UMAR was initially the softest rubber-filled mattress, and increased 0.3 CIV/H. The SCP was the softest rubber mat on the first test and increased 1.8 CIV/H, losing 3 times the cushioning ability of the next rubber mat. This result was probably due to the fact that it had a soft foam center. The SBII, a rubber mat over a felt pad, increased 0.6 CIV/H, more than twice as much as the combined average of HVYC and SDP.

A study done in Scotland (Tierney and Thomson, 2003) compared rubber-filled mattresses and rubber mats and reported similar results. Rubber-filled mattresses were found to be softer than new ethylene vinyl acetate mats. The rubber-filled mattress became harder, while the rubber mat changed very little. Our results differed from their results in that the average hardness of all rubber mats was not statistically different than rubber-filled mattresses (0.7 vs. 0.1). Part of this discrepancy may be explained by our method of categorizing rubber mats. Some rubber mats in our study had a foam interior.

Table 5 shows the correlation coefficients between Clegg CIV/H values for the rear of the stall base for lying or occupied percentages at high and low stocking densities.

Table 6 shows the correlation coefficients between Clegg CIV/H values and percentage lying and occupied when Clegg measurements from the front of stall bases are averaged with the rear measurement. Including the front measurement produces a slightly lower correlation coefficient. Tables 5 and 6 show the strong correlation between percentage lying and occupied and Clegg values. These consistently high negative correlations between cow preference and mattress Clegg values

Table 6. Clegg correlation coefficient (r)¹ between CIV/H value² for the front and rear of the stall base and lying or occupied³ percentages⁴ at high and low stocking densities.

Item	101% SD ⁵	66% SD ⁶
CIV/H vs. lying	-0.89	-0.77
CIV/H vs. occupied	-0.82	-0.83

¹Correlations are calculated with CIV/H value that is the average of first impact at the front and rear of the stall with a 20-kg Clegg hammer on 3 to 5 stall bases of each base type.

²Clegg value (CIV/H) utilized taken from data collected June 19, 2002.

³Occupied is defined as lying + standing + half in/half out.

⁴Percentage = number of stall-day-status observations/total number of stall-day observations by stall base by side.

⁵The 101% SD pen is the north pen with 101% stocking density.

⁶The 66% SD pen is the north pen with 66% stocking density.

were interpreted as illustrating cows' preference for softer free-stall bases and the ability of the Clegg hammer to predict the relative acceptance of different stall base types by cows.

Clegg Impact measures were correlated highly with cow preference measurements. This suggests that Clegg Impact measures of compressibility were good indicators for predicting stall base acceptance. The CIV/H value as measured by the Clegg Impact hammer is in tens of gravities, based on peak deceleration of the 20-kg hammer's impact with the surface from a height of 30 cm. Clegg impact values increased over time for most stall base types, which indicated a tendency of stall bases to harden. Only PMFL CIV/H value decreased in this study. Clegg values also differed for stall base types (foam-filled mattresses, rubber-filled mattresses, and rubber mats), suggesting stall base types change differently in CIV/H over time. Four of the most preferred stall bases in this study (FBS, UMAR, CCM2, M100) were as soft as or softer than pasture (1.5, 2.5, 2.6, and 3.6, vs. 3.6, respectively) based on CIV/H.

This study suggests foam-based mattresses lose cushioning ability faster than rubber mattresses, or rubber mats. Foam mattress Clegg values increased by an average of 1.1 CIV/H, which was a significantly greater increase than that of rubber-filled mattresses. Rubber-filled mattresses had the smallest numeric increase in average Clegg value at 0.1 CIV/H, whereas the average rubber mat CIV/H increases were intermediate (0.7 CIV/H).

When Clegg values taken at the front of the stall base are included, results were similar, with the foam-based mattresses showing an increase of 1.8 CIV/H, significantly greater than increases for rubber-filled mattresses, which had the smallest numeric increase in average Clegg value at 0.3, and rubber mats, with an average increase of 0.6 CIV/H.

The gain in Clegg values for foam-filled mattresses was 10 times greater than those for rubber-filled mattresses. The SCP with foam insert had a Clegg value difference 4 times greater than the average increase of the other 3 rubber mats. This would suggest that the foam layer deteriorated over the time of this study. It would appear that any mattress containing foam would lose compressibility faster than its foam-free counterparts.

CONCLUSIONS

Clegg impact values appear to provide a good means of predicting cow preference for stall bases. The Clegg Impact Soil Tester (20 kg) is portable, easy to use, and could easily be used by producers and researchers as a tool to evaluate stall bases. More work is needed in this area to confirm results. Waterbeds were difficult to assess with Clegg Impact testing, as the water could move about freely. In future studies, measures need to be developed to accurately measure cushioning performance of waterbeds.

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REFERENCES

- Brouillette, J., and N. Spanski. 1998. Cow comfort and the effects on productivity and profitability. *Hudson Valley Agric. Newslett.* 2:1.
- Fulwider, W. K. 2004. Factors affecting cow behavior relating to different stall base type, stall design, and alley surfaces. M. S. Thesis, Univ. Wisconsin-Madison.
- Gaworski, M. A., C. B. Tucker, D. M. Weary, and M. L. Swift. 2003. Effects of stall design on dairy cattle behavior. Pages 139–146 in *Proc. 5th Int. Dairy Housing*, Fort Worth, TX.
- House, H. K., J. Rodenburg, and B. R. Lang. 2003. The effect of neck rail and mounting rail position on cow behavior. Pages 147–154 in *Proc. 5th Int. Dairy Housing Proc.*, Fort Worth, TX.
- McFarland, D. F. 2003. Freestall design: Cow recommended refinements. Pages 131–138 in *Proc. 5th Int. Dairy Housing*, Fort Worth, TX.
- Nilsson, C. 1992. Walking and lying surfaces in livestock houses. Pages 93–110 in *Farm Animals and the Environment*. CAB Int., Wallingford, UK.
- Rulquin, H., and J. P. Caudal. 1992. Effects of lying or standing on mammary blood flow and heart rate of dairy cows. *Ann. Zoo.* 41:101.
- Rushen, J., A. M. de Passille, D. B. Haley, E. Manninen, and H. Saloniemi. 2001. Using behavioral indicators to assess the effect of stall flooring on cow comfort. Pages 716–723 in *Livest. Environ. VI: Proc. of the 6th Int. Symp.*, Louisville, KY.
- Sonck, B., J. Daelemans, and J. Langenakens. 1999. Preference test for free stall surface material for dairy cows. Paper no. 994011 in *Proc. Am. Soc. of Agric. Eng.*, Toronto, Ontario, Canada.
- Sonck, B., N. Van havermaet, and V. Vervaeke. 2000. Short-term wear test and elasticity test on cattle mattresses. Paper no. 004147 in *Am. Soc. of Agric. Eng.*, Milwaukee, WI.
- Stokes, M. E., C. S. Davis, and G. G. Koch. 1995. Using the GENMOD procedure. Pages 208–212 in *Categorical Data Analysis Using the SAS System*. SAS Institute, Inc., Cary, NC.
- Tierney, G., M. Kelly, R. D. Thomson, and A. E. Kirkbeck. 2001. Cow comfort on cubicle beds. MDC Report no. 97/R6/13. The Milk Development Council of Great Britain, Cirencester, Gloucestershire, UK.
- Tierney, G., and R. Thomson. 2000. The role of finite element analysis in predicting the short-term and long-term injury reduction potential of dairy cow cubicle synthetic beds. Paper no. 004041 in *Am. Soc. of Agric. Eng.*, Milwaukee, WI.
- Tierney, G., and R. Thomson. 2003. Methods for assessing the cushioning performance of free-stall dairy cow synthetic beds. *Trans. ASAE* 46:147–153.
- Tucker, C. B., and D. M. Weary. 2001. Stall design: Enhancing cow comfort. *Adv. Dairy Tech.* 13:155–168.
- Wagner-Storch, A. M., R. W. Palmer, and D. W. Kammel. 2003. Factors affecting stall use for different freestall bases. *J. Dairy Sci.* 86:2253–2266.